Poster Abstract: Wildlife and Environmental Monitoring using RFID and WSN Technology

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Abstract

Wireless Sensor Networks enable scientists to collect information about the environment with a granularity unseen before, while providing numerous challenges to software designers. Since sensor devices are often powered by small batteries, which take considerable effort to replace, it is of major importance to use energy carefully. We present two efficient ways of extending the lifetime of such systems: 1. an adaptive duty cycling protocol and 2. an adaptive data management protocol. Further, we present some details of our deployed sensor network in Wytham Woods, Oxfordshire.

Categories and Subject Descriptors

C.3 [**Computer Systems Organization**]: Special-purpose and application-based systems

General Terms

Algorithms, Design

Keywords

Wireless Sensor Networks, RFID Technology, In-Network Storage, Duty Cycling

1 Introduction

There are two main approaches to wildlife tracking: VHF radiotelemetry and satellite based systems (GPS and ARGOS) [3]. VHF tracking has been widely used to track animals, however it requires considerable effort to track a small number of animals for a very limited amount of time. GPS gives more accurate location information, however it is very power hungry, and therefore needs large batteries. In the case of small animals, devices weighing more than 5% of body weight are often considered too heavy. ARGOS is both expensive and relatively inaccurate but has low power requirements.

With the increasing popularity of WSNs, systems have been proposed to put sensor devices on animals, and deliver the data using opportunistic data delivery protocols. Although these systems promise an extended lifetime, sensor devices are still not able to compete with tiny RFID tags when it comes to lifetime and physical size [1].

We devised an RFID-WSN hybrid system to monitor European badgers (*Meles meles*) in a forest. The aim of the project is to investigate the social behaviour of badgers and their use of resources with respect to microclimatic conditions. The study of badgers has been an ongoing project since 1987 in Wytham Woods, Oxfordshire, UK and has attempted to record the life history of all Wytham badgers in that time. The data have been based on relatively infrequent observations of badgers caught and released at denning sites ('setts'), and occasional VHF tracking studies on small numbers of individuals. With the use of RFID tag collars on the animals, concurrent tracking of multiple animals requires minimal human intervention, whilst providing continuous data.

The main difficulty with deployed wireless sensor networks is the maintenance required to keep such a system running for extended periods of time (e.g. two years of unattended operation). Replacing the batteries of tens or hundreds of sensors requires unnecessary effort from the users, not to mention scenarios where it is simply not possible (e.g. where sensors are attached to animals). The two components in our system which consume the most energy are the detection nodes and the transmission of data to the end users. To tackle the first problem, we propose an adaptive duty cycling protocol which learns the typical daily patterns of badger activity and adjusts its sampling to optimize future detection. The second problem is addressed using an adaptive data management protocol which alters routes according to both the latency requirements of the data, and the predicted mobility patterns of the zoologists.

2 Scenario

Figure 1 shows the different nodes of our system: the detection nodes detecting the badgers, static sensor nodes for in-network data storage and environmental sensing, and a 3G link and mobile sinks for data retrieval. A mobile sink is a node carried by a zoologist or a forester. The network of detection nodes has been running in Wytham since February '09, while we are deploying the static network with the 3G link at present.

3 Adaptive Duty Cycling

One of the major sources of power consumption in our system are the detection nodes – they detect when a tagged animal comes in range. Currently, they are powered from a 12V, 7Ah battery, but without duty cycling, they can only last for up to a week. Solar panels are not an option as they do not provide nearly enough power due to insufficient sunlight.

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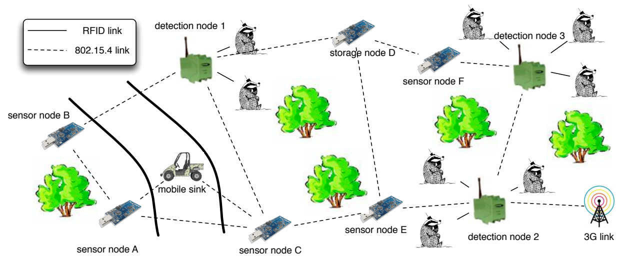

Figure 1. Our hybrid network with different nodes.

One naive approach to extend the detection node's lifetime could be to preprogram the node to turn off 50% of the time (for example, one minute on, on minute off), but this may lead to missed detections. Ideally, we would want the node on only when we expect animal activity, and have it turned off when nothing happens. Formally, the problem is as follows: Given a limited energy budget, maximize the number of animal detections.

Badgers are nocturnal with little or no daytime activity. We can exploit these periodic patterns to cycle the readers. However, a fixed schedule would not follow seasonal patterns, hence a method of automatically learning and adjusting to these patterns is required. We devised an adaptive protocol which, through machine learning techniques, learns the active periods, and adapts its duty cycle dynamically.

This approach has been previously applied for energy conservation in mobile sensor networks by learning temporal patterns in node activity and using this information for duty cycling the radio [2].

4 In-Network Data Storage and Delivery

Due to the nature of the application, most of the data are delay-tolerant, i.e. it is not necessary to deliver all the data immediately if delaying the delivery results in energy saved. We devised a data storage and delivery protocol which delivers data based on its relative *priority*, defined by our users. For example, in our wildlife monitoring application, observations of dispersing badgers have a higher priority than observations of resident badgers; the former readings must be collected within minutes, whereas the latter within hours or days.

Our protocol prioritizes sensor nodes based on their frequency of encounter with a mobile sink (in our case, a zoologist or forester roaming through the forest), e.g. a node next to the road will have a higher priority than a node in the woods. Similarly, nodes around the 3G link have a higher priority.

Our in-network storage management system is very simple and effective. It selects to store a data item with priority p to the closest sensor node with priority q, where $q \geq p$. When a mobile sink happens to visit that node, it collects the stored information and delivers it to all application users.

The strength of our approach is that in environments with mobile sinks that visit different sensor nodes with different frequencies, we have the flexibility to define multiple layers of storage nodes with different priorities. By asking domain experts to classify data into priority groups, we can map data to suitable storage nodes, and in this way we can ensure that it is delivered on time and with the least necessary communication cost.

5 Deployment

We have tagged 36 animals last year, and are tagging more this year – our aim is to have a large portion of the population tagged. These tags last for about two years using an onboard battery, periodically transmitting a beacon in the 433 MHz frequency band, with a period of about 0.4s (plus some random dither). The tags were potted onto collars using waterproof epoxy resin. Such collars allowed easy attachment to badgers during routine trapping sessions.

To get fine-grained location information, we put out 28 detection nodes in the forest, near carefully selected locations, including the main setts of the animals as well as some latrines which are known to be visited often. We plan to expand this network further and increase the number of tagged badgers.

We connected an RFID-reader with a Tmote Sky sensor node using a custom-designed extension board - we refer to this combination as a 'detection node'. The connected Tmote can duty-cycle the reader on/off as well as receive data from it. The received data are stored in the Tmote's external 1 MB flash memory for future, wireless retrieval over the sensor's 802.15.4 radio interface. Data are downloaded routinely, using a client running on a laptop (with a Tmote connected), when the zoologist visits the detection nodes to change batteries. The static sensor network can query the detection node about its state for quick delivery to the zoologist as well as download the data for storage, if needed.

6 Conclusion

We have presented a deployed RFID-WSN hybrid wildlife and environmental monitoring system. The goal of the project was to collect environmental data, track badgers and deliver this information efficiently to the zoologists. We have devised an efficient duty cycling algorithm to adjust the on-time of the detection node to the activity of the animals, as well as an adaptive in-network storage and delay-tolerant delivery protocol. We have a deployed system in Wytham Woods, near Oxford, where we have been collecting data for many months.

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7 References

[1] M. Buettner, B. Greenstein, A. Sample, D. Wetherall, and J. R. Smith. Revisiting smart dust with RFID sensor networks. In *Proceedings of the 7th ACM Workshop on Hot Topics in Networks (HotNets)*, pages 63 – 75, 2008.

[2] V. Dyo and C. Mascolo. Efficient node discovery in mobile wireless sensor networks. In *DCOSS '08: Proceedings of the 4th IEEE international conference on Distributed Computing in Sensor Systems*, pages 478–485, Berlin, Heidelberg, 2008. Springer-Verlag.

[3] S. A. Ellwood, R. P. Wilson, and A. C. Addison. Technology in conservation: a boon but with small print. In *Key Topics in Conservation Biology*, pages 105 – 119, Oxford, 2007.