A Hybrid WSN System for Environment Monitoring at Poultry Buildings

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ABSTRACT

The environmental quality inside a livestock building is very important for the welfare of the animals and stockmen. Environmental quality is normally assessed by measuring air temperature, relative humidity, and airborne dust concentration. With the advance of wireless communications technologies, it is possible to automatically monitor and control the environmental variables continuously inside a livestock building with low cost and without much human intervention. This paper introduces a system which uses hybrid fixed and mobile wireless sensor network (WSN) technologies to achieve such outcomes. This system consists of a number of fixed sensors to measure the environmental variables, a wireless network gateway and a small mobile vehicle/robot. The fixed sensors are used not only for collecting the environmental data but also positioning the mobile vehicle. The system was implemented and some experiments were carried out at labs at the University of Southern Queensland. Comparing with other methods, the results show that the system can automatically collect accurate environmental data periodically with flexibility and reliability.

Keywords: wireless sensor networks, environment monitor, mobile measurement system, animal welfare.

1 INTRODUCTION

Environmental quality within livestock buildings can potentially affect the health and welfare of the animals and also the stockmen working in these buildings (Banhazi *et al.*, 2009a; Banhazi *et al.*, 2009b). The main factors influencing environmental conditions inside livestock buildings include air temperature **(**AT), relative humidity (RH), ammonia (NH_3), carbon dioxide (CO_2) and airborne dust (Wathes *et al.*, 1998). Dust concentrations in poultry buildings are usually quite high especially when compared to average dust concentrations measured in pig and cattle buildings (Takai *et al.*, 1998). High temperatures in the piggery buildings might affect the appetite and fertility of pigs that can lead to reduction in production efficiency (Chang *et al.*, 2001). Therefore, it is very important to control the temperature and relative humidity levels as well as minimise dust concentrations inside livestock buildings to maintain optimal environmental quality. In order to control these environmental variables, first they have to be accurately and continuously measured. A number of systems have been used in the past to measure environmental variables in livestock buildings, but these systems all had shortcomings.

Wireless sensor networks (WSNs) offer an interesting alternative for accurate monitoring of environmental conditions inside livestock buildings. WSNs are composed of spatially distributed sensor nodes that communicate with each other through wireless transmission. Each sensor node is connected to one or several sensors (such as temperature, relative humidity etc.) and consists of radio frequency (RF) transceiver with an internal antenna, an electronic circuit for interfacing with the sensors, microcontrollers and power sources. Wireless transmission has the obvious advantage of reduction and simplification in wiring and improves flexibility and mobility of the network. Therefore, WSNs provide a unlimited installation flexibility and low cost application option in hazardous and remote locations (Wang *et al.*, 2006). WSNs are widely used in different agriculture applications. For example, a ZigBee WSN was designed for the cattle localization in grazing areas (Huircán *et al.*, 2010) and WSN systems were deployed in a wheat field to monitor the soil property, such as soil water-holding capacity, moisture content, bulk density, temperature and salinity (Li *et al.*, 2011). The WSNs have great potential in agriculture as their cost and improved performance compares favourably with traditional wired networks.

In order to optimise environment in livestock building, a real-time data monitoring and measurement system is desirable, where environmental conditions are measured and potentially readjusted real time using the combination of WSNs and computerised control systems. Thus a study was designed and implemented at the National Centre for Engineering in Agriculture, at the University of Southern Queensland to develop a WSN based measurement system. This paper introduces a WSN system that might be suitable for the measurement of environment parameters in free-range poultry buildings.

2. SYSTEM DESIGN AND EXPERIMENTAL METHODS

A measurement system was designed that utilized a combination of WSN technology and a mobile robot. The system deployed a number of wireless sensor nodes which was evenly distributed in a livestock building. These sensor nodes continued collecting environmental data such as temperature and humidity at the interval suitable for the task. A mobile robot/vehicle is deployed to carry the more expensive sensors (such as NH_3 and Co_2) and a wireless gateway. The mobile robot regularly travelled through the defined path in the building at a certain interval. The data at the fixed sensor nodes was uploaded to the mobile gateway when the robot approaches to the closest point to the individual sensors. The fixed sensor nodes node only collected more frequent environmental data but also assisted the robot to identify its location through the signal strengths during the communications.

The time interval for the fixed sensor nodes deployed in the field can be set at an arbitrary interval (e.g. every 1 hour). However, the optimal time interval can be chosen by balancing the need of adequate capture of the environment changes and the energy consumption saving of the sensors. For much less frequent interval based on the requirements (e.g. every 24 hours), the mobile vehicle travelled along the path around the field to collect the data. When the vehicle had the nearest distance to one node, the GW communicates with the node and collected the node’s data. These field nodes’ data included the all day environmental AT & RH situation of the building. The sensors of the mobile vehicle itself also collected the environmental AT & RH data and dust concentration data while the vehicle moved along the given path.

One example of the system is illustrated in Figure 1. The combined temperature and relative humidity sensors (SHT1X; Manufactured by OFROBOT) and a dust sensor (GP2Y1010AU0F COM-09689, Little Bird company Pty Ltd.) are fixed on the vehicle together with a Crossbow gateway (Crossbow, MIB520CA, USA). The fixed sensor motes (Crossbow MPR2400 Motes) included temperature and relative humidity sensors. The gateway (Crossbow, MIB520CA) was connected to a computer via a USB interface board. The vehicle measurement system structure is shown in Fig.2.

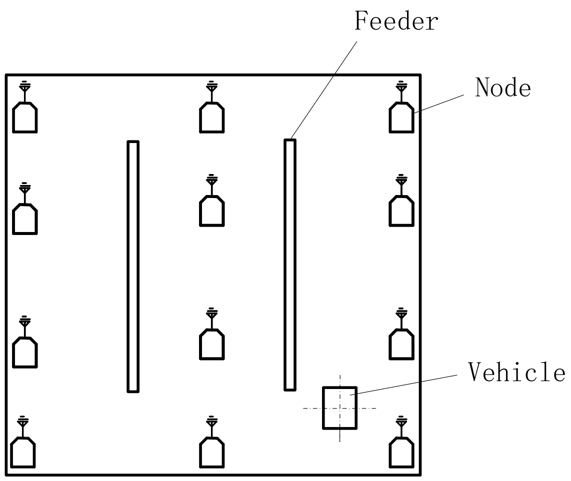

Fig.1 the Nodes distribution diagram

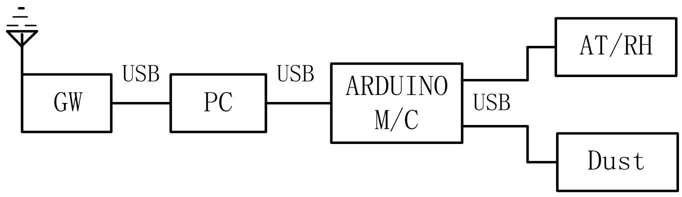

Fig.2 The vehicle measurement system structure

The system prototype was implemented and experiments were carried out at our labs at Faculty of Engineering at USQ, i.e. Z, Z2, and P12. The same system and experiment methods were used at three different experimental fields to test the instrumentation's accuracy and reliability. For comparison, different types of sensors were used to measure the environmental parameters, that is, the WSN measurement system, the vehicle sensors system, and the two Dataloggers (Tinytalk, Gemini Data Loggers UK Ltd.).

3 EXPERIMENTAL RESULTS AND DISCUSSIONS

The environment parameters' data (temperature, relative humidity and dust concentrations) at 3 buildings were shown below in Table 1, 2 and 3. The tables include the mean, medium, and maximum values, standard error, and standard deviation values. As the data collected are similar among different motes during one experiment, only the data from one sensor mote is given in the table. The data collected from the dataloggers is given in the table for the comparisons.

3.1 Air Temperature Data

Table 1 Temperature (°C) data at 3 buildings

Location	Mote/Datalogger	Mean	Ave.	Max.	Min.	S.E.	S.D.
Z	Mote	23.34	22.97	24.53	22.86	0.01	0.54
Z2	Mote	23.40	22.99	25.71	22.31	0.01	0.95
	Datalogger	22.10	21.60	24.10	21.30	0.04	0.85
P12	Mote	17.96	17.21	26.35	11.50	0.03	4.37
	Datalogger	16.14	15.30	31.40	10.60	0.18	4.41

*S.E.---- Standard Error; S.D.----Standard Deviation.

From the experiments, we observed that (1) the temperatures were steady in Z and Z2. This is because they both are office buildings and have the air conditioners to adjust the indoor environment parameters. (2) The S.E. and S.D. were very small. The data are all close to the mean value and it shows that the measurement accuracy was high. (3). In P12 building, the maximum and minimum temperature value varies over 20 degrees. This is because P12 lab has no air conditioner to adjust the indoor environment parameters.

The temperature Datalogger was deployed close to the Crossbow mote (ID 9042). The data from the mote and the Datalogger are compared in Fig. 3&4.

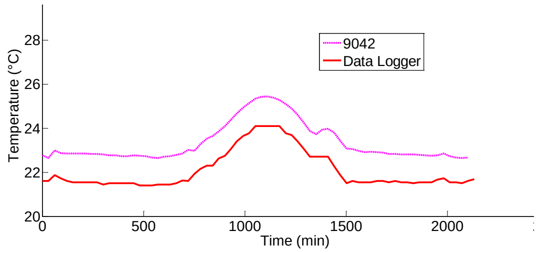

Fig 3. The temperature data comparison at Building Z2

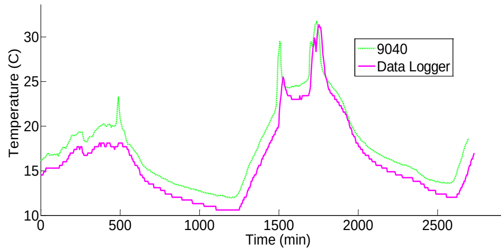

Fig 4. The temperature data comparison at Building P12

From Fig. 3 and 4, the temperature data collected from Datalogger and the mote were all very close to each other while the Datalogger values were slightly lower than the mote values. The differences of the two different sensors' temperature values were within 1.5°C and 3°C, respectively in two buildings. The S.E. and S.D. of the motes were lower than the dataloggers, which indicate the motes were probably more accurate than the dataloggers.

3.2 Relative Humidity Data

Table 2 Humidity (%HR) data at 3 buildings

Location	Mote/Datalogger	Mean	Ave.	Max.	Min.	S.E.	S.D.
Z	Mote	43.59	44.20	48.30	41.20	0.03	1.12
Z2	Mote	24.99	24.90	30.80	20.90	0.02	2.54
	Datalogger	30.64	30.40	35.10	26.70	0.12	2.52
P12	Mote	41.19	40.40	56.80	23.70	0.06	9.48
	Datalogger	47.64	48.68	61.77	23.87	0.41	9.74

*S.E.---- Standard Error; S.D.----Standard Deviation.

In Table 2, we can observe similarly that (1) the relative humidity was steady and very similar in Z and Z2 building. Again this is because they are both the office environment and have air conditioners. (2) The S.E. and S.D. were all very small. This shows that the measurement accuracy was quite high. (3) At P12 building, the humidity changed significantly between day and night over 40%RH. This is because P12 shed has no air conditioner and there were many wet soil sample and experiment liquid which probably affected the humidity.

Again the humidity Datalogger was deployed close to mote (ID 9042). The data from the mote and the Datalogger are compared in Fig. 5&6.

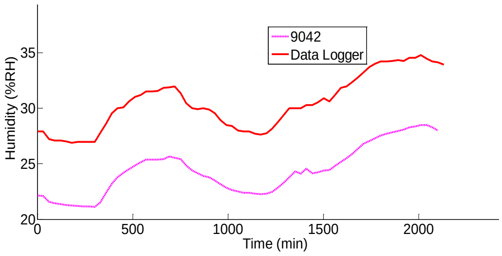

Fig 5 The humidity data comparison at Building Z2

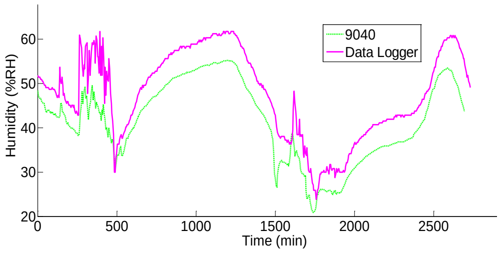

Fig 5 The humidity data comparison at Building P12

From Fig. 5 and 6, the humidity data collected from Datalogger and the mote were all very close to each other while the Datalogger values were consistently higher than the mote values. The differences of the two different sensors' humidity values were within 6%RH to 10%RH, respectively in two buildings.

3.3 THE DUST CONCNETRATIONS

The dust concentration experiments were carried out in P12 only. Some saw dust was placed in the ground for comparison.

Table 3 Data Analysis Dust Concentrations Table

Location		Mean	Ave.	Max.	Min.	S.E.	S.D.
P12	No dust	0.05	0.05	0.08	0.03	0.00	0.01
	dust	0.10	0.09	0.19	0.06	0.01	0.03

From table 3, it shows that the concentration of dust in P12 shed was very low initially without dust. After putting some sawdust on the concrete, dust level increased as expected.

4 CONCLUSIONS

In this research, we designed and developed a new environment measurement system for poultry buildings. The system uses both fixed and mobile wireless sensor motes to automatically monitor the environment. Two different sensing methods were used in our experiments. Comparing with traditional method, the system can automatically collect the environmental data with higher accuracy, flexibility and reliability. The number of sensors deployed to cover the building and the energy consumption by the sensors can be minimized in our design. In future research, we plan to use a wireless gateway collect the data from the mobile vehicle to the workstation and carry out the experiments over larger building areas. Another area of research is to enhance the accuracy of the mobile vehicle localization function based on the signal characteristics from the fixed sensor motes.

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