A Model-based Routing Protocol for a Mobile, Delay Tolerant Network

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Abstract

This short-paper presents the design and experimental validation of model-based, mobile routing protocol for a delay tolerant network (DTN), where herds of animals are utilised as message ferries. We develop a novel routing protocol that utilises knowledge of the predicted behaviour of each ferry in order to choose optimal ferries for carrying messages from source to sink nodes, as well as minimise routing overhead of the network via adaptive beaconing based on current behaviour.

Categories and Subject Descriptors

C.2 [**Computer Systems Organization**]: Computer Communication Networks

General Terms

Experimentation, Design, Mobility

Keywords

Delay Tolerant Network, Mobile Ad-hoc networks

1 Introduction

The increasing focus on reliability in sensor networks to date has brought about an important sub-class of sensor networks known as Delay Tolerant Networks (DTNs) [4]. At the heart of DTNs is the concept of store-carry-forward (SCF) routing. This is a natural way to cope with intermittent connections and delays and requires that each node must be capable of buffering incoming data.

This paper investigates an application in the use of herds of cattle as message ferries for gathering data from disconnected static nodes in the farming environment and delivering it to "sink" nodes located at common meeting locations such as water-points. In particular we present a methodology for dealing with nodes with stochastic mobility patterns where we train models to learn about mobility characteristics, allowing us to make improved decisions about which node to choose as a good ferry of data.

Some previous work to date has focussed on "context aware" routing, where the current state of a node can be used to assess its usefulness as a message ferry. In [2], a Kalman filter is used to predict future values of colocation with other sinks, connectivity and battery level from past values at each node. A wearable computer system has also been developed [1] which can learn the state of a user and their surrounds and modify the behaviour of the system accordingly. One of the first major uses of wireless sensor networks for animal monitoring was in the tracking of zebras as part of the *ZebraNet* project [3]. In this system, animal GPS position data, taken every few minutes, would be hopped in a peer-to-peer fashion to other animals when they came in range.

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2 Hardware Platform

The hardware platform we used for the mobile animal nodes was custom designed for this purpose. The basic platform consisted of "mote-like" Atmega128 nodes, known as Flecks, which were augmented by additional GPS and inertial sensors. The Fleck boards were mounted inside ABS plastic boxes measuring 130x90x60mm. These boxes fitted into the pocket of a specially designed collar, that went around each cow's neck. The collar also had pockets for the power source, GPS antenna and radio antenna. A photo of a herd fitted with the equipment during one of our trials is shown in Figure 1.

Figure 1. Photo of the water trough which acted as the location of a sink point.

3 Mobility model for Ferries

Cattle are in a class of mobile nodes which have stochastic mobility patterns. The focus of our work has been on ways for modelling these patterns to allow us to choose the optimal animal for ferrying data from a source to a message sink. In particular we have exploited the derived knowledge of animal behaviour patterns during periods of “normal” or general behaviour, and behaviour during periods just prior to approaching locations of interest such as water points or supplement feed points.

In order to obtain this information, our system is based around the use of Hidden Markov Models (HMMs) that learn the relationship between node observations (derived from GPS and inertial sensors) and behaviour patterns. HMMs are trained offline, where the bulk of computation occurs, whereas the Viterbi decoding stage takes place on the node. We derive a likelihood, in realtime on the node, which calculates the likelihood that node is showing behaviour characteristic of approaching a sink node as opposed to general behaviour. An example of these scores, along with associated behaviour states is shown in Figure 2.

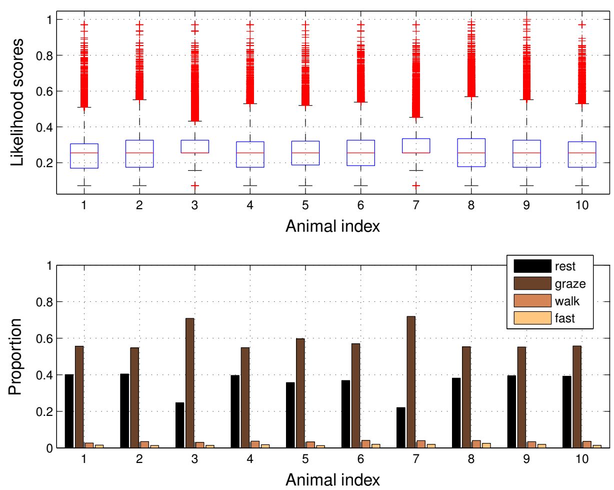

Figure 2. (a) Box-whisker plot of sink likelihood scores calculated over four days for each animals; (b) Proportion of times that respective animals spent in each behaviour state.

The other key use of behaviour state in our system has been to develop an algorithm for adaptive beaconing. Beaconing is required by mobile nodes to alert their presence to source nodes. By only beaconing when a node is likely to be a good choice of ferry, we can greatly reduce the amount of overhead in the network whist still achieving the same system performance.

4 Experiments

We have commenced a number of experiments at Belmont Research Station in Australia which has many different areas available for grazing by cattle. In our initial experiments, a herd of up to 10 cattle were fitted with the collars. Sink nodes were placed at common meeting locations such as water and feed points. Existing static nodes had already been installed at Belmont measuring parameters such as soil moisture and temperature. We chose a number of disconnected static nodes in the grazing area which acted as source nodes for the network.

Figure 3 shows the result the number of ferries (animals) has on the packet delivery to the sink. Results for our adaptive system, derived from behaviour likelihood scores, are compared with simpler approaches of epidemic or random choice of ferry routing. It can be seen that as the number of ferries increases the adaptive protocol clearly performs best.

Figure 3. Performance of three different DTN protocols as number of ferries (animals) are varied.

5 Future Work

Future work will seek to extend our trials to involve larger herds of cattle over longer periods of time. This will give us the opportunity to investigate the benefits of individually trained behaviour models which can adapt and learn from an animals behaviour over time. For example some animals may behave differently during hotter days, or during the night, etc. We have also commenced initial work into the development of custom antennas, where we control the radiation patterns around animals for improved performance.

6 References

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