Ratpack: Using Sensor Networks for Animal Observation

Jó Bitsch Link,
Klaus Wehrle
Distributed Systems Group
RWTH Aachen
first.last1.last2@rwth-aachen.de

Okuary Osechas,
Johannes Thiele,
Hanspeter Mallot
Cognitive Neuroscience
Department of Zoology
University of Tübingen
first.last@uni-tuebingen.de

ABSTRACT

The goal of this project is to describe the behaviour of rats. To study this behaviour, we will resort to the use of wireless sensor networks, monitoring various quantities that yield important information to complement current knowledge on the behavioural repertoire of rats. The challenges we face include data acquisition and processing on the one hand, as rat-borne sensor nodes will need to be small enough not to interfere with the rats' own activities, thus limiting the available memory and processing capabilities. Additionally, rats spend a significant amount of time underground, making data transmission and routing a very interesting challenge, for which we are currently developing novel strategies.

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 environmental phenomena. In this paper, we discuss our contribution to make this vision a reality. With the help of sensor networks, we plan to observe several aspects of rat behaviour.

Currently, we are equipping rats with standard sensor nodes (mica2dot) and a sensor suite consisting of light, audio, and acceleration sensors. Sensors are attached to laboratory rats with the help of 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. The long term goal is to attach (or even implant) the sensor nodes to wild rats; this will have consequences on the accessibility of the data.

In the wild, rats live in underground burrows and so radio propagation is very limited. Therefore, sensor nodes can only communicate when the rats carrying these sensors meet somewhere. As a result, the sensor nodes are only sporadically connected and the network 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 describes the quantities we are interested in measuring and the type of information we hope to obtain from them, while section 4 discusses the impact of sporadic connectivity on sensor network algorithms and protocols. Finally, section 5 offers some concluding remarks on our work.

2. RELATED WORK

Recently, a considerable number of sensor networks have been deployed in the environment [8, 11, 13, 14]. Most of these deployments – except ZebraNet [8] – 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 customised sensor nodes. Via GPS, the sensor nodes recorded the animal's position and other relevant quantities. Furthermore, the sensor nodes recorded when and where zebras met. From this data, biologists could evaluate the movements and social interactions of 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; (2) due to the small size of the rats, we need to use standard sensor nodes without large batteries or several MB 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 not relevant in the ZebraNet project.

The DTAG project [7] has an application that relates to ours in certain aspects but again differs in others. A very interesting aspect is that whales spend most of their time (up to 95%) underwater, making constant radio communication impossible, and thus, the scenario is in a way similar to ours. Their approach was to build a tag that records the relevant data onto a digital tape; when the data storage is full, the tag separates from the whale and floats to the surface, where it is picked up by the research team. This solution is not viable for our purpose since our motes need to stay attached to the rats as the danger of losing them in the burrow system is too high. Furthermore, our approach has the advantage of automatic data collection (as opposed to the manual collection of the tapes), thus speeding up the availability of the collected data.

3. SENSING PRINCIPLES

The scheme we propose for studying the behaviour of rats differs from existing methods in that it allows us to monitor rats directly in their natural environment (as opposed to traditional laboratory experiments). One fascinating prospect is the possibility of studying the structure of a burrow with a minimally invasive method, as this was previously done by excavating existing ones, thus disturbing the natural course of its inhabitants. Should our scheme be accurate enough, it would allow us to describe burrows, not only without disrupting their everyday life (as, for example, in [1]), but also in near-real-time as they are being built.

3.1 Social Interaction

Norway Rats live in burrows, usually shared in groups, which naturally leads to the formation of social hierarchies [1]. The communication between these rats is partially based on ultrasound vocalisations Several scenarios of interaction between rats are already known (mother/child, resident/intruder). Our setup should allow us to verify these and find new situations. The main tool for this approach will be the analysis of the vocalisations emitted by rats.

3.2 Motion

The motion of a rat may enable us to describe its foraging habits, as well as the layout of its burrow. This may also allow us to draw conclusions as to the actual use of different sections of the burrow, in a non-destructive fashion. The first approach to this problem will be through inertial measurements (acceleration, turn rates), but we expect to require further sensing principles for more accurate descriptions of the motion paths.

3.3 Activity

Sleeping and eating habits could be of interest as indicators of energy consumption. For example instead of a description of the seasonal variations in the rats' metabolism, it should be possible to obtain a higher time resolution. Activity monitoring could be accomplished by complementing the motion information (see section 3.2) with heart rate and breathing frequency data.

3.4 Higher Level Description

From the behavioural aspects described above, more abstract concepts can be inferred; we expect to exploit the synergy between different types of data, so we can interpret behavioural patterns in more abstract concepts. For example, the detection of vocalisations from infant rats, followed by movements previously determined to be characteristic of a mother carrying a child, might hint to a fostering behaviour. These vocalisations could then be conferred a certain interpretation, in the previously described case they could be thought of as cries for help.

4. SPORADIC CONNECTIVITY

Currently the main research focus in the sensor network community is on continuously connected sensor nodes. Thus, although the network topology may vary slightly over time, for example, 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 (MAC), routing, and data aggregation focus on this static scenario. The requirements of our own scenario quickly made obvious that the available algorithms and implementations are not efficiently usable for the following reasons.

4.1 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 find each other, they switch to the high throughput mode to exchange data. Existing MAC protocols such as [12, 15] do not provide this functionality.

4.2 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 sensor nodes to exchange their measurements. Today's tree-based routing protocols [10] or even new any-to-any versions [4] are not suitable for this purpose. Similar to delay tolerant networks [3], data should be relayed from one sensor node to another when their bearers, 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.

4.3 Data Aggregation

Sensor nodes have very limited storage space, typically 4 kB of RAM and about 500 kB of additional flash space [6]. 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 has met. Efficient high-level data aggregation is necessary to reduce storage requirements and the communication overhead when two rats meet.

4.4 Time Synchronisation

Accurately synchronised clocks on the sensor nodes ensure consistent time stamps and measurements for the distributed observation of events. Nonetheless, typical time synchronisation algorithms [2] assume continuously connected nodes and are thus not applicable.

4.5 Reprogramming

The lessons learned during the deployment may result in changing application needs and therefore require flexible schemes for reprogramming sensor nodes. We expect modular and flexible communication protocols [9] and operating systems [5] to be very beneficial in our application scenario.

5. 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 presented scenario, it becomes obvious that the necessary communication paradigms for sporadically connected networks are missing in the sensor network community.

In this paper, we discussed the features such a communication paradigm 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 Naked Mole Rats (Heterocephalus glaber), as their social interaction is highly complex. Newly available platforms have become sufficiently small to make it seem plausible to even study smaller bats.

6. ACKNOWLEDGEMENT

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