A method transmitting data to manage crops using WSNs in large-scale farm

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Abstract-- At a large-scale farm, it is time-consuming work for a farmer to manage the state of all the crops. To increase efficiency of this work, it is considered that a base station collects the sensing data of daylight hours and temperature by wireless sensor networks (WSNs). And the base station guesses the state of crops. In order for this to enable a more prompt action and to collect these data, a high-speed communications network is needed. Moreover, since the farmer needs to manage a sensor, the device which makes the battery of a sensor withstand long use is needed. Especially in this paper, I adjust a transmitting interval based on frost damage. Furthermore, I propose the technique of communicating between clusters and sensors according to the data to transmit.

1. Introduction

In the crop management in vast area, in order for an administrator to check a state in a circumference, to see crops one by one becomes time-consuming work. Then, in order to know the state of crops, it is considered that a base station collects temperature data from sensors installed near crops or daylight hours from sunshine sensor by WSNs. And technique which a base station guesses the state of crops is being considered.

Tart Cherries			
Tart Cherries	Swollen Bud	Side Green	Green Tip
10% kill	15	24	26
90% kill	0	10	22

Fig. 1 Critical temperature of the cherry of a bud

The unusual state of crops is roughly divided into three kinds. The first is which bad influence may cause to crops due to the fall of temperature. The index of critical temperature is exhibited as a standard of this temperature. In Fig 1, the critical temperature of the cherry of a bud state is expressed. The 1st line expresses the photograph of a bud and the name of the state is described in the 2nd line. The 3rd line is critical temperature, "10% kill" means having influence bad to 10% of crops. As shown in Fig 1, since it is classified in detail, we have to know precise temperature. Since the administrator needs to protect crops before temperature falls to critical temperature, they need the thermal data in every minute.

The 2nd is the state which crops damaged by a drought. This is which crops damaged when a fine day continues for a long period. So, the farmer needs to supervise the state of crops periodically. There are two kinds of surveillance methods of a drought. First scheme is that a base station collects daylight-hours data by a sunshine sensor and predicts a possibility that crops are hurting by the drought. However, this method has a problem which the cost of many sunshine sensors are high and damage becomes large when a base station cannot predict exactly. The 2nd is considered in the technique of sending the picture of crops to a base station. Since farmer can guess the state of crops from a picture, their experience can be reflected by this method.

The 3rd is the theft by man or eating away by a wild animal. In order to supervise this state, installation of a surveillance camera and a periodical round can be considered by farmers. In this paper, we concentrate on image transmission to prevent drought and thermal data collection near critical temperature.

2. Related work

In the sensor network employment in the large-scale area, increase of delay and energy consumption of sensors becomes big problems. In order to lessen delay time, to use higher frequency band can be considered. However, it will be necessary to increase the sensor number because the range which a sensor can be communicated narrow area. Then, sensor cost and sensor employment cost will become big problems.

The data aggregation is considered as a method of making sensor battery consumption small. This lessens the number of times of sending data by sensors and it makes energy consumption small. However, there is a problem which delay becomes large by the overhead of a data aggregation.

Moreover, the technique of clustering sensors is considered. As for this technique, the sensors in a cluster transmit data to a cluster head, and a cluster head only transmits to other cluster head. Finally the cluster head around a base station transmits data to a base station. By applying this technique, the network traffic between sensors is decreased and reliable communication is attained. However, since sensors near a cluster head communicate frequently, there is a problem which the sensor near a cluster head becomes a bottleneck. In this paper, we propose the technique of changing communication between clusters and between sensors based on critical temperature.

3. Network model

A network model is assumed by basing in the Yakima farm which actually builds and collects thermal data. The sensor node called VikingX is used at this farm. VikingX transmits the measured temperature data to a Master terminal by the frequency band of 902- 928 MHz. A Master terminal receives the data from VikingX currently installed in every place, and does a statistical work. Since VikingX is an expensive device, extending for more precise data collection is difficult.

So, in this paper, the cluster which uses VikingX as a cluster head is formed and VikingX collects data from neighboring cheap sensors. We assume sending data to a Master terminal finally. The specification of VikingX and

Sensor is as in TABLE 1. The width of a farm is 120 acres (about 480x480m^2). Sensor placement is shown in Fig. 2. It is 60 m between sensors and is 180 m between VikingX(s). A square portion is one cluster and 16 clusters exist in 120 acres.

TABLE 1. Specification of VikingX and Sensor

	Frequency band	Communication range	Nominal speed	Effective speed
VikingX	902-928Mhz	Few km	230 kbps	Approx. 80kbps
Sensor	2.4-2.5 GHz	0~0.1 km	11 Mbps	Approx. 4Mbps

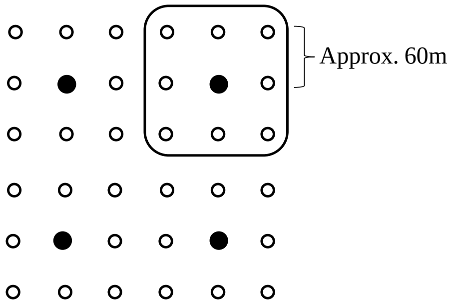

Fig. 2 Distribution of nodes (black circle: VikingX, white circle: Sensor)

4. Proposal to transmit data in large-scale farm

This chapter describes the definition of Frosting time and Warm time, the kind of data to transmit, transmission system and data collection system. Frosting time and Warm time are time to become an index which determines data collection interval. Moreover, the kind of data is distinguished based on the size of data. And we propose a data transmission system based on 4.1 and 4.2.

4.1. Frosting time & Warm time

Near the critical temperature, since a possibility of having bad influence on crops is high, it is necessary to carry out a more exact guess by narrowing the interval of temperature sensing. As one of the means which make this possible, we decide to carry out sensing in every minute. However, since sensing in the period which can become neither daytime nor critical temperature will consume a battery vainly, the maintenance cost of a sensor becomes large.

Here, the period from the critical temperature to the time which becomes higher than critical temperature is defined as frosting time. In frosting time, since a possibility that the influence on crops will arise is high, sensing interval of temperature is changed for every minute. Moreover, periods other than frosting time are defined as Warm time. In Warm time, it changes to the sensing interval in every 30 minutes for statistics collection.

We describe how to change a collection interval in Chapter 5.

4.2. Types of data

Sensing data has two kinds, the thermal data of tens Bytes and the image data of tens Kbytes. Since image data is an about 1000 times of thermal data size, the problem which transmission delay becomes large, and it becomes more remarkable in vast area communication. Therefore, it is necessary to add a device to the transmission method in image data communication.

4.3. Data transmission

We propose the data transmission system in Frosting time and Warm time.

4.3.1. Data transmitting in frosting time

In frosting time, since the influence on crops may arise, we consider communication of only thermal data. Since thermal data is small, delay does not become large even if communication nodes communicate using VikingX. Therefore, communicating thermal data between clusters establishes reduction of the number of hop and power saving and highly reliable communication. The sketch of this data communication technique is shown in Fig. 3. Sensors transmit data to nearest VikingX or base station and VikingX transmits data to neighboring VikingX or base station.

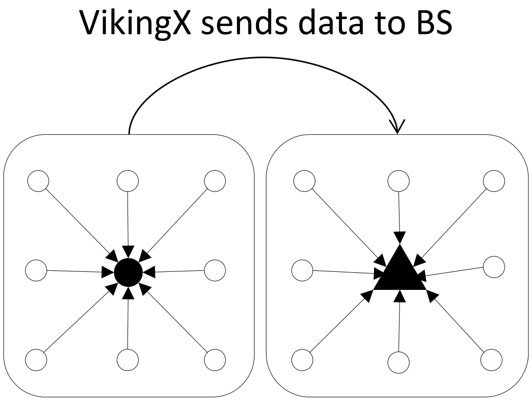

Fig. 3 Sketch of cluster communication

(White circle: sensor, black circle: VikingX, black triangle: base station)

4.3.2. Data transmitting in warm time

In warm time, sensors exchange image data other than thermal data. VikingX collects thermal data every 30 minutes and uses communication between clusters. This data-communications technique is the same as 4.3.1 in Fig. 3. In image data communication, we assume transmitting the picture of bright time (A. M. 12:00 etc.). Since the size of image data is large, delay becomes large by communicating through VikingX. Therefore, when transmitting a picture, only sensors communicate. Since this relays only sensors with high speed access, delay can be suppressed small. However, since the communication range of sensors is narrow, so the number of hop increases and energy consumption of sensors becomes large. In order to solve this problem, we apply Long-cut routing which avoids a sensor with little battery residual quantity. By including battery residual quantity in send data, sensors can tell neighboring sensors about their battery residual quantity. This data-communications technique is shown in Fig. 4.

Sensors transmit image data to a base station without passing VikingX. Furthermore, the route which avoids sensor with little battery residual quantity is built based on neighboring sensors battery residual quantity information. In Long-cut routing, the shortest hop routing is set up in early stages, and route construction based on battery residual quantity is performed dynamically.

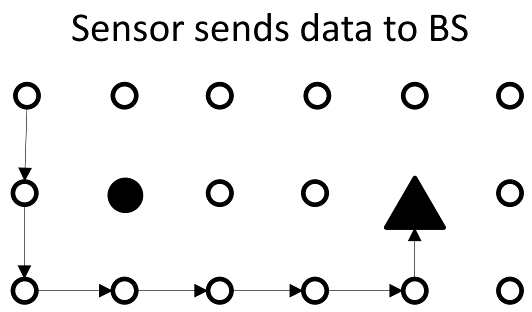

Fig. 4 Sketch of communication between sensors

(White circle: sensor, black circle: VikingX, black triangle: base station)

5. Determination of frosting time and warm time

This chapter describes the determination method of frosting time and warm time. The two determination methods are considered. The 1st is the method of guessing from climate statistics of the area of a farm. Since a collection interval can be set up beforehand, it is not necessary to newly guess the state of crops. However, by the guess method using statistics, an error may arise in a guess result. Thereby, in spite of approaching critical temperature, farmer's correspondence may be overdue while the collection interval has been long. The 2nd is a method which a sensor calculates sending interval from a temperature variant. A temperature variant can be calculated from $\mathrm{Temp_{diff}}$ in formula (1).

$$\mathrm{Temp_{diff}} = \alpha \cdot \left(\mathrm{Temp}(t + \Delta T) - \mathrm{Temp}(t)\right) \; (1 \le \alpha) \tag{1}$$

$\mathrm{Temp_{diff}}$ is the amount of change of the temperature between the temperature at time t and $t + \Delta T$. α is a coefficient for weighted $\mathrm{Temp_{diff}}$. When α is large, weigh is added to the amount of change of temperature and shift of a sensing interval is promoted. If $\mathrm{Temp_{diff}}$ becomes more than a threshold value, frosting time and warm time will shift to warm time and frosting time respectively. Each is described below.

Frosting time to warm time

After frosting time which sender sends one data every 1 minute, it shifts to warm time which sensor sends one data every 30 minutes. The shift to warm time from frosting time is smoothly performed by the frequent collecting the amount of change of temperature. Therefore, the finish time of frosting time can be found more correctly and the shift to warm time will be done correctly. Thus, α in frosting time is set as 1.

Warm time to frosting time

On the other hand, since during warm time, sensor collects data at the long interval of 1 time in 30 minutes, the amount of change of a prolonged temperature is known. That is, even if farmers know that crops are safe in a certain time, they cannot perceive that it is less than critical temperature in 15 minutes. Therefore, we set up the alpha in Warm time greatly, and make shift to Frosting time smooth.

Moreover, farmers may predict the necessity of protecting crops from a sensing interval. Therefore, in the case of the shift to frosting time from warm time, the sensing interval is gently narrowed like 30 to 15 minutes and 15 to 5 minutes. A sensing interval is calculated from a formula (2). β expresses a coefficient. A sensing interval is in inverse proportion to a difference in temperature. That is, an interval will become short if a difference in temperature is large. Moreover, an interval will become long if a difference in temperature is small.

$$\mathrm{Interval} = \beta \cdot \frac{1}{\mathrm{Temp_{diff}}}$$

In Chapter 6, we perform simulation evaluation supposing frosting time and warm time becomes clear beforehand.

6. Simulation

At first, as basic simulation, I simulate communication between sensors, VikingX and one base station using event driven simulator. Simulation parameters are follows. The specification of sensors and VikingX is in TABLE 1. And we show network topology in Fig. 5. White circle is sensor, black circle is VikingX and black triangle is base station. We assume to send one picture, so we set the number of packets to 600 (Total size is 30 KB).

TABLE 2 Simulation parameters in basic evaluation

Number of sensors	64
Number of VikingX	16
Transmission rate	2Mbps
Media Access Control protocol	CSMA/CA
Routing protocol	Dynamic Source Routing
Data size	50 Byte
Sending rate	1 Packet / min
Number of packets to send	600
Source node	All sensors
Destination node	Base station
Relay node	All VikingXs

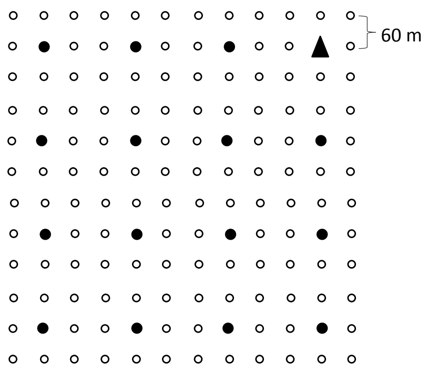

Fig. 5 Network topology

In the result of this simulation, total transmission time is 2041[s], and packet arrival ratio is 0.979 (Number of total sending packets is 47420 and that of arrival packet is 40414). In the case of the picture, packet loss becomes crucial problem. Because JPEG is composed of relative frames, loss of initial frame means loss of picture.

7. Conclusion and Future work

I will conclude after simulating and considering results.