Rat Watch: Using Sensor Networks for Animal Observation

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ABSTRACT

In an attempt to employ sensor network technology for animal observation, in particular of wild rats, we identified several restrictive shortcomings in existing sensor network research, which we discuss in this paper.

Categories and Subject Descriptors

C.3 [**Special-purpose and Application-based Systems**]: Real-time and embedded systems

Keywords

Sensor network, Animal observation, Rattus norvegicus, Sporadic connectivity

1. INTRODUCTION

One of the core motivations for the research in sensor networks is the vision of deploying sensor networks in nature to observe the environment phenomena. In this paper, we discuss our contribution to make this vision a reality.

With the help of the sensor network, we plan to observe the following phenomena:

- **Social interaction:** It is very interesting to observe the social interactions of rats. Thus, we want to know when, where, and how long rats meet.
- **Motion:** Acceleration sensors give insight into the social behavior of a rat.
- **Sounds:** The microphone gives more information on rat activity, for example whether a rat is sleeping or eating.
- **Light:** Light sensors give additional information, such as the occasions when a rat leaves its burrow.

Currently, we are equipping rats with standard sensor nodes (mica2dot) and a sensor suite consisting of light, audio, and acceleration sensors. A sensor is attached to a lab rat via a special leather jacket, which has a pocket fitted for this equipment. This jacket has openings for the front legs and wraps around the rib cage and the back. As an additional feature, it also has a reflective marker to allow optical tracking in a controlled lab setting, such as a maze. Eventually, the sensor node will be attached to wild rats, leading to the following set of challenges.

In the wild, rats live in underground burrows. Thus, radio propagation is very limited. Therefore, sensor nodes can only communicate when the rats carrying these sensors meet somewhere in the burrow. As a result, the sensor nodes are only sporadically connected and the topology is highly dynamic, making our deployment scenario significantly different from the typically envisioned static networks.

The remainder of this paper is structured as follows: First, section 2 discusses other deployments of sensor nodes and compares our deployment scenario to these. Section 3 discusses the impact of sporadic connectivity on sensor network algorithms and protocols. Finally, section 4 concludes this paper.

2. RELATED WORK

Recently, a considerable number of sensor networks have been deployed in the environment [6, 9, 11, 12], all of which – except ZebraNet [6] – are static networks. In these, researchers placed sensor nodes at locations of interest and ensured that the nodes could communicate with each other and the base station.

The ZebraNet project equipped zebras with customized sensor nodes. Via GPS, the sensor nodes recorded the animal position and other relevant sensor readings. Furthermore, the sensor nodes recorded when and where zebras met. From this data, biologists could evaluate the movements and social interactions of the zebras.

Our deployment scenario is somewhat similar to ZebraNet, but has a number of interesting differences: (1) we cannot use GPS for the observation of rats, as they live under the surface ground; (2) due to the small size of the rats, we need to use standard sensor nodes without large batteries or several MBytes of storage space as was the case in the ZebraNet project.

The GPS signal in the ZebraNet project provides absolute and accurate time and location information. Slotted medium access and routing benefit heavily from this knowledge. As a result, many of the research challenges we discuss in this paper are non-existent in the ZebraNet project.

3. PROBLEM: SPORADIC CONNECTIVITY

The main research focus in the sensor network community is on continuously connected sensor nodes. Thus, although the network topology may change slightly due to node failure or changing radio conditions, the network infrastructure mostly remains the same. Today's algorithms and protocols such as Medium Access Control, routing, and data aggregation focus on this static scenario.

The requirements of our scenario made quickly clear that available algorithms and implementations are not efficiently usable for the following reasons:

3.1 Medium Access Control

Medium access control in a sporadically connected network, especially in a sensor network, should have two modes of operation: (1) an ultra low power beacon mode and (2) a high throughput mode. In the beacon mode, two nodes can find each other by periodically sending beacon messages and listening for such messages from other nodes. Once two nodes found each other, they switch to the high throughput mode to exchange data. Existing MAC protocols such as [10, 13] do not provide this functionality.

3.2 Routing

As we do not expect to know all exits of a rat burrow and some rats may stay in the burrow for long durations, we need the rat sensors to exchange their measurements. Today's tree-based routing protocols [8] or even new any-to-any versions [3] are not suitable this purpose. Similar to delay tolerant networks [2], data should be relayed from one sensor node to another when their carriers, i.e. the rats, meet. We place a base station at one (or more) exits of the rat burrow. When a rat passes along this exit, all measurements, e.g. data collected by this rat as well as the data received from other rats, are transmitted to the base station.

3.3 Data Aggregation

Sensor nodes have very limited storage space, typically 4 kbytes of RAM and about 500 kbytes of additional flash space [5]. As discussed, it may take some time until a certain rat passes one of the base stations. Thus, its sensor node needs to store large amounts of measurement data – its own and those of the rats it met. Efficient high-level data aggregation is necessary to reduce storage requirements and the communication overhead when two rats meet.

3.4 Time Synchronization

Accurately synchronized clocks on the sensor nodes ensure consistent time stamps and measurements for the distributed observation of events. Nonetheless, typical time synchronization algorithms [1] assume continuously connected nodes and are thus not applicable.

3.5 Reprogramming

Changing application needs and lessons learned during the deployment require flexible schemes for reprogramming sensor nodes. We expect modular and flexible communication protocols [7] and operating systems [4] to be very beneficial in our deployment scenario.

4. CONCLUSION

At first glance, the merits of a software architecture required for our deployment may not be very obvious – implementing a software that can (1) record when two rats meet and (2) record some additional sensor readings of temperature and motion seems to be straightforward. However, when looking at the scenario presented, it becomes obvious that the necessary communication paradigms for sporadically connected networks are missing in the sensor network community.

In this paper, we discuss the features such a communication paradigms should provide for efficient and energy-aware animal observation. Currently, our ongoing work focuses on designing and implementing the required features. The main deployment scenario is rat observation. However, we think that this architecture can be easily adapted to the observation of many other species such as flying foxes or – once sensor nodes further decrease in size – smaller bats.

5. REFERENCES

[1] J. Elson and K. Römer. Wireless Sensor Networks: A New Regime for Time Synchronization. *ACM SIGCOMM Computer Communication Review*, 2003.

[2] K. Fall. A delay-tolerant network architecture for challenged internets. In *Proc. of the conference on Applications, technologies, architectures, and protocols for computer communications (SIGCOMM)*, 2003.

[3] R. Fonseca, S. Ratnasamy, D. Culler, S. Shenker, and I. Stoica. Beacon Vector Routing: Scalable Point-to-Point in Wireless Sensornets. In *Proc. of Symposium on Networked Systems Design and Implementation (NSDI)*, 2005.

[4] C.-C. Han, R. K. Rengaswamy, R. Shea, E. Kohler, and M. Srivastava. SOS: A dynamic operating system for sensor networks. In *Proc. of the International Conference on Mobile Systems, Applications, And Services (Mobisys)*, 2005.

[5] J. Hill, R. Szewczyk, A. Woo, S. Hollar, D. Culler, and K. Pister. System architecture directions for networked sensors. In *Proc. of conference on Architectural support for programming languages and operating systems (ASPLOS)*, 2000.

[6] P. Juang, H. Oki, Y. Wang, M. Martonosi, L. Peh, and D. Rubenstein. Energy-efficient computing for wildlife tracking: Design tradeoffs and early experiences with zebranet. In *Proc. of conference on Architectural support for programming languages and operating systems (ASPLOS)*, 2002.

[7] O. Landsiedel, J. A. Bitsch, K. Denkinger, and K. Wehrle. Modular Communication Protocols for Sensor Networks. In *Proc. European Workshop on Wireless Sensor Networks (EWSN)*, 2006.

[8] P. Levis, S. Madden, D. Gay, J. Polastre, R. Szewczyk, A. Woo, E. A. Brewer, and D. E. Culler. The emergence of networking abstractions and techniques in tinyos. In *Proc. of Symposium on Networked Systems Design and Implementation (NSDI)*, 2004.

[9] J. Paek, K. Chintalapudi, J. Caffrey, R. Govindan, and S. Masri. A Wireless Sensor Network for Structural Health Monitoring: Performance and Experience. In *Proc. of Workshop on Embedded Networked Sensors (EmNets)*, 2005.

[10] J. Polastre, J. Hill, and D. Culler. Versatile Low Power Media Access for Wireless Sensor Networks. In *Proc. of Conference on Embedded Networked Sensor Systems (SenSys)*, 2004.

[11] R. Szewczyk, J. Polastre, A. Mainwaring, and D. Culler. Lessons from a Sensor Network Expedition. In *Proc. of European Workshop on Wireless Sensor Networks (EWSN)*, 2004.

[12] G. Werner-Allen, J. Johnson, M. Ruiz, J. Lees, and M. Welsh. Monitoring Volcanic Eruptions with a Wireless Sensor Network. In *Proc. of European Workshop on Wireless Sensor Networks (EWSN)*, 2005.

[13] W. Ye, J. Heidemann, and D. Estrin. An Energy-Efficient MAC Protocol for Wireless Sensor Networks. In *Proc. of conference on Computer Communications (InfoCom)*, 2002.