Using Internet of Things for Wildlife Tracking

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Abstract

This paper provides a comprehensive examination of the utilization of Internet of Things (IoT) devices in wildlife management and tracking, their evolutionary trajectory, and practical implementation in data acquisition. Central to the discussion are key components of IoT networks, including Sigfox, Wi-Fi-enabled devices, and IoT-based wireless sensor networks, each analyzed for their role and efficacy. Communication modalities within IoT frameworks, coupled with an evaluation of protocol performance are evaluated.

Furthermore, this seminar also addresses challenges inherent in wildlife data collection methodologies, such as memory constraints, battery life, transmission range and rate, and security vulnerabilities within IoT ecosystems. By delving into potential solutions and technological advancements, this paper aims to contribute to the refinement of wildlife monitoring practices, fostering a more robust and effective approach to conservation efforts.

This is a preliminary abstract, I mainly added it just so I had something.

Keywords: IoT, networking, Wi-Fi, data transmission, data collection, animal trackers, Sigfox, WildFi, Biologging, ecology

1 Introduction

2 Background

Comprehending the foundational technology behind the Internet of Things (IoT) is paramount in grasping its applications in wildlife tracking. This section aims to furnish a concise overview of biologging, the IoT, and their intersection in wildlife tracking. Additionally, it will explore current and past technologies employed in biologging, shedding light on their operational mechanisms and comparative advantages. By delving into the workings of traditional wildlife tracking technologies, we can evaluate their merits and demerits, thereby establishing a framework for evaluating the suitability of IoT solutions for wildlife tracking.

2.1 What is Biologging?

Biologging is a concept that gained popularity in the early 2000's and has continued to play a pivotal role in understanding animal behavior and ecology. Biologging can be defined as "The investigation of phenomena in or around free-ranging organisms that are beyond the boundary of our visibility or experience. [2]" It is a method of tracking animals in the wild using electronic devices that are attached to the animal. These devices can be used to track the animal's movements, monitor its behavior, and collect data on its environment. Biologging emerged as a powerful tool in ecology in a similar way genomics did for the study of cell and organ function. The obvious difference being that biologging provides insights into the behavior and functions of various organisms in environments that can be hostile or difficult to reach for the observer, rather than the function of cells and organs [2]. The ability to track animals in their natural environment has provided researchers with a wealth of data that was previously unattainable. This data has been used to study animal behavior, migration patterns, and the effects of climate change on various species[3]. The data collected from biologging devices has also been used to inform conservation efforts and to help protect endangered species [4]. It is important to understand that biologging is simply the collection of data from animals in the wild, and it is then up to scientists or conservationists to use the data to answer questions about the animals or to inform conservation efforts.

2.2 How does WiFi work?

2.3 What is the Internet of Things?

The Internet of Things (IoT) represents a transformative shift in the realm of technology, encompassing a vast array of physical objects empowered with sensors and software to interact autonomously. These objects collect and exchange data through network connectivity. In essence, IoT devices, ranging from commonplace gadgets to sophisticated systems, have the capability to interface with the internet or communicate wirelessly, thereby facilitating seamless integration into various facets of daily life. The IoT has been applied to a wide range of fields, including healthcare, agriculture, manufacturing, and most important to this paper, wildlife monitoring. The fundamental structure of an IoT system is comprised of three interconnected layers: the perception layer, the network layer, and the application layer[9]. The perception layer is responsible for collecting data from the environment, which is then transmitted to the application layer via the network layer. The transmission layer can use a variety of different methods to transmit data, the two most common being ethernet/WiFi, and cellular networks like 5G and LTE[7]. Lastly, the application layer is responsible for doing something with the data, such as graph positional data from an animals GPS sensor. The physical implementation of these layers can vary greatly, but in general, the perception layer consists of a sensor or device that can output a signal to be received by a gateway device(the most common gateway device for the average person would be a wireless router). The gateway device is connected to the internet using one of the aforementioned methods, and it is responsible for receiving the data from the perception layer device and transmitting it to the application layer, which could be a database to store the data, or a web application to display the data[9]. These three theoretical layers are important in understanding the IoT, and how it can be used in wildlife tracking. The Wild-Fi biologging tag, is a prime example of how these three layers are implemented in a biologging device and is visually explained by figure 4.

2.4 What are the Other Biologging Methods?

Various stratagies have been used in the past to track animals in the wild. Many implement variations of the same technology within the tracking sensors; GPS, accelerometers, and magnetometers are the most common sensors used in biologging devices. These data from these sensors help researchers understand the animal's speed, direction, and position, which allows for a 3D mapping of positions[8]. The compilation of this data can be seen in Figure 1 from the Smithsonian's National Zoo and Conservation Biology Institute, which shows the 3D movement of a prairie dogs. Most

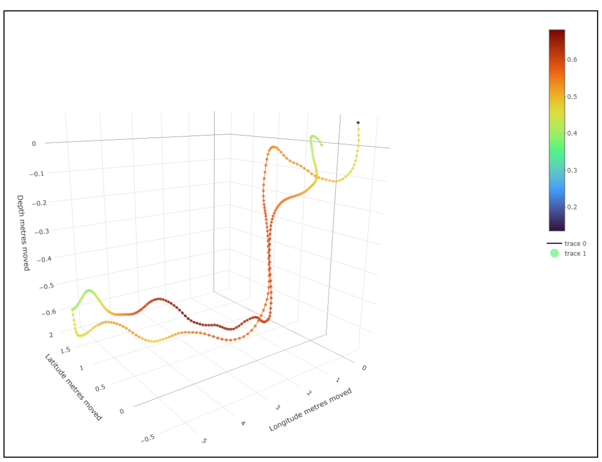

Figure 1. 3D movement of a prairie dog [8]

biologging trackers will implement these types of sensors, but the implementation of these sensors can vary greatly. More importantly, the communication of the data from these sensors can vary greatly. One of the most popular methods for transmitting data is the use of cellular networks. A study conducted by a professor from UC Irvine tested the use of cellular networks to analyze the pollution levels in the San Jose area by using pigeons equipped with GPS and automotive emissions sensors [11]. Professor Da Costa had to pay about 10 cents for each message transmitted, and two messages are sent every minute by each pigeon[11]. This leads into one of the biggest disadvantages of using cellular networks: cost. Another obvious disadvantage is that cellular networks are not available in all areas, and the range of cellular networks is limited. It is also practically impossible for researchers to improve the range of cellular networks by adding more cell towers to cover their study area. Radio frequency is another technology that has been used to transmit data from biologging devices for decades. The use of radio frequency to transmit data from biologging devices requires a receiver to be within range of the transmitter, and the range of the transmitter is limited by the power of the transmitter and the frequency of the radio waves. The receiver and transmitter used by Cooke et al. on marine animals had an effective range of 5 to 1000m and is only able to transmit periodic tracking records or time stamped data from loggers [5]. This falls short of the capabilities of IoT enabled biologging devices using LPWAN networks, which are able to transmit data in real time, and can transmit data over much longer distances.

3 Components of a IoT Biologging System

3.1 The Sensor Device

4 Networking

The networking of a IoT based biologging system is crucial in ensuring safe and efficient data transmission. The networks used in a biologging system are responsible for transmitting data from the sensor device to the application layer, and are also responsible for ensuring that the data is transmitted safely and securely. The two most popular types of networking protocols used in biologging systems are Low Power Wide Area Networks (LPWAN) and Traditional Wifi. These two types of networks have their own advantages and disadvantages, and the choice of which network to use is dependent on the specific use case. No matter what method is used, the networking must be able to transmit data over long distances, and they must be able to do so in a secure way. The security of the data is especially important in a biologging system, as the data being transmitted is often sensitive and can be used to track the location of an animal, which in the hand of an illegal hunter, could be disastrous.

4.1 Low Power Wide Area Networks (LPWAN)

LPWAN networks provide a few benefits compared to a traditional mesh wifi network, the primary benefit being that LPWAN networks are able to transmit data over much longer distances than a traditional mesh wifi network. This is especially important in a biologging system, as the animals being tracked are often in vast, remote areas where a 200m range would not be sufficient. LPWAN networks typically utilize sub GHz frequencies and ultra-narrow band modulation to transmit data over long distances [15]. Proprietary LPWAN networks like the SigFox network are popular and designed to handle up to a million IoT devices using only a single gateway. These services are subscription based, and the cost of the service is based on the number of devices that are used in the network. On the other hand, there are LPWAN standards that exist to allow in house development of an LPWAN network. The LoRaWAN protocol is one of the most popular LPWAN standards, and it is used by many to implement their own LPWAN networks[1]. Both of these network solutions are explored further in subsections 4.1.1 and **??**.

4.1.1 SigFox. The SigFox network is a proprietary LPWAN network that is used for IoT systems, and it can be used to cover an area as big as Belgium ($30,600km^2$) with only seven base stations [13]. The node device in a SigFox network is able to transmit 6 messages per hour, each having a maximum size of 12 bytes. While 12 bytes may seem limiting, it is sufficient for transmitting the GPS coordinates of an animal, as well as other sensor data such as temperature[13]. The SigFox company also offers the Atlas technology which uses the signal strength and location of the receiving base station to calculate an approximate location of the node device, which frees up the node device from having to explicitly send GPS data, allowing for other sensor data to be sent instead[13]. Ultra-Narrow bands (UNB) are used in the SigFox network

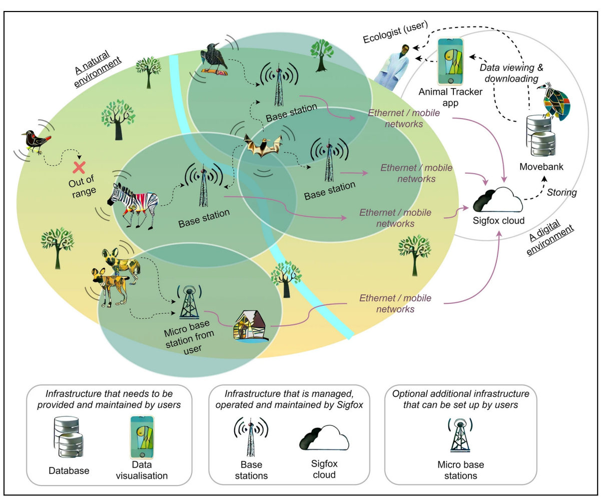

Figure 2. SigFox network infrastructure[13]

and many other LPWAN networks, which allows for the transmission of data over long distances, and the use of UNB also allows for the use of low power transmitters, which is important in a biologging system, as the devices are often attached to animals and must be as small and light as possible. UNB works by using a low radio frequency(868.034MHz to 868.226MHz), and transmits data three times on different channels at different times, which ensures a message is received and robustness to interferences[10]. One of the greatest benefits of UNB is that it allows for the use of low power transmitters, which are able to have incredibly long battery lives. Using the specifications of SigFox's UNB network, a node is able to send 140 packets per day, and the power consumption is between 19 and 49 mA, two AAA batteries are able to power a node up to 6.5 years [10]. Because SigFox is a proprietary network, end users do not maintain the base stations or connection to the SigFox cloud: they only need to design their devices within the SigFox specifications and connect them to the SigFox network. An overview of the SigFox infrastructure and how it can be applied to biologging is shown in Figure 2.

4.1.2 LoRa. The LoRa and SigFox networks have many similarities in how they are structured and operated, however there are some key differences. The transmission modulation technique used by LoRa is called chirp spread spectrum, and it is slightly different from SigFox's UNB modulation technique.

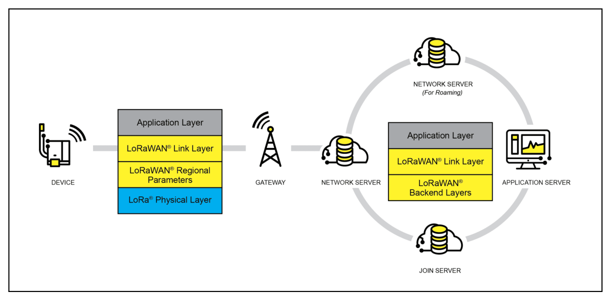

Figure 3. LoRaWAN network Stack[1]

4.2 Traditional Wifi

A more traditional Wifi network is another method that is used by some companies to implement biologging systems. There are some useful benefits to using a traditional Wifi network over an alternative like LoRa or LPWAN; The biggest of which is data transfer rate. However, because traditional Wifi uses 2.4/5/6 GHz, the range is much more limited than that of a LPWAN network, and the power consumption is higher. The WildFi biologging system designed by Timm Wild and his colleagues is just one example of a device that uses traditional WLAN to collect data from a biologging device. Wild is also the leading member of the team that studied the use of the SigFox network for a IoT based biologging system, and claimed that the data transmission capacity was one of the reasons that they chose to investigate the use of a traditional Wifi network for biologging[14]. The WildFi tags and others like it, connect and communicate by using a traditional wireless local area network (WLAN), which provides a versatile way for tags to offload collected data. As seen in Figure 4, the WildFi tag has the capability to connect to a WLAN router, smartphone hotspot, specially designed gateway, and more. When the tags establish a connection to one of these

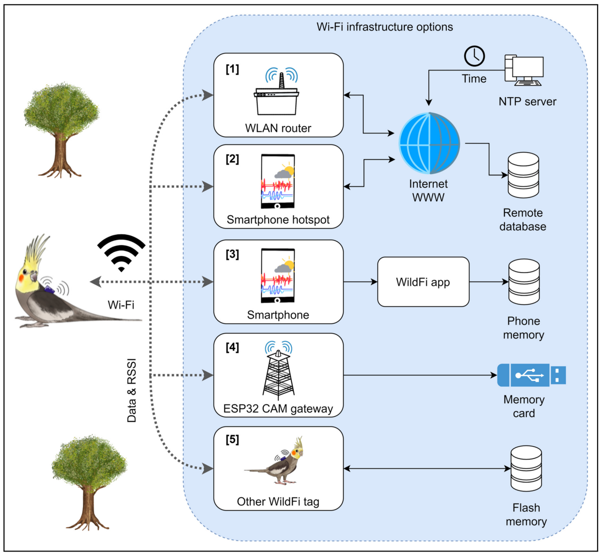

Figure 4. Wild-fi IoT infrastructure overview [14]

devices, data is packaged, encrypted, and transmitted to the receiving device. From there, the data can either be stored on device to be physically collected, or uploaded to a remote database. When connected to a ESP32 CAM gateway and the data is stored locally, a transmission rate of 230 kByte/s can be achieved at a distance up to 200m and only consume 108mA using a WildFi tag[14]. This is more power consumption than a LPWAN based device, however the energy cost per byte transmitted is lower than a LPWAN based device. Wild et. al claim that using a traditional Wifi network with a logging device that has a 70mAh battery and a small solar panel, data can be transmitted 24 hours a day for an entire lifetime of an animal[14].

4.3 Comparison and Selection Criteria

4.4 Security Protocols

5 Challenges to Overcome

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This is where you thank those who helped you better understand the material and gave you helpful feedback on the paper, usually including your adviser. This is not a place to thank your family, your significant other or your best friend, or anyone else for moral support or yummy cookies.

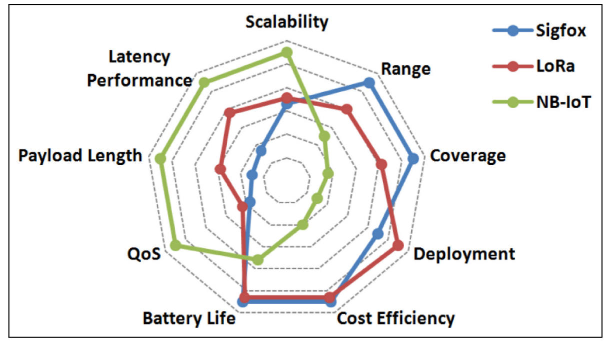

Figure 5. Respective advantages of Sigfox, LoRa, and NB-IoT in terms of IoT factors. [12]

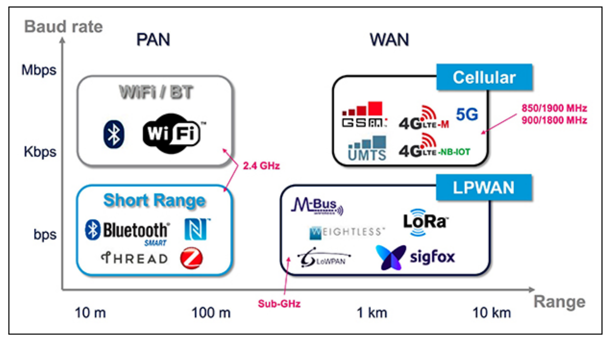

Figure 6. Data rate vs range for different LPWAN technologies. [6]

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