A Study on Data Transmission Performance of Sensor Networks for Livestock Feedlot

Ji-woong Lee, Hyun-joong Kang, Jeong-hwan Hwang,
Meong-hun Lee, and Hyun Yoe*

School of Information and Communications Engineering, Sunchon National Univ.,
315 Maegok-dong, Sunchon-Si, Jeonnam 540-742, Korea
leejiwoong, hjkang, jhwang, leemh777, yhyun@sunchon.ac.kr

Abstract. Recent development of versatile small size and multifunctional wireless sensor nodes enables the research on various applications to improve human life with rich information and automation. In this study, we virtually simulated the efficiency of the livestock feedlot sensor network by utilizing the propagation model, as one of the different methods of collecting data regarding livestock in feedlot is researched. As indicated in the conclusion of the study, the differences in terms of the methods make a difference to the amount of dropped data packets. It is believed that the observations made in this study could prompt the development of more effective methods of collecting data regarding livestock in feedlots by adopting additional devices or alternative routing manner.

1 Introduction

In feedlots, where a large number of livestock is raised in a group, the chances that the livestock will be exposed to disease and that such disease will spread rapidly [1][2]. Accordingly, many studies have been conducted with the aim of predicting the potential diseases of the livestock, using a sensor-based network, which involves the measurement of the temperature, symptom of disease, activity status, etc. of the livestock being raised in feedlots [3][4][5][6]. Most feedlots employ the method of breeding a certain number of livestock in a group by installing hedges of lumbers on a spacious pasture and setting up partitions between them. Although a large number of the livestock raisers are more conscious of possible diseases, it is very difficult to transmit measured data from a Wireless Sensor Networks (WSN), where the sensor is driven by low power due to the differences in propagation performance on account of the position of the sensor attached, interrupting by the livestock being raised, etc. Blocking elements like these will certainly require a more effective method of data transmission from a livestock-feedlot-based sensor network. The chief aim of this study is to try to compose the measurement of data for a large number of livestock, which is difficult to apply, in virtual reality, via simulation. Much research has been conducted on the routing efficiency in a WSN on account of the channel condition of

* Corresponding author.

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the physical layer (PHY) according to such blocking elements as indoor furniture [7][8]. As far as is known, however, no research has yet been conducted on the subject of livestock. Although some simulations have been done, in a similar form, through individual link paths, on man according to sensor's location [9], schemes other than those proposed in the foregoing studies are required because livestock, unlike man, do not act intelligently, and their behavior is different from that of men.

The rest of this paper is organized as follows. Section 2 reviews propagation models. In Section 3, we present the conducted simulation environment in detail. Section 4 describes the simulation results. Finally, we conclude this paper in Section 5.

2 Related Research (Propagation Models)

In this section, we explain the current propagation models for simulating the physical layer for researching the relation between physical layer condition and data exchanging performance. The propagation model has huge influence on performance of WSN. A model depends on various parameters like the distance between sensor nodes. But others expressed as random functions and constant factors [10].

2.1 Free Space (FS) Model

The free space model is the simplest propagation model. It only presumes the direct path between transmitter *t* and receiver *r*. The receiving power P_r depends on the transmitted power P_t, the gain of the receiver and transmitter antenna (G_t, G_r) the wavelength λ, the distance d between both nodes and a system loss coefficient *L*. All parameters, but the distance *d*, are system wide constant parameters. While a simulation runs, the receiving power P_r only changes with the distance between sender and receiver. As both receiving parameters RX_{Thresh} and CS_{Thresh} are also constant during a simulation, receiving nodes must be inside a perfect circle. Otherwise, they are unable to receive data properly.

$$P_{r,FS} = \frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi \cdot d)^2 \cdot L}$$

2.2 Two Ray Ground (TRG) Model

The TRG model is an improved version of the FS model. It assumes the direct ray between sender and receiver and also considers the ground reflection. As with the FS model, both nodes are assumed to be in LOS. The heights of both antennas over the ground are present with h_t and h_r and are constant during a simulation. Up to the crossover distance $4_{Threshtrh}=\pi\ h_t\ h_r\ \lambda d$, the TRG model is equal to the FS model. Beyond this distance, the ground reflection destructively intervenes with the direct ray and further reduces the field strength. The receiving signal strength is then inverse proportional to d^4. Just like the FS model, TRG has only the distance between sender and receiver as variable parameter *H*.

$$P_{r,TR} = \begin{cases} P_{r,FS} & d < d_{Thresh} \\ \dfrac{P_t \cdot G_t \cdot G_r \cdot h_t^2 \cdot h_r^2}{d^4 \cdot L} & d \geq d_{Thresh} \end{cases}$$

2.3 Shadowing Model

For both FS and TRG models, the sender-receiver distance is the only variable parameter during a simulation. This forms a circular coverage around a sending node and has a cutting range limit. Beyond this range, further reception is impossible. To introduce random events, the shadowing model uses a random variable *X*. The shadowing model needs a reference distance d0 to calculate the average received FS signal strength $P_{r,FS}(d_0)$. The path loss exponent β is influenced by the simulated environment and is constant throughout simulations. Values vary between two (free space) and six (indoor, non-line-of-sight). *X* is normal distributed with an average of zero and a standard deviation σ (called shadow deviation). Again it is non-variable and reasonable values vary between three (factory, LOS) and twelve (outside of buildings). Values for β and σ were practically determined.

$$P_{r,SH} = P_{r,FS}(d_0)\left(\frac{d}{d_0}\right)^{-\beta} \cdot 10^X$$

$$X(x): \{x \in [-\infty, \infty] \big| P(x) = N(0, \sigma^2)\}$$

3 Simulation

3.1 Simulation Scenarios

The scenario that was studied in this research consisted of 24 mobile sensor nodes in an area 100m × 100m big, and the sink node for collecting the sensing data was placed at the center of the simulating environment. Based on such an environment, simulation was done on two occasions.

In scenario 1, the livestock moved about freely in the feedlot, and the mobile nodes (attached to the livestock) moved at a slow rate and transmitted data periodically.

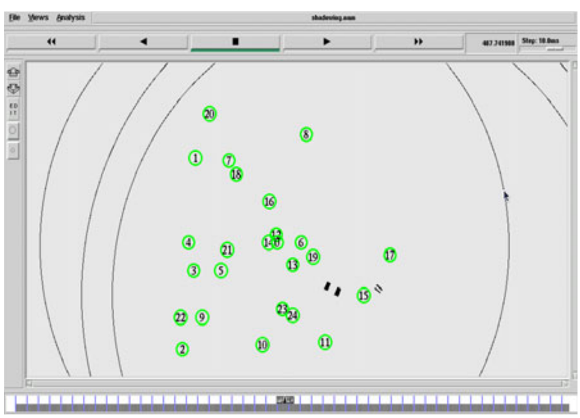

Fig. 1. Scenario 1, Sensor nodes move freely

In the other case, in scenario 2, using the behavioral characteristics of livestock, it was assumed that the sink node was installed at the feeder from which the livestock feed. Also in the second scenario, the mobile nodes got together at the feeder in the center, while the sink node, a collecting node, collected data from each of the animals in the system.

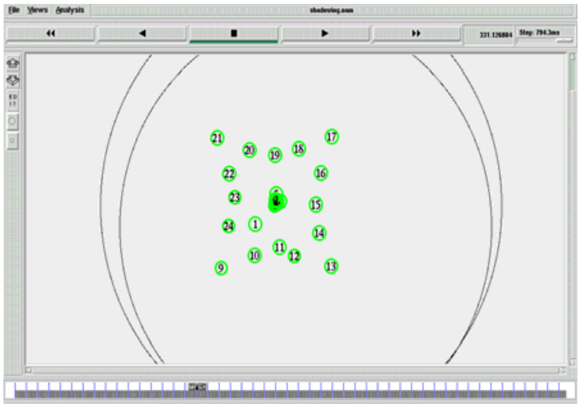

Fig. 2. Scenario 2, Sensor nodes move to the sink

3.2 Route Setup and Data Delivery Process

To determine the route path between sensor nodes, initially, sensor nodes search adjacent nodes within the transmission range. Then request for the path information toward a sink node or destination node. From this information, a sensor node forward data to the destination node through other sensor nodes using multi-hop manner. In case, if there is no adjacent node or no information from nodes within the transmission range, a node periodically send a discover message or Query message.

3.3 Propagation Model

The NS-2 simulator [11], which is most commonly used at present, was used as the simulator in this simulation. In the first assumption (scenario 1), in the system where data were collected while the livestock moved around freely in the feedlot, it was decided that the livestock had different channel conditions according to their distance from the central sink node. Although in NS-2, the propagation model by livestock within the demand has not yet been defined, since there is such a propagation model as a shadowing model, the blocking by livestock was composed in such a way that, according to distance, different shadowing models were applied among different sensor node links.

3.4 Simulation Environment

It was assumed that there was no moving of the livestock to another place, no exception caused by death, etc., and that the sensor node had ample initial energy that could not be used up within the period of the simulation.

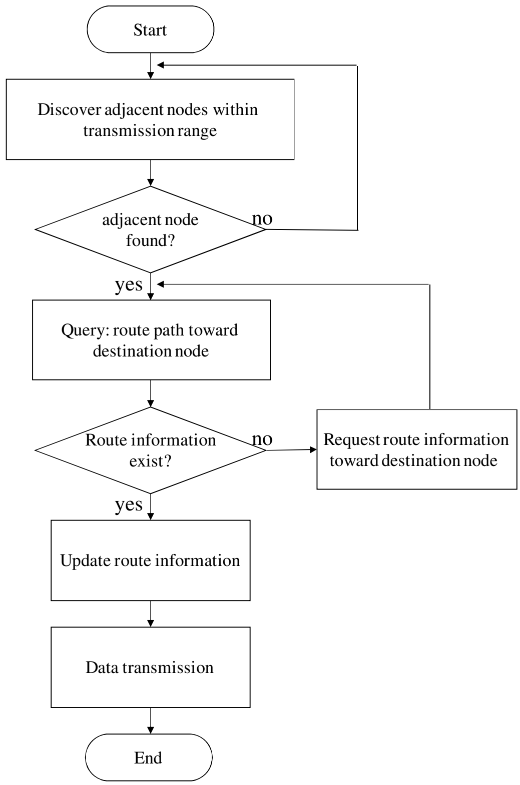

Fig. 3. Route setup and data delivery process

For the simulation, the basic parameters of NS-2 were used, together with a Lucent WaveLAN radio interface at 914 MHz. As for the antenna, it was assumed that a unity-gain omni-directional antenna was placed at the center of the node, with a height of 1.5m. $RX_{Threshold}$ of Wireless Phy was adjusted to receive data with 95% probability from a 20m distance, which allowed different scope of coverage to be made among different links.

In the simulation, which was carried out for 1,000sec, all the nodes, except the Sink node, transmitted information towards the Sink node in a 5sec cycle, with a transmitted data size of 512 bytes. The initial energy was placed at 10,000 joules, which was deemed sufficient for the entire duration of the simulation, with 0.660 joules used for data transmission and 0.395 for reception. In both the mentioned simulations, it was supposed that a mobile node for transmitting biological data was attached to the livestock, and that all the nodes moved at a low rate of 0.1 m/sec. Furthermore, in scenario 1, where the nodes moved around freely, each node was made to have different direction and moving distance values, while in scenario 2, where the nodes moved at the same rate while they were gathering towards the center.

The MAC layer was not considered, and routing was made using Destination Sequence Distance Vector (DSDV) [12], Ad-hoc On-demand Distance Vector (AODV) [13], and Dynamic Source Routing (DSR) [14], which are adhoc-based typical proactive and reactive routing protocols. DSDV, a representative proactive routing protocol, is based on the Bellman-Ford routing system used in wired networks, and each node always keeps routing information regarding all the other nodes in the routing table. AODC, a very light routing protocol for ad-hoc networks, is the routing protocol that is used to make routing possible while using less memory. DSR is an on-demand routing protocol that is based on a routing source. Mobile nodes maintain a route cache, including the source routes known to a node.

4 Simulation Results

Figure 4 and figure 5 represent dropped data packets from each routing protocol. In the case of scenario 1, AODV and DSDV universally kept the dropped packets uniformly, while DSR revealed a severe shift span in the amount of dropped packets through scenario 1 and 2. It assumed that as the movement of sensor node is unpredictable, streamlined data transmission is quite difficult so the dropped data packets occur during the simulation continuously.

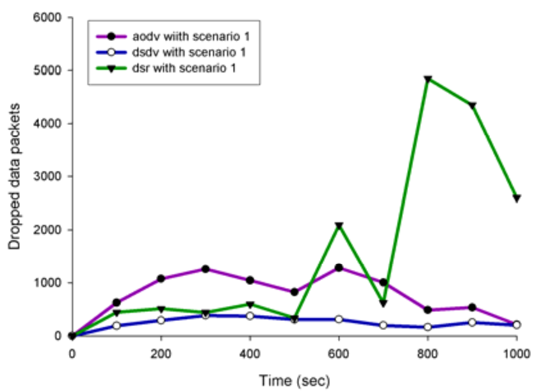

Fig. 4. Dropped packets with Scenario 1

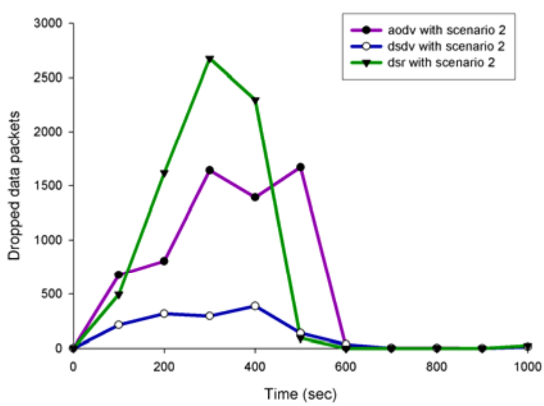

Fig. 5. Dropped packets with Scenario 2

In the case of scenario 2, at the initial state, dropped data packets are severely increased and it was shown to decrease gradually, starting from around 300 sec, and to hardly appear at 600 sec and over. It assumed that as sensor nodes gather to the center of simulation area, link path toward the sink node is constantly changes. After 600 seconds and later, data dropping is considerably decreased it is because the node movement is declined and variation of position of sensor node is almost predictable.

5 Conclusion

In this study, difference in efficiency between routing protocols in the aspect of dropping packets was researched. For this purpose, the research was conducted with two different scenarios aimed to examine the influence on routing protocols related to the data transmission of sensor nodes caused by free movement of livestock. With the results from simulation, there is a certain difference between two scenarios. It can thus be concluded that diverse methodical attempts like global positioning system(GPS) or relative position anticipate method to reduce the dropping packets caused by movement are needed for the collection of data of freely moving nodes regarding livestock in feedlots and an efficiently streamlined routing protocol design is needed.

Acknowledgements

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