CraneTracker: A Multi-Modal Platform for Monitoring Migratory Birds on a Continental Scale

[DEMO Abstract]

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ABSTRACT

Low-cost wireless sensor networks (WSNs) provide novel opportunities for conservation efforts. This paper will demonstrate a new hardware platform for monitoring Whooping Cranes, which conduct migrations that extend from Texas to Canada. This high mobility necessitates a multi-modal communications architecture to maintain connectivity. As such, the traditional ZigBee radio used in WSNs has been augmented with a GSM modem. The conventional role of WSNs in tracking wildlife has been expanded to include more extensive behavior monitoring. Finally, the motes are integrated into a complete system that collects and visualizes the data for use by ecologists that study the birds. To the best of our knowledge, this is the first multi-modal sensor network for real-time monitoring of migratory birds on a continental scale.

1. INTRODUCTION

The Whooping Crane (*Grus Americana*) is one of the most endangered bird species native to North America. As of spring 2011, there are only 575 birds in existence, with no more than 279 individuals in the Aransas-Wood Buffalo Population (AWBP). The AWBP is the only wild migratory population. AWBP is also the source of the nearly 300 birds that are in captivity or have been released in efforts to re-establish the species in Wisconsin, Florida and Louisiana [2]. These birds conduct an annual migration of 4,000 km (2,485 miles) between Texas and Canada, during which they travel as much as 950 km/day (590 miles/day). Since mortalities generally occur during migration, tracking and monitoring the cranes in real-time during migration is of prime importance to conservation efforts.

Real-time tracking of migratory birds faces several challenges in terms of communications, sensing, power, and weight. The size of the birds places tight restrictions on the weight and size of the mote. The extreme mobility and unpredictable movements during migra-tion creates severe challenges in maintaining communications with the birds. Moreover, it is very difficult to recapture a bird. Once the device is attached, it must operate reliably under unpredictable environmental conditions for multiple years. The weight and mission duration constraints also impose significant challenges to energy management. Finally, the collected information must be reliably stored, made accessible, and visualized by conservationists.

In this demo, we present a platform with multi-modal communications for monitoring Whooping Cranes. This demonstration includes a presentation of a hardware platform that has been developed, the visualization component for the collected data, and a 3D model that replicates the movements of the monitoring platform. In Section 2 we give a more detailed description of the background and challenges of the project. A platform for solving these challenges is presented in Section 3. Section 4 describes the demo to be presented. Finally, our conclusions and demo requirements are presented in Section 5.

2. BACKGROUND

The AWBP population of Whooping Cranes resides in Aransas National Wildlife Refuge, in southern Texas, during the winter months. Beginning in March, the birds fly to Wood Buffalo National Park in Alberta, Canada, and arrive by mid-April. The birds begin their return migration in September, and are finished by mid-November. These migratory periods are of primary interest to conservationists because crane mortality greatly increases during these periods.

Monitoring the cranes during these periods poses several challenges. First, the cranes are highly mobile during these times, and the intermediate stops during the migration are unpredictable. Second, an adult crane weighs approximately 7 kg, which limits any tracking device to 95 g. Third, it is extremely rare to capture
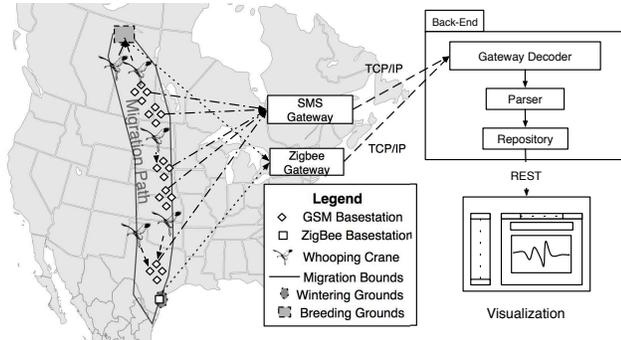
Figure 1: System Architecture

a Whooping Crane more than once, which means any devices attached to the cranes must function for 3 to 5 years. Finally, the cranes do not travel in large groups, instead preferring to travel with only their mate and any juvenile children.

Prior conservation efforts have attempted to track the Whooping Cranes during their migration. Initially, ground based spotters were used, which were later replaced with short range radio transmitters, and culminated with satellite transmitters being attached to the birds. Unfortunately, the impact of these efforts have been mitigated by high implementation costs, long delays in locating the birds, and only location information being collected about the birds.

To address these shortcomings, a new generation of monitoring devices is needed. These devices must be much cheaper to construct and operate. The communication links in these devices must be more available during the migration. Finally, more than just location information needs to be collected in order to isolate the environmental triggers that change the birds' behavior.

3. SYSTEM DESIGN

To effectively monitor the cranes and meet the requirements of conservationists, a new hardware platform, the *CraneTracker100* was designed. This platform leverages the well-known and proven Iris mote [1], and extends the capabilities with additional sensors and communication methods. These additional capabilities allow for data collection over a wide geographic area, and timely reporting of the results. This system is capable of operating for extended periods with a limited power supply and no intervention from users. An overview of the system architecture is shown in Fig. 1.

3.1 Hardware

Existing solutions, such as the MTS-420 [1], lack the sensing and communication capabilities needed for this mission. The *CraneTracker100*, shown in Fig. 2, has been developed to address these shortcomings. It utilizes an Iris mote for processing, storage, and short range communications, while adding additional sensors and improved communication capabilities. The ZigBee radio is complemented with a GSM modem. A mod-

Figure 2: *CraneTracker100*

ern and compact GPS is added, along with a solid state compass. The system's power supply has been augmented with a solar panel in order to extend the mission duration.

3.2 Multi-modal Communication

To fulfill the communication requirements the *CraneTracker100* includes a GSM modem. This modem is much cheaper to operate, compared to satellite transmitters, and can be more reliable. The widespread deployment of cellular towers throughout the United States and Canada enables the cranes to maintain a high degree of connectivity, even though they are highly mobile. While effective, the GSM modem is very power hungry compared to the low-energy ZigBee radio. Thus, the ZigBee radio is used while the cranes are in their long-term nesting grounds to form ad-hoc networks with pre-deployed base stations. These relatively constrained areas make it possible to deploy base stations and allow the system to conserve energy by avoiding the use of the GSM.

3.3 Sensing

Despite its compact size and weight, the tracking platform incorporates multiple sensors. The primary sensor on the platform is a modern GPS receiver [4], which can more quickly acquire a GPS fix than the solution in the MTS-420 that is generally used for WSNs. The new GPS receiver consumes less power while doing so, which results in significant savings in energy. Moreover, the GPS antenna is on the same physical package as the receiver, which is lighter and more compact than the MTS-420.

To more effectively characterize the bird movement and flight behavior, a three-dimensional solid state compass is used [3]. This compass allows the system to fully describe the orientation of the bird in flight and on the ground. The compass capabilities also include a three-dimensional accelerometer. This accelerometer is used to measure bird activity. This in turn can be used to determine whether or not the bird is alive. Finally, the compass includes a thermometer, which is used to monitor the cranes' environment.

Lastly, the GSM itself can be thought of as a sensor. By sending the ID of the cell tower it is connected to when it communicates, the bird's location can be estimated. Given the long range of a cell tower (35km), the estimate is extremely crude, but is adequate if the GPS
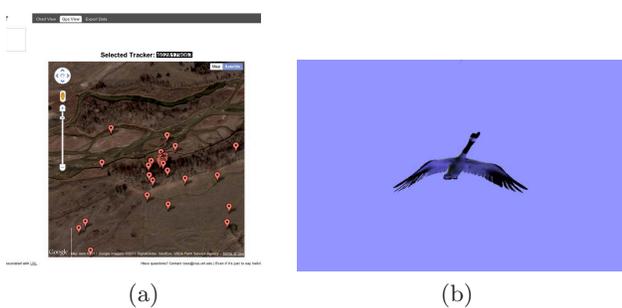
Figure 3: (a) Visualization (b) 3D Compass Demonstration

fails.

3.4 Power

Even with the most intelligent of power schemes, it is impossible for the motes to operate continuously throughout the entire time they will be attached to birds. To maximize the lifetime of the motes, a lithium polymer battery is used in conjunction with a solar panel. The solar panel is capable of completely replenishing the energy reserves. The lithium polymer battery ensures that the system will continue to function throughout extended periods of inclement weather which limit the solar energy harvesting.

4. DEMONSTRATION

The system demonstration will consist of three components. The first portion will highlight the multi-modal communication capabilities and sensors. The second will demonstrate the ad-hoc networking capabilities. The third will showcase the data-gathering possibilities of the platform.

Multi-Modal Communications and Sensors The first component will use a mobile user to show the different communication methods on the *CraneTracker100*. A ZigBee base station will be deployed at a stationary location. As the users moves enters and exits the range of the base station, the system will switch between GSM and ZigBee communication modes. Data collected from the compass and GPS will be collected. These results will be visualized by the backend software, similar to Fig. 3(a).

Proximity Detection The second part of the demo showcases the ad-hoc capabilities of the system by utilizing multiple motes. The motes will be distributed to audience members. Each mote will use the ZigBee radio, operating at a low transmit power, to discover other motes. It will then send this informaiton over the GSM to the base station. This demonstration will highlight the potential for this system to track family groups of cranes and correlate their movements to each other.

Flight Characteristics The third section will utilize the compass to demonstrate the system's ability to detect its orientation. The compass data will be broadcast to a base station, which will visualize the orientation as shown in Fig. 3(b). If the compass ceases to detect motion, it will send a warning message over the GSM, as if a crane had died and needed to be recovered.

5. CONCLUSION AND DEMONSTRATION REQUIREMENTS

We demonstrate a solution for monitoring the endangered Whooping Crane by developing a multi-modal communication and sensing platform. This demonstration illustrates the usefulness of our platform for monitoring a highly mobile endangered species. Especially in cases where access to the species is unfeasible and sparse.

To facilitate the demonstration, multiple components will need to be in place. In terms of facilities, wireless internet will need to be readily available. This access is required for the visualization software and base stations to communicate with the back end. Also, power is required by the presentation and base station computers. The first exhibition will require at least a square block for the user to move around and be monitored. For the second and third exhibitions, sufficient space is needed for users to move around during the demo. Lastly, a projector or display monitor will be required to show the visualization and demonstration software. All motes and demonstration hardware will be provided by us. In addition to facilities, an hour will be needed to setup the demonstration.

This demonstration is applicable for the Student Research Demo competition, as the first two authors are students in the graduate program at the University of Nebraska-Lincoln.

6. REFERENCES

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