IoT Technology for Wildlife Conservation Based on Energy Harvesting

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Abstract

Wildlife conservation is the practice of protecting wild plant and animal species. Wildlife plays a vital role in balancing the ecosystem and stabilizing different natural processes. In order to enable real-time tracking and monitoring of animal movements, different tracking devices can be used. A collaboration work with a telecommunication industrial partner in senior capstone design projects considers enhancing animal tracking devices. In this work, IoT-based tracking device is designed to be powered from animal's motion by using build-in harvesting unit. The device will be used to monitor and track animal's motions as well as biological signals such as temperature, pressure and heart rates in order to observe and study animal species in their natural habitat.

Keywords
Internet of Things, Tracking devices, Energy harvesting, ESP8266 controller, Wildlife conservation.

1. Introduction

Internet of things (IoT) platform provides huge collection of data that can be used in research and supervision applications (Bahga & Madisetti 2015; Kranz 2016; Acharjya & Geetha 2017). IoT is a system of interrelated diverse subsystems such as computing devices, machines, objects, animals and people that are uniquely identified. These subsystems have the ability to transfer data over the global Internet without the need of human-to-human or human-to-computer interaction.

Energy harvesting is the process of deriving energy from external ambient sources such as solar energy, wind energy, thermal energy, RF radiation and vibrations. Commercially off-the-shelf (COTS) energy harvesters provide a very small amount of power that can be used for applications that require low-energy electronics. Recently, there has been an increase interest in harvesting energy from natural resources to power up IoT devices and allow longer periods of operation while sending high rate of data (Bizon et al. 2017; Chen 2019).

Technology noticeably contributed in tracking animals' movement. Detail spatial and temporal data are collected and used in animal conversation (Katzner & Arlettaz 2020). A study conducted by Lei et al. (2019) targeted five geese species including birds' migratory using Satellite tracking devices. The solar-powered global system for mobile communication (GSM) transmitter has an integrated general packet radio service (GPRS) subsystem for short message service (SMS). Bird tracking real-time data were collected inside China. However, no real-time roaming data were collected outside China, but instead data is downloaded once the birds come back to china. Data loss is estimated in 80 cases within China due to device failure. Others data loss cases include confirmed death, and one third due to poison or hunting. An IoT based expert system using wireless device is utilized to collect and analyze data related to animal management (Todorov & Stoinov 2020). Utilizing ZigBee and using four sensors, animal's data related to heart rate, temperature, pulse rate, and respiration rate were gathered to track animal heath activities (Choudhary 2020).

This paper introduces a new sector to the IoT platform aiming at observing and studying animals in their natural habitat. Wildlife conservation is essential for protecting animals and keeping track of their migration across the oceans and continents (Yang & Yan 2015; Markov & Markov 2005). United Arab Emirates supports a rich diversity of animals and it embraces a stunning variety of natural habitats, which support a vast group of species that the country has with each perfectly adapted to its particular environment. Consequently, IoT technology will help to clarify how animals can adapt to the UAE's climate and hence, find the ultimate way to preserve and protect the animals living on the UAE land especially the endangered ones.

The idea of this paper is to build an IoT device for animals that can send vital sensor information to the IoT platform. The main purpose of this device is to collect a database of animal's data and save them on a cloud server that can be used for research and development. Additionally, the device is having a build-in harvesting unit that can convert animal motion into an electrical signal that can be used to extend the battery life of the device. Finally, the device is equipped with a GPS unit to track the location of the animals.

In Section 2, the system description is presented. The block diagram of the suggested system is introduced in Subsection 2.1. Arduino programming flow chart is given in Subsection 2.2. In Subsection 2.3, system testing is discussed. Results and discussion are presented in Section 3. Conclusions are given in Section 4.

2. Methodology

This section presents the methodology adopted to achieve the objective of building an animal tracking system powered with an energy harvesting unit. The suggested block diagram, programming flow chart, and system testing are introduced in the following subsections.

2.1 Block Diagram

The suggested animal tracking system is divided into three main parts based on their functionality, see Figure 1. The three parts are as follows:

Input part

The input part in the suggested IoT system for wildlife conservation consists of a GPS module and a hybrid energy unit. The GPS module is included in the system to provide the exact coordinates of the animal, and the hybrid energy unit will help in providing energy for powering up the IoT device.

The hybrid energy unit is consisting of a small battery and an energy harvester. The energy harvester will extend the life of the battery by charging it using piezoelectric transducer. The piezoelectric transducer is an instrument that converts kinetic energy to electrical energy. The piezoelectric energy harvester, see (Vives 2004) and (Rupitsch 2019), needs vibrations or shocks to allow electrical energy conversion. Moreover, the advantages of the piezoelectric transducer are its small size, availability in the different shapes and its good frequency response. However, it is only used for dynamic measurement and temperature sensitivity.

Controller part

The controller part will be an ESP8266 (Muniz 2019), (Lee and Mun 2019) which is a low-cost Wi-Fi microchip with full microcontroller capability. The ESP8266 will be activated when the voltage from the harvesting unit reaches a predetermined voltage value so that the GPS information can be sent through the cloud to the output part. The ESP8266 controller is a very low power consumption device that can be perfectly fitted in this IoT application to achieve the required results and send tracking information to the IoT cloud.

Output part
The organic light-emitting diode (OLED) display and Blynk App represent the output part of the system. Blynk (Noar and Kamal 2017), (Serikul et al. 2018), (Durani et al. 2018) is a platform with iPhone operating system (iOS) and Android apps to control Arduino, Raspberry Pi and similar platforms over the internet. The OLED display is built in the module to show the output voltage coming from the harvester and the Blynk App is used to demonstrate the animal location to the user. Identifying pet's location using smart phone application is one of the most applicable methods nowadays.

Figure 1: The suggested IoT system for wildlife conservation.

2.2 Programming Flow Chart
The ESP8266 is programmed to receive the voltage values from the energy harvester and display the incremental readings on the OLED display. As the piezoelectric energy harvester vibrates and generates voltage, the battery starts to charge, and the value of the charging voltage on the OLED is increased. When the voltage of the hybrid energy unit reaches a predetermined voltage (3 volts in the code), the ESP8266 sends the coordinates through Wi-fi to the cloud. The programming flow chart is shown in Figure 2.

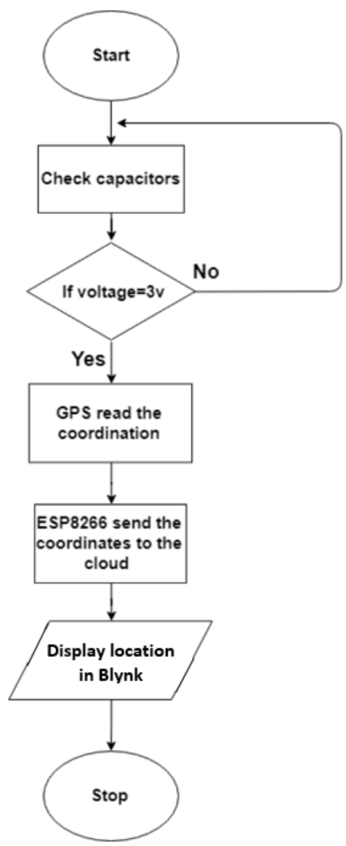

Figure 2. Programming flow chart

2.3 System Testing

Component Testing

The project consists of two main circuits which are the ESP8266 that will be connected directly to GPS Module and the piezoelectric energy harvester included in the Hybrid energy unit. The first circuit was designed to send the location of an animal to the ESP8266 by using the GPS Module. This circuit has been simulated on Fritzing and tested using Arduino software as shown in Figure 3. The second circuit is used to test the piezoelectric energy harvester. The objective is to test results of the maximum output voltage that the harvester can generate while vibrating. The initial test has been done on the harvester by vibrating it gently and observe the output voltage in the oscilloscope as shown in Figure 4.

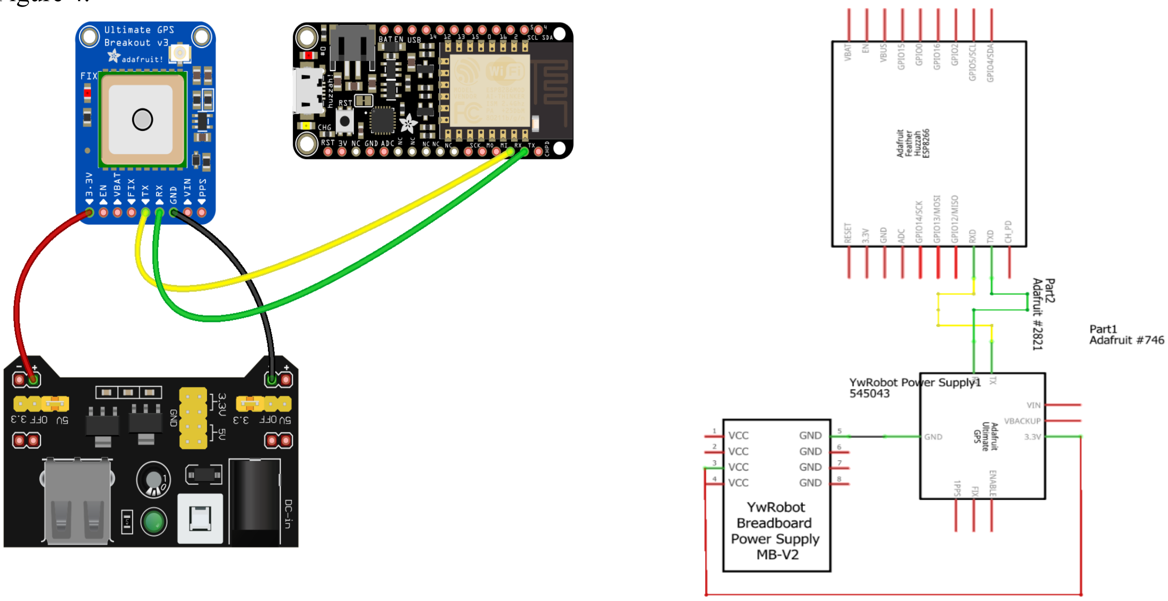

Figure 3. The breadboard (left) and schematic connection (right) of ESP8266 and GPS Module.

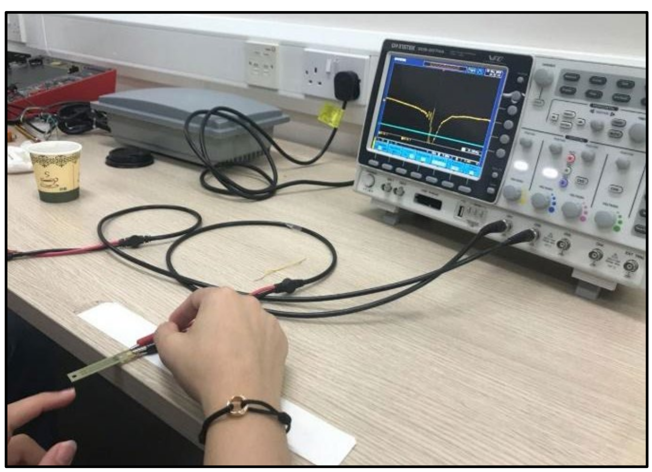

Figure 4. Testing the amount of generated voltage from piezoelectric energy harvester.

Subsystem Testing

Developing the proposed system has been done by using various software to make it useful. Arduino was used to program the OLED to display the variable values of the voltage generated by the piezoelectric energy harvester and to integrate the circuit with Blynk App. Fritzing was used to connect the hardware components with the ESP8266. The ESP8266 board used to read the analog input and turn it into an output based on the written programming code.

The ESP8266 is programmed to receive the voltage values from the energy harvester and display the incremental readings on the OLED Display. As the piezoelectric transducer vibrates and generates voltage, the battery starts to charge, and the values of the charging voltage on the OLED is increased, see Figure 5. Once the voltage reading reaches a predetermined value (chosen as 3 volts), the ESP8266 sends the coordinates through Wi-Fi to the cloud.


```
#define BLYNK_PRINT Serial    // Comment this out to disable prints and save space
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <SPI.h>
#include <Ethernet.h>
#include <Wire.h>
#include <ACROBOTIC_SSD1306.h>

char ssid[] = "sarablynk";
char pass[] = "sara12345";

int Num1,Num2;
char OutputString[10];
float voltage;
BlynkTimer timer;

// You should get Auth Token in the Blynk App.
// Go to the Project Settings (nut icon).
char auth[] = "a2e37a7ef5f941178fb7f60ea3565373";

void myTimerEvent()
{
  float Long,Lat;
  Long = 24.479;
  Lat = 54.376;
  // Read voltage
  voltage = ReadVoltage();

  // Send to Blynk
  Blynk.virtualWrite(V0, voltage); // Piezo voltage
  Blynk.virtualWrite(V1, Long); // GPS longitude
  Blynk.virtualWrite(V2, Lat); // GPS latitude

  // Send to oled
```

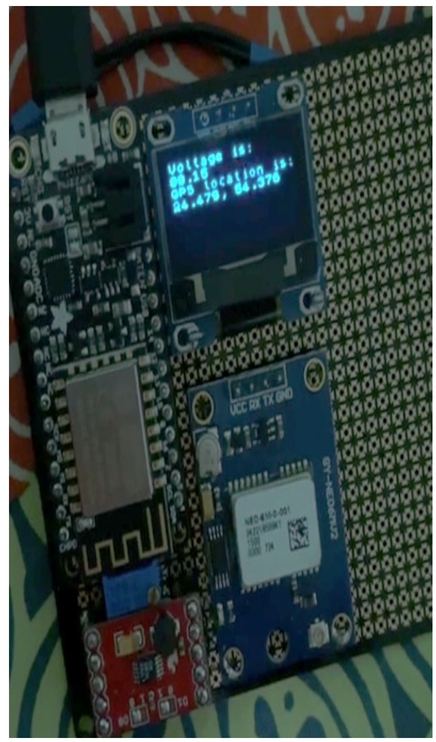

Figure 5. Programming code (left) and the PCB of the system showing the OLED (right).

c) Assembled System Testing

In order to assemble the whole system, the piezoelectric transducer is placed on a bell with a swinging ball and connected to the energy harvester through flexible wires. PCB board was designed to connect the circuit, and Iron solder was used to connect the ESP8226, OLED, GPS, and the hybrid energy unit containing the energy harvester on the board. Flexible wires were used to link these components.
The assembled system has been tested on three animals as follows:
1. ***A lazy cat:*** when we placed the circuit on the cat and put the bell on her neck, no voltage was produced as she was very lazy.

2. ***An active dog:*** in this case, the circuit worked properly and the voltage starts to increase with the motion of the dog. See Figure 6.

3. ***A very active cat:*** the motion of this active cat generated enough voltage but as she was very active, the weight get separated from the piezoelectric transducer and the soldering has gone.

Passing through all of these experiments leads the team forward to have a better understanding of the application of the project and how to harvest the maximum energy from animal motion and vibration. Also, the experiments reflect the need to develop a robust prototype that tolerates rough operation conditions.

Figure 6. The developed prototype (right) and the prototype on an animal for testing (left).

3. Results and Discussion

During the assembly and testing process, there were many difficulties until reaching to the desired output. For example, the software program has been modified several times in order to allow the OLED to display the changing generated voltage by the piezoelectric energy harvester. Another challenge was to find an efficient method to cause the harvester to vibrate by the animal's motion which is an essential task in the energy harvesting process. Several methods were proposed but finally the team came up with the idea of placing the piezoelectric on a bell with a weight (small metallic ball) and connect it to the pins of the energy harvester through flexible wires and then to the circuit board, see Figure 6. The results obtained from testing the prototype show that an enough harvested voltage of 3 volts can be produced from the energy harvester in order to operate the ESP8266 for sending the animal location as shown in Figure 5.

In future, in addition to the GPS module, additional sensors to the device can be added in order to expand the study on the animals and get more information. For example, if a heartbeat sensor is added to measure the heartbeat of the animal, observers can know that something happened to the animal if the heart rate changed. Furthermore, adding more piezoelectric energy harvesters can be used to increase the charging voltage so the whole device can be charged using the harvesting unit only. A multiple piezoelectric energy harvesters will enable the device to conduct more information using different sensors types or send information to the observer multiple times a day rather than once for example.

4. Conclusion

IoT can be utilized in wildlife conservation to track animal migration, especially for endangered animals. With IoT, data can be gathered, stored, and analyzed. The generated reports from these databases can be used to keep track of animals' migrations as well as animals' behaviors. In this work, the authors came up with a lightweight IoT tracking device for animals that can be operated in a very demanding and versatile environment. The reliable lightweight IoT tracking device operates under different weather conditions and requires little maintenance after long time usage. The special embedded energy harvesting unit converts animal motion into energy. This contributes to extending the life of the battery used to operate the tracking device and extending the operation of the device to continue gathering GPS information. Moreover, the GPS unit in the circuit adds an option to track animals' locations and send gathered data to an IoT cloud using the ESP8266 controller. The IoT device is tested on cats and dogs, however, different animal species can also be used to test the device and to generalize the research findings.

References

Bahga, A., and Madisetti, V., *Internet of Things: A Hands-On Approach*. Orient Blackswan Private Limited - New Delhi, 2015.

Kranz, M., *Building the Internet of Things: Implement New Business Models, Disrupt Competitors, Transform Your Industry*. Wiley, 2016.

Acharjya, D. P., and Geetha, M. K., *Internet of Things: Novel Advances and Envisioned Applications*. Springer, 2017.

Yang, X. T., and Yan, B., Internet of Things for wildlife monitoring, *Proceeding of 2015 IEEE/CIC International Conference on Communications in China* - Workshops (CIC/ICCC), Shenzhen, China, 2015, pp. 62-66.

Markov, V., and Markov, G., Design and description of the Radio Telemetry investigation of the animals, *Proceedings of the Balkan Scientific Conference of Biology*, May 2005, pp. 409-412.

Bizon, N., Tabatabaei, N. M., Blaabjerg, F., and Kurt, E., *Energy Harvesting and Energy Efficiency: Technology, Methods, and Applications*. Springer, 2017.

Chen, Y., *Energy Harvesting Communications: Principles and Theories*. Wiley, 2019.

Choudhary, R. K., Internet of Things: Wildlife conservation and its challenges, Asian journal of Computer and Technology, vol. 9 , no.1, pp. 8-13, 2020.

Katzner TE, Arlettaz R. (2020). Evaluating contributions of recent tracking-based animal movement ecology to conservation management. Front Ecol Evol. 7:1–10

Lei, J., Jia, Y., Zuo, A., Zeng, Q., Shi, L., Zhou, Y., Zhang, H., Cai, L., Lei, G., & Li, W., Bird satellite tracking revealed critical protection gaps in east Asian–Australasian flyway. International Journal of Environmental Research and Public Health, vol.16, no.7, pp. 1147, 2019. . https://doi.org/10.3390/ijerph16071147

Todorov, T., and Stoinov, J. (2020). IoT based animal monitoring system, Proceeding of the 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), 1-4, doi: 10.1109/ISMSIT50672.2020.9254522.

Vives, A. A., *Piezoelectric Transducers and Applications*. Springer, 2004.

Rupitsch, S. J., *Piezoelectric Sensors and Actuators: Fundamentals and Applications*. Springer, 2019.

Muniz, R., Diaz, J., Nuno, F., Prieto, M. J., and Pernia, A. M., A Smart Power Meter to Recharge Electric Vehicles in Communal Parking Areas, *Transactions of IEEE Journal of Internet of Things*, vol. 6, issue 2, pp. 3448-3454, 2019.

Lee, K. T., and Mun, H. K., Real-time power monitoring using field-programmable gate array with IoT technology, *Transactions of IET Science, Measurement & Technology*, vol. 13, issue 6, pp. 931-935, 2019.

Noar, N. Md, and Kamal, M. Md, The development of smart flood monitoring system using ultrasonic sensor with blynk applications, *Proceedings of the 4th IEEE International Conference on Smart Instrumentation, Measurement and Application (ICSIMA)*, 28-30 November 2017, Putrajaya, Malaysia.

Serikul, P., Nakpong, N., and Nakjuatong, N., Smart Farm Monitoring via the Blynk IoT Platform : Case Study: Humidity Monitoring and Data Recording, *Proceedings of the 16th International Conference on ICT and Knowledge Engineering (ICT&KE)*, 21-23 Nov. 2018, Bangkok, Thailand.

Durani, H., Sheth, M., Vaghasia, M., and Kotech, S., Smart Automated Home Application using IoT with Blynk App, *Proceedings of the Second International Conference on Inventive Communication and Computational Technologies (ICICCT)*, 20-21 April 2018, Coimbatore, India

Biographies

Emad Abd-Elrady received his Licentiate and PhD degrees in Signal Processing from Uppsala University, Sweden, in 2002 and 2005, respectively. From 2006 to 2009, he was a senior researcher at Christian Doppler Laboratory for Nonlinear Signal Processing, Graz University of Technology, Austria, where he was working on realization and implementation aspects of adaptive digital compensation methods for analog nonlinearities in VLSI circuits for broadband communications. In 2010, he was a research fellow at the Institute for Digital Communications, The University of Edinburgh, UK, where he was working on distributed sensor network. Since 2011, he has been electronics engineering faculty at Abu Dhabi Women's College, UAE. His research interests include adaptive filtering, system identification, adaptive and nonlinear signal processing, dynamical system modeling, distributed sensor networks, and IoT.

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