Internet of Things Based Remote Sensing for Ornithological Monitoring

Muhammad Khan
Department of Electrical Engineering
Arkansas Tech University
Russellville, AR
mkhan3@atu.edu

Douglas G. Barron
Department of Biological Sciences
Arkansas Tech University
Russellville, AR
dbarron@atu.edu

Rajvardhan Patil
Department of Computer and Information Systems
Arkansas Tech University
Russellville, AR
rpatil@atu.edu

Matthew Nannemann
Department of Electrical Engineering
Arkansas Tech University
Russellville, AR
mnannemann@atu.edu

Michael Courson
Department of Electrical Engineering
Arkansas Tech University
Russellville, AR
mcourson@atu.edu

***Abstract*— Biologists have long struggled to monitor the behavior of wild animals, though remote sensing technologies have allowed recent insights into otherwise cryptic animal behaviors. Traditional methods of animal tracking use radio- or GPS-transmitters that are expensive, large, and unable to track animal movements on a fine-scale. Radio-frequency identification (RFID) technology poses a cheap and unobtrusive solution to track activity of animals near antenna stations, though current data loggers face problems with energy supply, data format, and data access/storage. Internet of Things (IoT) holds promise as a tool to advance this type of zoological research through its integration of embedded systems, sensors, control systems and wireless communications. In this project we propose the structure of a system that combines RFID and IoT technologies to enable real-time tracking of feeder usage by wild birds in central Arkansas. The proposed system will replace existing data loggers and provide continuous, automated, and real-time data collection with minimal personnel oversight. The design will be superior to more expensive commercially-available units and will represent a breakthrough in wildlife monitoring technology.**

Keywords—remote sensing, IoT, RFID, ornithology, bird feeding, animal tracking, real-time data logging.

I. Introduction

Internet of Things (IoT) is a rapidly evolving research area with unprecedented growth potential in application domains ranging from healthcare and home automation to transportation and infrastructure management. Projections for the impact of IoT indicate 100 billion connected devices with a global economic impact of more than $11 trillion by 2025 [1]. IoT has potential to similarly transform biological discovery and conservation. The implementation of IoT-based animal tracking applications is poised to improve our understanding of animal ecology and behavior [2-3].

The primary technological solutions for studying animal movements involve attaching expensive transmitters to animals and tracking their location using radio-telemetry, global positioning systems (GPS), or geolocation. The wide adoption of these technologies has advanced our understanding of animal behavior despite their potential limitations. First, large transmitter size restricts use to large animals and poses threats to the organisms' survival and reproduction [4]. Second, the location accuracy of these devices ranges from meters to kilometers, rendering them insufficient to provide information on animal visits to fine-scale features of the micro-habitat. Finally, the expense of tags and associated equipment restrict sample sizes and limit generalizability.

One promising alternative is radio-frequency identification (RFID) technology, which records visits of tagged animals to antenna stations affixed to a habitat feature of interest (e.g. nest, feeder). The passive integrated transponder (PIT) tags require no battery and are incredibly small (<0.1g) and inexpensive ($3). The systems operate continuously and generate vast quantities of publication-quality data without prohibitive personnel demands. RFID technology has already been used to study the behavior of wild birds, and it has the potential to "revolutionize studies of avian biology and behavior" [5].

The present study lays out design and development of an IoT based RFID data logger for use in ongoing research to study impacts of bird feeding on the ecology of wild songbirds. In the United States, over 57 million households feed birds [6], making it the largest wildlife management activity in northern temperate regions [7]. While feeders have been hailed as good conservation practices, feeding could carry negative consequences such as increased disease transmission [8]. To evaluate the effects of feeders, the frequency of feeder visits by individual birds must be quantified. Our IoT based data logger will accomplish this by sending continuous and real-time data from RFID feeder sensors to microcontrollers and gateways connected to the cloud for data processing and analysis.

Biologists established eight bird feeders across the Arkansas Tech University (ATU) campus in early 2017. The feeders are 18"x4" tubes with two perches and are continuously filled with black oil sunflower seed. To each feeder we affixed an IB Technology dual antenna RFID data logger (EM4102) capable of recording the frequency and timing of visits by PIT_tagged birds (Fig 1). These systems have been used to document long-term bird feeding behavior on an incredibly fine scale; more than 130,000 feeder visits have been logged by over 120 individual tagged birds.

Fig. 1: Bird Feeder with datalogger (A) and a bird banded with a PIT tag (B)

II. Project Objectives

A multidisciplinary team comprising faculty and students from Electrical Engineering (EE), Biological Sciences, and Computing and Information Systems (CIS) is designing an IoT based system for ornithological monitoring. The goal is to design a system that can address the limitations of existing RFID-based commercial data loggers. These limitations include:

- Cost: Each data logger costs approximately US $350.00.
- Maintenance: Approximately five hours of weekly maintenance is needed to replace batteries and retrieve USB thumb drives to download the data on to a dedicated Personal Computer.
- Data Format: The USB Drive needs to be FAT32 formatted. Data is stored as a text file in a comma separated variable (CSV) format. The data retrieval process is cumbersome, and involves opening the data logger case each time USB drive is retrieved or inserted.
- Technical Support: The system manufacturer is based in United Kingdom, and they offer limited support for the system due to obsolescence. The upgrade to newer system is prohibitively expensive.

The project is working to design the IoT based system considering the following features:

- Cost: Systems will cost under $250 despite additional features.
- Power: Solar-power will eliminate periodic battery replacement and improve reliability.
- Data Acquisition: Systems will connect wirelessly via LoRa protocol to transmit real-time data to a central gateway. Data retrieval with USB thumb drive will no longer be necessary.
- Data Handling: The gateway will handle processing, storage, and analysis of incoming data from feeder units. The gateway will periodically upload the data to Amazon Web Services for access via a web portal.
- Data Format: A relational database will organize uploaded data in a user-friendly format.
- Technical Support: Units will be produced by ATU faculty and students who can troubleshoot problems.

All necessary infrastructures for the biological elements of the project are already in place. An Interdisciplinary Research Grant was obtained to support the project. All biology methods were approved by the Institutional Animal Care and Use Committee at ATU (approval no. 103116), Arkansas Game and Fish (permit no. 051020161, 082820171, 092420181, 112020192), and United States Fish and Wildlife Service (permit no. 24044). With the aid of student assistants, over 120 birds from 8 species have been captured using mist nets located near the feeders. A USFWS band, a PIT tag with a unique identification code, and a combination of color bands (for visual resighting) were attached to the legs of each bird before releasing them unharmed. A team from the Biological Science Department will capture and tag additional birds on weekly basis, while also maintaining feeders and data loggers. A CIS team is working on developing an improved relational database for data storage and designing a web interface for real time visualization and monitoring. The EE team is working on developing the system and will be responsible for field testing, packaging, installation, and technical maintenance/troubleshooting.

III. Related Work

Recent research on IoT applications for ornithological monitoring include an autonomous bird nest to monitor and record breeding of the Great Tit (*Parus major)* species [9]. The system is based on double-switched RFID readers and antennas to monitor entry and exit of birds from the nests. The birds have 3D printed tags attached to their legs, and the system uses a GPRS communication system for wireless transmission of data to the cloud so that it can be accessed by ornithologists all over the world. During field tests, the IoT smart nests had success rates of 95%.

IV. System Design

The proposed system design is shown in Fig. 2. The system consists of IoT nodes which are installed on each bird feeder, and a gateway for processing and transmitting data to the cloud. It is based on 125 kHz EM4102 PIT (Passive Integrated Transponder) Tags. When a tagged bird arrives at the bird feeder, the unique identification code of the tag is read by the Eccel microRWD QT (Quad-Tag) 125 kHz reader. A custom firmware is installed on the tag reader. This system is essentially a proximity system with a read range of up to 20 cm. The system has a unique AST (Adaptive Sampling) feature that adjusts and re-tunes the sampling rate to allow for inductive changes in the RF field for reliable and robust operation. The tag reader needs a 700µH antenna coil and a 5V DC supply to enable read functionality. The data from tag reader is passed through a level shifter circuit to convert the 5V serial data to the 3.3V

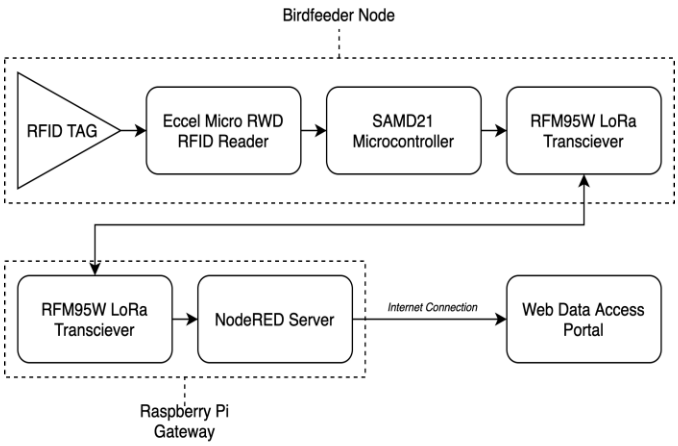

Fig. 2: System Design – Block Diagram.

logic level of the microprocessor. The Atmel SMART ARM Cortex SAM D21 low-power 32-bit microcontroller was chosen. Upon detection of a PIT tag, the program on the microprocessor wakes from sleep mode, reads the tag data, establishes contact with the gateway, and transmits the data. At night, the gateway sends a command to the nodes to enter a low power state to conserve battery power. This microcontroller is married to a SparkFun Pro RF LoRa-enabled wireless board. The wireless board also has an ultra-long range, high interference immunity, and low current consumption 915 MHz spread spectrum transceiver module (RFM95W). The entire system works on solar power through a 5V charger and batteries. The RFID reader and SAM D21/LoRa Transmitter combination uses very little power, making it ideal for a solar powered battery setup. This arrangement makes a compact and easy-to-use custom IoT board.

The data from each node is then transmitted to the gateway using LoRa protocol. A Raspberry Pi 4 with 1.5 GHz 64-bit quad-core ARM CPU acts as a gateway, coordinating the operation and data collection of all the nodes. A Python script runs on the gateway which controls the attached LoRa transceiver. The script manages the nodes, pinging them periodically to ensure they are online and operational, sending commands to the nodes to put them in a low power state at night, and forwarding the incoming data to the Node-RED installation. Node-RED software is installed on the Pi to timestamp incoming data and upload the data to the cloud, as well as notify members of the research team if a node is offline for an abnormal amount of time so that further troubleshooting can take place. The data from the gateway is transferred to the cloud using an internet connection. To enable the data transfer, the gateway is currently white-listed on the ATU WiFi network. The team plans to locate the gateway at a suitable location to provide coverage for all eight nodes.

The data is collected every 4-seconds by the each of these eight data-loggers on-campus. The gateway then forwards the data to Amazon Cloud Services (AWS) over its internet connection. GoDaddy.com hosting service was chosen to host the website. The domain name of the website is www.atubirdfeeders.com. On the backend side, NodeJS is used to communicate with the database hosted on AWS platform. AngularJS was used to design webpage and AJAX for asynchronous communication between AngularJS and NodeJS. The java-script refreshes the webpage once every 2 minutes to reflect the real-time data to the user. The interface allows the user to run queries, such as: what were the number of visits per-day for each bird, which feeder was used most frequently.

V. Conclusion and Future Work

An interdisciplinary team is working on this project. A prototype system has been developed and trials are in progress to determine the best location for the gateway. The team has identified the rooftop of Ross Pendergraft Library Building to have line of sight between gateway and the nodes, and a wired internet connection would be available for improved reliability and security. The nodes are installed on the birdfeeders around campus. The CIS team members have developed the relational database and are currently working on improving the design of web interface. The EE team is working to design a rugged case for installing the gateway in the open environment for the optimum wireless communication coverage and is also working to produce 7 additional nodes for the remaining birdfeeders. This project represents a model of interdisciplinary collaboration to solve real-world problems. The team plans to further advance their collaboration through future projects related to environmental monitoring and sustainability.

Acknowledgment

Funding was provided by an Interdisciplinary Research Grant through the Arkansas Tech University Office of Sponsored Programs and University Initiatives.

References

[1] Report, "The Internet of Things: An Overview", released October 2015, Internet Society.

[2] Ropert-Coudert, Y. and Wilson, R., "Trends and Perspectives in Animal-attached Remote Sensing". Frontiers in Ecology and the Environment, vol. 3, pp. 437-444., 2005.

[3] Shade, A. and Teal, T., "Computing workflows for biologists: A Roadmap", PLoS Biology, vol. 13, 2015.

[4] Barron, D. G., Brawn, J, and Weatherhead, P., "Meta-analysis of transmitter effects on avian behavior and ecology". Methods in Ecology and Evolution, Vol. 1, pp. 180-187, 2010.

[5] United States Fish and Wildlife Service Report: Available at: https://www.fws.gov/birds/bird-enthusiasts/backyard/bird-feeding.php#2

[6] Dayer, A., Rosenblatt, C., Bonter, D., Faulkner, H., Hall, R., Hochachka, W., Phillip, T., and Hawley, D., "Observations at Backyard Bird Feeders Influence The Emotions and Actions of People that Feed Birds", People and Nature, John Wiley and Sons, Vol. 1, pp. 1-14, 2019.

[7] Brittingham, M., and Temple, S., "Use of Winter Bird Feeders by Black-Capped Chickadees". Journal of Wildlife Management vol. 56, pp. 103-110, 1992.

[8] Fischer, J., Stallknecht, D., Luttrell, P., Dhondt, A., and Converse, K.," Mycoplasmal Conjunctivitis in Wild Songbirds: The Spread of a New Contagious Disease in a Mobile Host Population". Emerging Infectious Diseases , vol 3, pp. 69-72, 1997.

[9] Ruben, D., Lopez-Garde, J., Garibay, J., Macon, J., " Smart Nests: IoT for Ornithology". 2018 Global Internet of Things Summit (GIoTS), pp. 1-6, June 4-7, 2018, Bilabo, Spain.