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Wireless Sensor Network for Cattle Monitoring System

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Abstract: This paper describes a cost effective Wireless Sensor Network (WSN) technology for monitoring the health of dairy cows. By monitoring and understanding the cow individual and herd behaviour, farmers can potentially identify the onset of illness, lameness or other undesirable health conditions. However, the WSN implementation needs to cope with various technical challenges before it can be suitably and routinely applied in cow management. This paper discusses results concerning data transportation (i.e. mobility) from the cow mounted sensory devices.

1 Introduction

Farming industry contributes essential revenue to the UK economy. The two indelible incidents in 1986 and 2001 caused by Bovine Spongiform Encephalopathy (BSE) and Foot and Mouth Disease (FMD) respectively were estimated to have cost the UK economy £13 billion in total [MB01]. A health monitoring application to track individual animal activity as well as to monitor outbreak of animal diseases is hence important. One noteworthy application is the 'ZebraNet' [ZSL04]. The devices mounted on the zebra routinely exchange all their measured data with all other devices that fall within their transmission range via a so called store and forward approach. If sufficient memory space is available a user could then download historical position data of multiple animals by approaching a single zebra. However, the store and forward approach is not applicable in WSN since the memory space of sensor node is scarce due to commercial reasons. Other issues introduced by the conventional solutions are high maintenance and costly. This research investigates a new solution for animal monitoring by using low cost, low power consumption wireless sensor network platform. In contrast to traditional store and forward approach, a particular routing protocol is presented to facilitate real-time reporting to overcome mobility caused by animal movement.

2 The Design of Implicit Routing Protocol

There has always been an essential need for the owners or regional authorities to be able to observe their livestock in a real-time fashion. Although animal monitoring system by using wireless sensor platform has been presented [KGM08], [SGK08] and [SPM04] but the effect of animal mobility to the network performance is not studied. The primary concern in this study is to overcome the mobility issue caused by animal movement. In the case of mobility, the connectivity between collars is said to be sporadic leading to an unstable routing path and resulting in high packet loss and long delay. To diminish the impact of mobility, an Implicit Routing Protocol (IRP) is designed particularly for the cattle monitoring systems.

The proposed IRP works in the following phases: configuration phase and data forwarding phase. During the configuration phase, BS periodically sends a TIER message and this message will be relayed throughout the entire network. This TIER message contains a BS's ID field, and a hop count field. The hop count field is used to track the number of hops along the way which TIER message has travelled from the base station. The tiers are numbered starting from the BS. A collar in a given tier, *n,* is aware that it is *n*-th tier away from the BS. This critical information is defined as *TIER ID.* As animals are freely to move around and they can move away from their original tier region therefore to maintain the tier configuration correctly the BS is required to send TIER message periodically at intervals of T_s. At the data forwarding phase, if the collar desired to forward its measured data back to the BS. The collar will generate a packet which contains the measurement and its current *TIER ID*; this packet will then be broadcasted. This packet can only be received by the collars located close by. Only the received collars that have a smaller *TIER ID* will need to respond to the source collar with an acknowledgment (ACK). The received collars that have an equal or larger *TIER ID* will discard the received data immediately. This forwarding rule will then repeat until the data arrives at the BS. This proposed routing protocol has the following two beneficial features. Firstly, the protocol intuitively utilises the shortest routing path for data forwarding. Secondly, the protocol does not need to create and maintain an explicit routing path between the source collar and the BS.

3 Protocol Evaluation

This section further investigates the performance of proposed routing scheme and verifies the effectiveness through empirical experiments. The IRP is implemented on the MICAz [CRO] node using TinyOS [TIN] sensor network operation system. The test bed is configured into a 3-hop network with one source node, one base station (BS) and *N* relay nodes in each tier. Figure 1 illustrate the test bed with configuration $N = 4$, where 4 relay nodes are placed in each tier. During each experiment, the source node generates 10,000 packets continuously with 250 ms interval. The packet length is defined as 85 bytes. In order to simulate the phenomena of moving cows leading to a sporadic link between sensor nodes, an asynchronous random on/off mechanism is implemented. Each sensor node can independently determine its radio mode on a random fashion. When a sensor node stays in off mode, it represents the cow has moved out of the communication range and the radio link is disconnected. When a sensor node is switched back to on mode, it represents previous cow (or a new cow) has enter the communication range and a new radio link can be established. This on/off mechanism is characterised by an off probability P_{off} which determines the rate of a sensor node is disconnected from the others. Although the proposed mechanism used in this experiment can not directly represent the cow movement, it did provide a method to simulate a real farm environment where cow can move in and out of a tier freely.

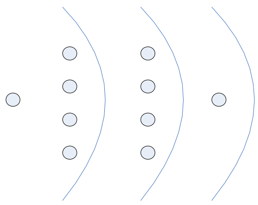

Fig. 1. Experiment configuration with N=4

In the conducted experiments (where results are captured by Fig. 2, 3 and 4), the interval of network configuration T_s is defined as 5 seconds, N is ranged between 3 to 5, and P_{off} is set between 0 and 0.3. Average packet delay, packet received rate and transmission failure are recorded respectively. Fig. 2 and 3 show the network performances that are impacted severely as P_{off} increases. This is due to the fact that the amount of time the sensor node in off state is prolonged. However, the performance is improved when the number of sensor nodes in each tier increases.

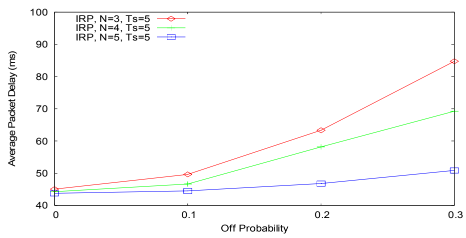

Fig. 2. Average Packet Delay

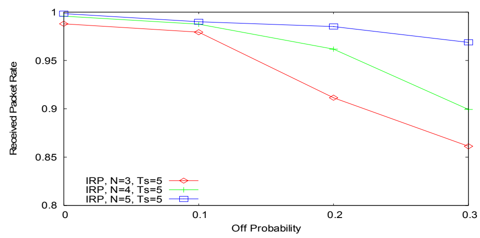

Fig. 3. Received Packet Rate

Fig. 4 summarises the performance of transmission failure count. The transmission failure happens whenever the connectivity between cows and BS becomes unavailable for example the sensor nodes at the same tier have all gone into off state. Fig. 5 shows that packet delay can be improved by increasing the frequency of network configuration. The results indicate that when T_s is set to 1 second packet delay reduced.

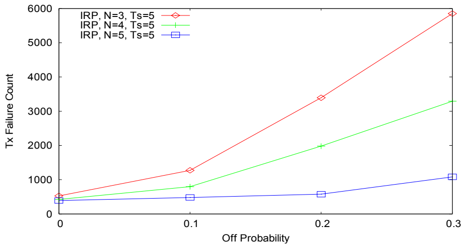

Fig. 4. Transmission Failure Count

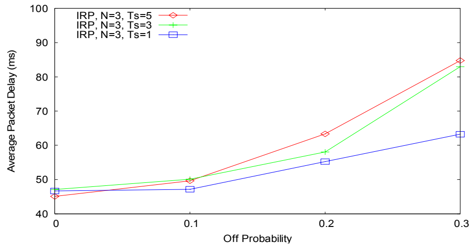

Fig. 5. Average packet delay ($N = 3$, T_s, P_{off} varies)

4 Conclusions

This paper looks into the feasibility of using low-cost, low power consumption wireless sensor platform for animal monitoring system. To facilitate real-time reporting while overcoming mobility caused by animal movement an Implicit Routing Protocol (IRP) is particularly designed. The experimental results indicated that the proposed IRP can successfully resolve the broken routing path problem caused by animal mobility. In the near future, the designed routing protocol is expected to be used in the farm trial in order to study its operation and implication in the field.

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