Monitoring Method of Movement of Grazing Cows using Cloud-Based System

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ABSTRACT: Currently, many operations are carried out manu-ally on farms for raising livestock. In particular, most farms do not use equipment to understand the condi-tion of animals, but rely on the farmer's perspective. If information can be obtained by monitoring farm animals, managers can determine the behavior of the animals and use this information to predict the health of the animals. In this paper, we propose a livestock monitoring system based on WSN. The proposed system can monitor farm animals using IoT equipment and cloud platforms. Collars were mounted on the necks of an animals using IoT equipment, and the ac-tivity of the livestock was monitored. Farming man-agers can supervise live information by transmitting livestock observation information to cloud platforms. Through actual implementation, we verified that the proposed system can monitor animals on farms in real time.

Keywords: Cloud Computing, Monitoring, IoT, Smart Farm, Wireless Sensor Networks

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1. INTRODUCTION

Of the national food businesses,the livestock industry occupies a very large proportion. According to a survey, in developed countries, 50% of the total output of agriculture is livestock, and in developing countries, about 34% are engaged in livestock production [1]. In recent decades, livestock production has continued to increase due to livestock management practices and changes in people's eating habits [2]. However, livestock farms have to meet various requirements in accordance with modern laws [3]. Requirements include ensuring animal health and welfare, epidemic prevention, efficient management, and food safety.

In order to meet the many requirements described above, many factors must be managed by the livestock farmers. In animal farms, however, it is impossible to monitor and control each animal individually 24 hours day [4]. Livestock farms often manage animals based on the personal experience of farm managers. This leads to a lot of manpower and cost to manage large numbers of animals. In addition, in some instances, the health status of animals is overlooked when checked by visual observation. In order to solve this problem, a livestock business may benefit from precise livestock farming (PLF) [5, 6].

PLF means managing farm animals using advanced IT technology. Due to the rapid evolution of IT technology, IoT and Wireless Sensor Network (WSN) technologies are used in many fields. Animals can be monitored at low cost by using miniaturized embedded boards and WSN technology in animal husbandry. Using IT technology is more efficient and more accurate than visual monitoring by farm managers [7]. It is possible to continuously monitor the state of each animal in addition to the monitoring of

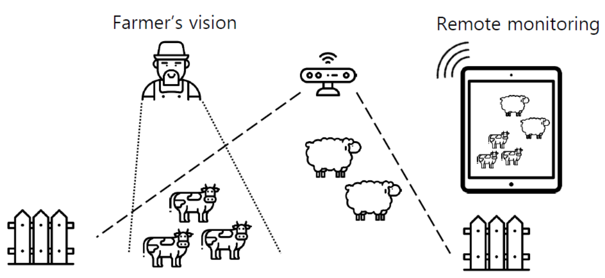

Fig.1: *Animal Monitoring using WSN.*

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the herd at the remote site. In addition, the measured data can be delivered to a farm administrator in real time [8, 9]. Figure 1 shows an architecture of animal monitoring using WSN.

Tracking animals using WSN technology can be a huge benefit for livestock farms [11, 12, 14]. The benefits can be divided into three categories as follows. First, the health status of livestock can be analyzed through monitoring of individual animals, thereby reducing collective infections caused by illness. Second, it is possible to maintain the optimal environment for livestock by collecting information on the farm environment in real time. Third, when livestock are graz-ing, it is possible to prevent the loss of livestock by analyzing the moving path of livestock.

By attaching a GPS sensor to the animals, it is possible to know the location information of the animals in real time when they are grazing in a large area. The location information thus obtained can be used for various purposes. In the first place, when livestock are grazing in large areas and it is time to bring them back to the barn, the livestock's location information can be used to collect them. Second, the farm manager can grasp the pattern of animals by identifying the movement path of animals. This pattern information can be used to determine each animal's grazing location. Third, if an infectious disease occurs in a particular animal, animals around it can be isolated and this can help solve the problem of mass onset of illness. Safer animal husbandry is possible this way.

In this study, we design and implement a system for monitoring livestock on farms. The aim is to minimize infrastructure to implement the system. For this reason, we propose a WSN based system for monitoring animals on livestock farms. The proposed system introduced a cloud platform taking into account the processing power and future scalability of the data collected. The system saves livestock moving locations in real time. Edible cows are often herds that graze on large areas of pasture [10]. Cows that do not move at regular intervals can be predicted to be unwell. Farm managers can use this information to identify animal characteristics and health status. In addition, when livestock are grazing, manages can know if leaves the farm.

2. RELATED WORKS

2.1 The Internet of Things for Smart Farming

Recently, IoT has been introduced rapidly in a smart farm environments. In the farming environment, the environment of the crop is monitored, water is supplied, and nutrients are supplied. IoT also serves to monitor animals and people from outside the farm. In the livestock environment, animal health such as body temperature and heart rate are monitored to monitor the animal's health and prevent epidemics [12]. We also use animal information to study animal behavior [13]. As shown in the previous example, IoT is now being adopted in the education, environment, science, and industrial fields rapidly [15–17].

In Shadrin's research, IoT was applied to smart agriculture [18]. In particular, humidity was measured inside the farm where the plants were grown and this information was monitored in real time. The collected information was used to analyze the growth of plants and to upgrade the farm system in the future. In addition, a system was established to notify the manager when there was a problem in maintaining humidity inside the farm. As in the previous study, many plant farms are using IoT [19–22].

In Vaughan's research, IoT was used to solve the problem of having to measure the body weight of animals on a livestock farm. In particular, a rubber bottom was installed on the farm floor to measure the weight and gait data of the livestock, and a sensor was placed below it. The data measured through the placed sensor was used to analyze the walking pattern of the livestock [5]. In Wang's paper, the amount of food in animals and the form of water intake were monitored in order to perform early checks to determine whether or not the animals in the group were sick. Directional antenna and wireless network technology were used to collect data collected from the animals [23].

2.2 Animal Monitoring

The ZebraNet project developed a system for acquiring animal data before IoT technology matured [24]. In this system, the data of animals in the wild was acquired and this information was transmitted to animal researchers to analyze animal ecology. In particular, the system aimed to monitor and study zebras distributed over Kenya's wide terrain. At the time of the project, there was no cellular network covering the entire area. For this reason, an ad hoc topology was used to transmit data from the node to the base station.

All nodes except the base station acquired the data and transmitted it to the base station. Typically, a base station is installed in a fixed location and collects data, while in this project it was assumed that the base station was moving periodically. The base station of the project was mounted on a car and collected information of the surrounding nodes.

Each zebra had a necklace with a sensor which stored GPS information of the zebra's movement route. This sensor node was made up of two communication devices, so that the energy could be adjusted and used. The first communication device was a short-distance communication device, and was generally used for multi-hop communication. This equipment was used for short distance communication within 100 m using main low power. Other communication equipment was used to communicate with the base station over long distance communication within 8 km. Even though this sensor node was capable of long-distance communication, it might not be within the range of the base station. In order to solve this problem, it was possible to transmit through another node without transmitting directly from the node to the base station. The ZebraNet used flooding a protocol and a history-based protocol to use the previous transmission scheme [24]. Figure 2 shows the architecture of ZebraNet.

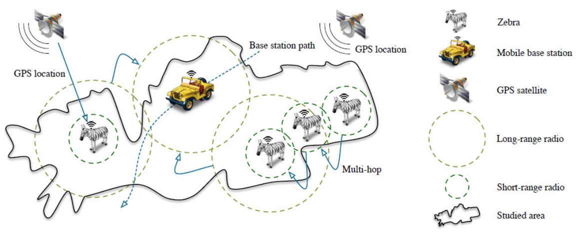


Fig.2: *Architecture of ZebraNet project.*

Nadimi's work has proposed a system that monitors each animal using an Artificial Neural Network and transmits information in the appropriate mode of action [13]. For example, through the moving radius of an animal, a farmer can determine a new grazing place for an animal, because the behavior and information about livestock farm animals can be used to determine the health status of those animals.

The purpose of this study was to monitor the behavior of herds of animals in Europe. We used an ad hoc WSN based on a MCU with wireless receiver. Movement path and head movement of each animal were measured and monitored using the system. In the system, many sensor devices were used as nodes of the sensor network and measured and transmitted environmental information. In this system using an ad hoc topology, each node acts as a router in a multi-hop based network. In the network, one gateway and two relay nodes are arranged around one node. By designing our system this way, it is possible to send the data of the sensor node directly to the gateway or to re-route it using the relay node. Figure 3 shows a ZigBee-based WSN architecture.

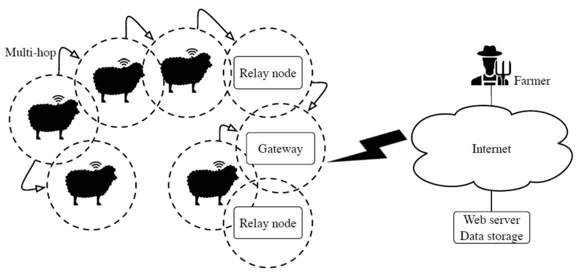


Fig.3: *WSN Architecture using ZigBee.*

3. CLOUD-BASED ANIMAL MONITORING SCHEME

This section describes the structure of the proposed monitoring system. The system can be divided into three components. The first describes the network structure and communication details within the WSN architecture. The second part is the Cloud platform, which handles the data sent form the WSN. In most WSN environments, the base station is used to collect and process data, but in this paper, the cloud platform is used to process the data. The WSN part collects and transmits the data generated by the nodes, but the actual data processing in performed on the cloud platform. The user interface allows the visualization of the status of the current system and processed data. Figure 4 shows the three components and details about them.

3.1 WSN Layer

The WSN layer is presented in Figure 4. The purpose of the WSN's configuration is to deliver the information measured at each node to the cloud platform. In this paper, an animal wearing a necklace

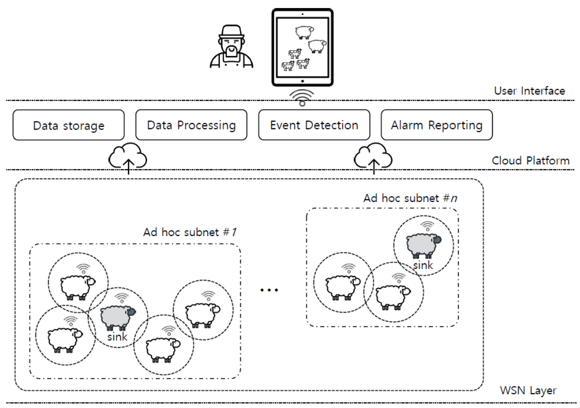


Fig.4: *Cloud-based Architecture for Animal Monitoring.*

containing a sensor is defined as a node. Each node acquires location information using a GPS receiver at a given time. As animals gather in large numbers, groups are formed and leaders are formed among them. The animal that became the leader remains unchanged. The animal leader was selected as the sink node as in the previous research [10]. Animals with leadership in the livestock group were identified in advance by farm managers. Animals which are not regular sink nodes transmit data to the sink nodes using short-range communication and multi-hop. In the experimental environment, 3G/4G cellular communication was possible, so 3G communication was used to transmit node data to the cloud. In the experiment, a 3G module was attached to the sink node and used as gateway node.

Animals on the farm can be divided into several groups instead of one because they move in groups according to their characteristics. This can lead to a loss of connection to the sink node. To solve this problem, all animals were equipped with a necklace with a 3G communication module. This allows temporary nodes to act as sink nodes when the regular sink node is not available. Using this method, the information acquired from the node can be transmitted to the cloud stably through the changed sink node. WSN configurations can be complex to handle data from many nodes. However cloud platforms can solve this problem. Nodes that can reduce complexity have the advantage of reducing costs in actual production. Figure 5 shows a schematic of the node structure. It is equipped with a wireless communication module for short range communication and a 3G module for cloud communication.

The MSP430F2274 MCU was used to implement the nodes in the Figure 5. The MCU is a widely used 16-bit low-power micro-controller from Texas Instruments [25]. The MCU can be easily programmed and debugged using the UART communication module. For quick node implementation, we used the eZ430-RF2500 development kit with MSP430F2274

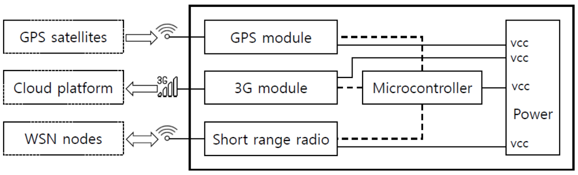


Fig.5: *Schematic of the node structure.*

Table 1: *The detailed specifications of MCU and Wireless receiver.*

MSP430F2274 (MCU)	CC2500 (Wireless receiver
- 16Bit Ultra Low Power MCU	- 2.4 GHz RF Transceiver
Active Mode: 270μA	Low current consumption (13.3 mA in RX, 250 kBaud)
Standby Mode: 0.7μA	- Frequency : 2400-2483.5 MHz
- 1K RAM	- Data rate : 1.2-500 kBaud
- 32KB Flash memory	- High sensitivity :
- UART, SPI, I2C, IrDA	(-104 dBm at 2.4 kBaud)

MCU [26]. The development kit includes two ez430-RF2500T boards with MCUs, a USB debugger interface, and a battery pack. The motherboard is equipped with the CC2500 short-range communication module in addition to the MCU.

The CC2500 wireless transceiver is manufactured by Texas Instruments, like the MSP430F2274 MCU, and is used for short-range communications. The module uses the 2.4 GHz frequency and uses the lowest power setting when communicating. Typically, this module uses 2400-2483,5MHz and was developed for scientific, medical, and industrial use. Table 1 shows the detailed specifications of the MSP430F2274 MCU and the CC2250 wireless receiver. Figure 6 shows the nodes used in the actual experiment. And Figure 7 shows a cow wearing a node collar.

Fig.6: *Node module used in experiment.*

3.2 Cloud Platform

This study assumed the use of cloud computing for the back-end infrastructure of WSN. Cloud computing platforms deliver computing power, data storage, and applications. In addition, without using a base station in WSN, sink nodes act as gateways to send data directly to the cloud. With cloud computing, farm managers do not have to worry about complex back-end environments.

Fig.7: *Cow wearing a node collar.*

In this paper, we used Amazon web Service (AWS) as a cloud platform. The Amazon's AWS offers multiple services and has a multi-tiered structure. Figure 8 shows the layers in AWS. The uppermost service layer is the starting point for the sink node and cloud platform to communicate. The listener layer periodically performs certain tasks on the system in the cloud. For example, at the end of the day on a 24-hour basis, if calculated the distance travelled for each animal per day. The business layer analyzes and processes steps to perform various system tasks. In the sink node, the measured raw data is converted to JSON format. The lower layer receiving the data analyzes that JSON-type data and stores only the actual GPS information in the database. The database tier is managed by the business tier and actually uses the PostgreSQL relational database server.

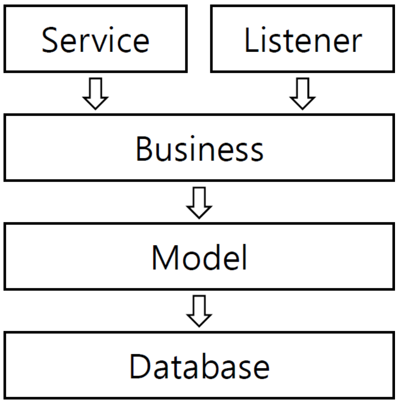
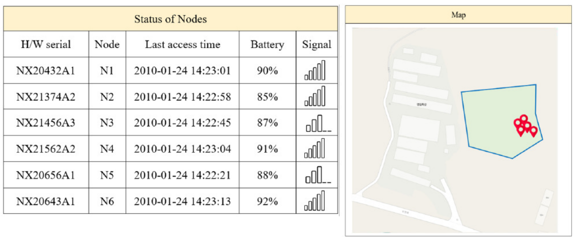


Fig.8: *Layers of Cloud Platform.*

3.3 User Interface

Data obtained from nodes in the WSN was stored in cloud storage. The GUI screen displays the status information of the nodes and the location of the nodes on the map. Node status information displays hardware serial number, node number, last time data was sent, battery capacity, and signals. The current GUI is composed of web applications applying the Model-View-Controller (MVC) design pattern. We used the JSON data format for communication within the cloud system and web applications. Figure 9 shows a web page for monitoring the animal's location. The management web page is automatically refreshed every three minutes and can be manually refreshed by the administrator.



Status of Nodes

H/W serial	Node	Last access time	Battery	Signal
NX20432A1	N1	2010-01-24 14:23:01	90%	
NX21374A2	N2	2010-01-24 14:22:58	85%	
NX21456A3	N3	2010-01-24 14:22:45	87%	
NX21562A2	N4	2010-01-24 14:23:04	91%	
NX20656A1	N5	2010-01-24 14:22:21	88%	
NX20643A1	N6	2010-01-24 14:23:13	92%	

Fig.9: *Webpage for animal monitoring.*

4. RESULTS

The experiment was carried out in three main ways. The first measured the value of RSI over distance to analyze the basic performance of the wireless receiver. The second measured message transmission and processing performance to analyze the performance of the cloud platform. Third, we monitored the battery consumption and the animal's travel distance by establishing nodes on the actual farm.

4.1 Verification of Data Gathering

The first experiment was conducted to confirm the WSN-based behavior. The experiment checked whether the node receives location information regularly and whether it transmits the collected information to the network accurately. The whole system is equipped with a number of general nodes that collect and transmit location information, and these nodes send the collected information to the sink node.

In the initial experiment, the GPS receiver installed in the node was set to turn on every 30 seconds to collect location information. Nodes are also programmed to be used as sink nodes that can receive data from normal nodes. The node used the eZ430-RF2500 kit described in Section 3.1, and the sink node was connected to the monitoring PC for information verification. We checked the data transmitted from the sink node by displaying it on a real-time map using a monitoring PC. To do this, the node was equipped with the SIM808 receiver module for accurate position reception. The chip manual stated that it was possible to measure at a distance of 50 to 60 m. However, the actual experiment using the device resulted in many deviations above 20 m, and accurate values were only measured reliably within 20 m

The experiment of location information acquisition using a node was performed for 15 minutes and location information was collected 30 times. The WSN node continued to move within a 500 m square area during the experiment. The normal node and the sink node moved together at a close distance of about 10 m, and all packets were transmitted normally without losing any transmitted packets. GPS information received from the node was stored in NMEA (The National Marine Electronics Association) 0183 format to utilize the information in Google Map. Figure 10 shows the actual map displayed using the days measured at the nodes.

Fig.10: *Actual map with GPS information.*

4.2 Verification of CC2500 Wireless Receiver

In the proposed system, Ad Hoc communication between nodes in the WSN layer plays the most important role. For this reason, we tested performance of the CC2500 transceiver. An important factor in selecting a wireless transceiver in a WSN is the communication range of the communicator. For this reason, the communication range was chosen as the first experiment to perform usimg the CC2200 transceiver. The change of RSSI (Received Signal Strength Indication) according to the physical distance between two transceivers was measured. This experiment attempts to determine the maximum distance that can be transmitted reliably data between transceivers.

Two nodes were prepared for the experiment, one of which was used as a general node and one as a sink node. The sink node connected wirelessly to the notebook for data verification and RSSI information verification. The node experiment was performed in a wide area without obstacles around the experiment. The node was set to 1 m in height considering the height of the animal. In the experiment, the sink node was fixed and the general node was moved to 1, 2, 4, 8, and 16 m. The general node transmits the packet to the sink node every 5 seconds and uses the maximum power.

We confirmed that the packet was received at the sink node and our software simultaneously visualized the RSSI information received by serial communication. The node sent 10 packets at each location. The sink node recorded RSSI information when it received the tenth packet. Figure 11 shows the RSSI values for distances. To reduce the energy used by the wireless nodes, there is a way to reduce network connectivity complexity or power consumption. In unit experiments, if the distance of the wireless node was more than 20 m, the power usage on the node increased by about 25% and received data was often lost.

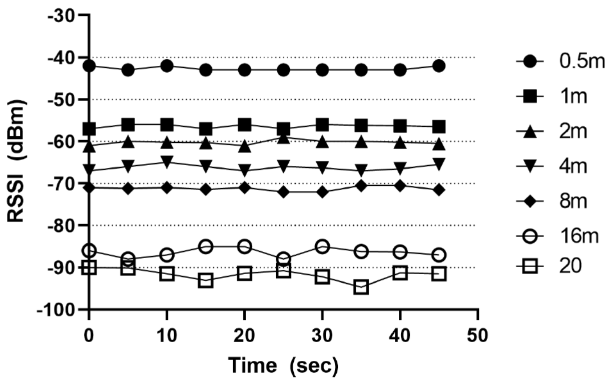


Fig.11: *RSSI value according to change in distances.*

4.3 Verification of Cloud Platform

The currently implemented system was produced as a prototype for animal monitoring. For this reason, a large amount of animal information is not currently collected in real time and transmitted to a cloud server. In the future, we will collect a large amount of animal data and location information using a prototype, and use a cloud platform to analyse various information about the animal. The information refers to the habits of animals discoverd through analysis. If we collect the information, we can predict the health status of animals.

In this experiment, we used Amazon Elastic Compute Cloud (EC2) as our cloud platform for free experimentation. We observed the state of the cloud platform as the number of messages sent from nodes increased. In the cloud experiment, we examined the latency of the messages. The delay time here means the time before the message arrives at EC2 and is processed by the actual platform.

Amazon API Gateway was used to send message data to EC2 cloud server and socket communication was performed. The task sent various numbers of messages (10, 100, 1000, 10000, and 100000) to the server. In order to obtain accurate results, a total of five experiments were performed, and the average and standard deviation of the processing time of all messages sent were calculated. Figure 12 shows the number of messages sent and the processing time.

As in general servers, the ec2 server increases the processing time linearly as the amount of transmitted messages increases. Basically, the more messages sent, the greater the number of messages in the

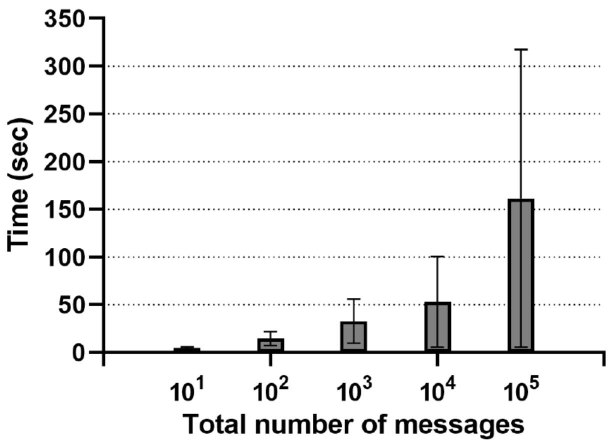


Fig.12: *Mean value of processing latency after sending messages.*

server's message queue. For this reason, the difference between the processing time of the first arrived message and the processing time of the last arrived message is large. As a result, the standard deviation of the message processing delay is large. However, to improve performance, the server processes messages in the message queue in parallel instead of in order. Currently, due to the limitation of server performance, messages are processed in parallel, but processing delays still occur.

4.4 Verification of Livestock Farm 1

In order to verify the proposed system, experiments were conducted on livestock farms in the area where the school is located. There wewe about 30 cows on the animal farm participating in the experiment, grazing in the daytime, and sleeping in the barn at night. Livestock farm managers need monitoring when animals are grazing outside. In the first experiment, we used a total of five nodes that consisted of 2 sink nodes and 3 normal nodes. We selected a cow group which included five cows with the help of a farmer and put a collar on each cow's neck. Figure 13 shows the area where the actual experiment was performed.

Fig.13: *Environment of livestock farm.*

To monitor the cattle in the farm, the nodes in Figure 6 were mounted on the cow's neck. Using those nodes, we collected GPS location information and battery information. This information was transmitted every 15 minutes in order to track the cow's movement habits and make the batteries last longer. In the farm experiments, only two of the five nodes enabled 3G/4G modules to be used as sink nodes. The remaining three nodes were used as normal nodes and buffered the data collected when the sink node was disconnected. The information collected at the node was transmitted to the EC2 server using the sink node. This experiment was performed for 3 days considering the battery. The reason for setting the frequency of trasmissions to 15 minutes is that the 4G module was out of sleep and the battery usage was high.

WSN infrastructure plays a major role in monitoring individual animals on the farm. To verify this, we checked the node's connection time and the battery consumption of the nodes in the WSN. First, we verified the connection time during node operation. When cattle graze during the day, they are divided into several groups. And at night, the cows move to the barn and stay indoors at night. For this reason, it was assumed that all cows will be within the processing range of the CC2500 wireless receiver module embedded in the node, and that the sink node and the normal node collecting data will remain connected most of the time. To verify this, the normal node is connected to the sink node every 30 minutes to transmit the collected data. At this time, the connection with the sink node was set to enable both single hop and multiple hop. The results of this experiment are shown in Figure 14.

To analyze the connection rate between nodes, 12 hours of total data were used, with 6 hours during the day and 6 hours during the evening. Daytime hourly nodes stayed connected to sink nodes for about 342 minutes (about 95%) out of 360 minutes. In addition, at night time, the connection between mesh node and sink node was 100%, because the cows were together in the barn. As can be seen from the experiment in section 4.2, the maximum transmit/receive range of the CC2500 communication module is 20 meters. This fact shows that cows live together most of the day.

When running a wireless monitoring system on a farm, it is important to know the actual energy consumption of the wireless nodes. To determine the energy consumption of the nodes, we measured the battery usage of two sink nodes and three mesh nodes. Figure 15 shows the energy consumption of nodes for 24 hours. Before the experiment, it was assumed that sink nodes had higher energy utilization than mesh nodes. This is because the sink node performs two functions: the mesh node performs more functions (receives GPS information, measures battery usage, etc.) and sends information to the cloud. However, the actual battery usage shows that the difference in

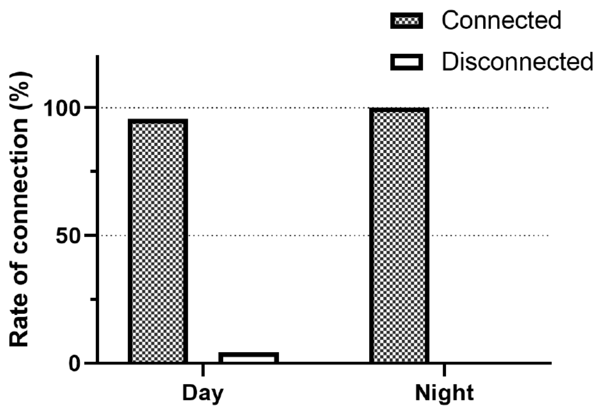


Fig.14: *Connection rate between sink node and mesh node.*

power uasge between the sink node and the mesh node is not large. A detailed analysis of the sink node reveals why it used a current of 80 to 430 mA when transferring data from the sink node to the cloud platform, but the actual transfer time was very short (less than a few seconds). In idle mode, the 3G/4G modules used 20 mA of current. At the node, the GPS module uses a large amount of energy of about 78 mA until it receives accurate GPS information from the device, causing with high energy consumption.

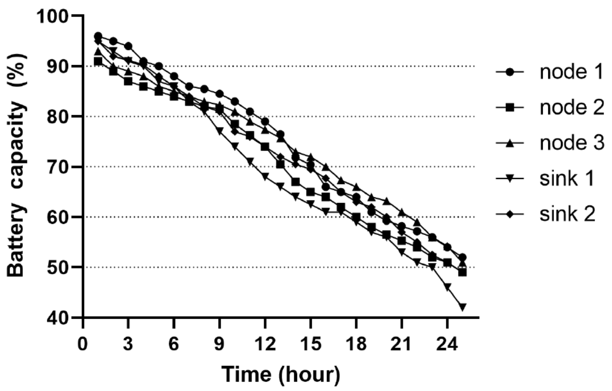
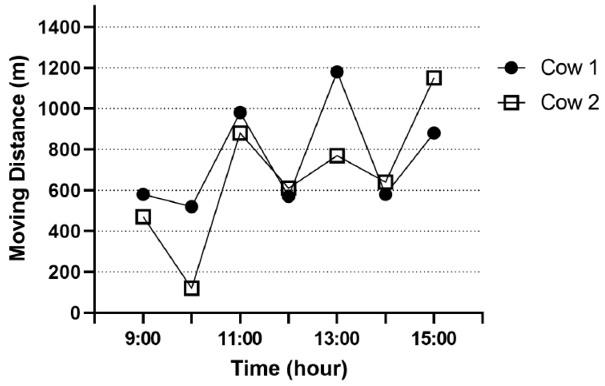
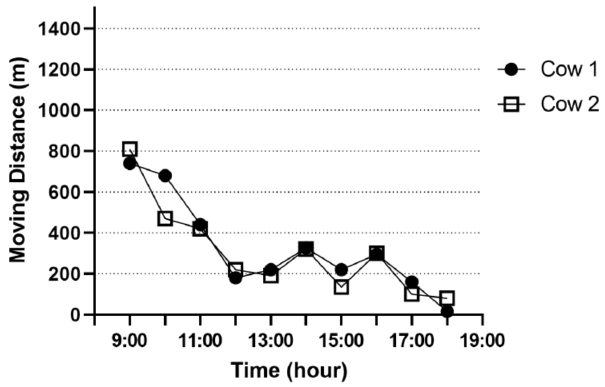


Fig.15: *Battery consumption of nodes.*



(a)Day 1



(b)Day 2

Fig.16: *Total distance travelled by cattle.*

4.5 Verification of Livestock Farm 2

One of the goals of this study is to understand the behaviour characteristics of animals. To do this, we decided to store GPS information every three minutes and turn on the SIM808's GPS module at all times to collect as much animal information as possible. In order to understand the characteristics of the animals, we used the cattle on the farm and selected two of 58 cows. The experiment was carried out for two days and the information was collected until all the batteries of the nodes mounted on the cows were used up.

Figure 16 shows the distance of travel by two cows measured during the day. The starting distance is not zero because the cumulative distance is included before 9 o'clock when grazing begins. Figure 16(a) shows the travel distance of the two cattle on the first day. The two cows have slightly different distances and are in different positions, but are gathered again to live as a group. Figure 16(b) shows the travel distance of the second two cattle. The day shows that the two cows are living in groups from the start of grazing until they return to their barn in the evening. Having such information on cattle can identify abnormal signs when the cows in the group vary significantly in travel distance compared to other cows.

5. CONCLUSIONS

In this paper, we proposed a cloud platform based WSN system for farm animal monitoring. The proposed system constructed a WSN using its own protocol and transmited the data measured by each data node to the sink node. The sink node transmited the collected data to the cloud platform utilizing communication technology. The cloud platform stored the data of all nodes and composed a web page that administrators dould check in real time. The farm manager can check the status of each animal through a web page and analyze the behavior of the animal group. We implemented the proposed system and conducted experiments using animals with the help of a farm. As a result of the experiment, it was confirmed that data was normally transmitted and received. The web page enabled the administrator to get real-time status information for each animal and its location could be checked on a map.

In the future, we will develop a system that predicts the health status of animals by compiling longterm data. Also, we will modifiy the WSN model to be more robust so it can monitor many animals.

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