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Research on Wireless Sensor Network for Scale Livestock Farm

Xiao Yu [a], Liren Fu, Zhongping Zhang, Yongdong Jing

School of Electrical and Information Engineering, Northeast Agricultural University, Harbin, China

[a]neaufish@163.com

Abstract: We design establishment of wireless sensor network in livestock farm by high-performance and low-power-consumption microcontroller ATmega32L and wireless telecommunication module CRM2400CNC by aiming to difficult complete coverage in detection zone and complex cable pavement problems during data acquisition of livestock farm. In the meanwhile, we focus on discussion with key problems such as system structure, hardware and software design of sensor nodes and software design. We also research on simplification of system structure and propose a kind of self-adaptation cluster routing algorithm so as to improve comprehensive performance of wireless sensor network of livestock farm by combination of actual conditions of farm.
Keywords: wireless sensor network; sensor nodes; livestock farm

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1. INTRODUCTION

Real-time acquisition of temperature, humidity, ammonia content, animal activity quantity and body temperature, etc of livestock farm have important significance to increase economic benefits and strengthen management of livestock farm in the cultivation industry. All animals are observed by breeders to gain animal and livestock farm information in most of medium and small livestock farms in China. It is difficult to supervise all animals and livestock farms in a real-time manner. Thus, economic benefits reduce greatly because often missing the best processing chance [1,2].

Detection system of dairy cow activity quantity is researched and developed by domestic combination of wireless telecommunication module and microcontroller for estrus detection of dairy cow. However, detection distance is restricted due to point-to-point or point-to-multi-point telecommunication mode. Wireless Sensor Network (hereinafter referred to "WSN") is a kind of new network technology of specific advantage once application for livestock farm. Firstly, it is a kind of AdHoc network of convenient deployment without requiring for infrastructures such as base station and cables, etc; Secondly, sensor nodes are transmitted to users' terminals in a network form of multi-hop ad-hoc so as to cover detection

zone completely and easily. Thus, wireless sensor network can be applied for livestock farm so as to solve regional coverage problem of animal data acquisition shown in this paper excellently and acquire various kinds of parameters of livestock farm in a real-time manner[3-5].

Network system structure plays an important role for design of network protocol and various functional modules in wireless sensor network. Besides, it determines network planning and integral performance greatly. However, traditional OSI/RM module and TCP/IP module designed for static Internet are unsuitable to dynamic wireless sensor network of livestock farm of restricted energy, calculation and telecommunication ability. Thus, this paper proposes positioning algorithm of non-surveying multi-dimensional calibration and indication value of radio signal strength on the basis of traditional network level. It positions by combination of wireless network characteristics so that positioning algorithm can reduce calculation sot and reach high positioning precision at the same time. Besides, it has better robustness for possible poor characteristics of wireless network so as to improve comprehensive performance of wireless sensor network of livestock farm[6-8].

2. WIRELESS SENSOR NETWORK SYSTEM STRUCTURE ON LIVESTOCK FARM

2.1 Wireless Sensor Network Deployment in Livestock Farm

Deployment strategy of sensor nodes determine network perceived quality, cost reduction, minimization of energy consumption and final elongation of node service life greatly.

Main monitoring parameters in livestock farm include animal body temperature, pulsation and exercise frequency, etc. Thus, integrated sensor node can be installed for every animal. Wireless sensor nodes can be installed manually because of inaccessible livestock farm environment. As shown in Fig.1, we set 1 “anchor” node around feedlot respectively, divide every feedlot into 1 “loop” and set “cluster head” node in the middle so as to realize precise positioning [9].

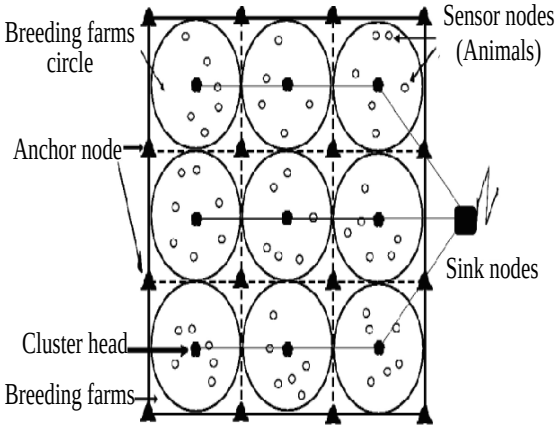

Fig. 1 Wireless sensor network deployment diagram in livestock farm

We will not only fix “cluster head” but also supply power in an active form by considering large energy consumption of “cluster head” node to guarantee effective energy. Manual

intervention will eliminate randomness of "cluster" formation and selection of "cluster head". It will reduce calculation quantity, save energy and guarantee stable and convenient management of system structure [10, 11].

2.2 Wireless Sensor Integration Node

Node constitution varies in different applications, as shown in Fig.2. However, it includes following basic units: Sensor unit (sensor and related signal modulation and digital-analog conversion, etc), processing unit (CPU, memory and embedded operation system), telecommunication unit and power (including related power management). At present, there is no integration sensor node which meets demand because detection of animals' physical health relies on acquisition of related physiological and biochemical data. We not only integrate sensors but also reserve some extension interfaces to increase extensibility for synchronous detection of physiological parameters such as body temperature, pulsation and respiration frequency, etc. In the meanwhile, design nodes must be as small as possible, energy-saving, durable, water and corrosion resistant because animals may be destructed by water or other articles during stocking in rainy days or when drinking water or eating food. Besides, we improve positioning system, movement system, actuator, power self-power-supply device and complex signal processing (including sound, image, data processing and information merging). We carry out all calculations on "cluster head" to reduce calculation quantity. Nodes on animals are only used for data transmission [12].

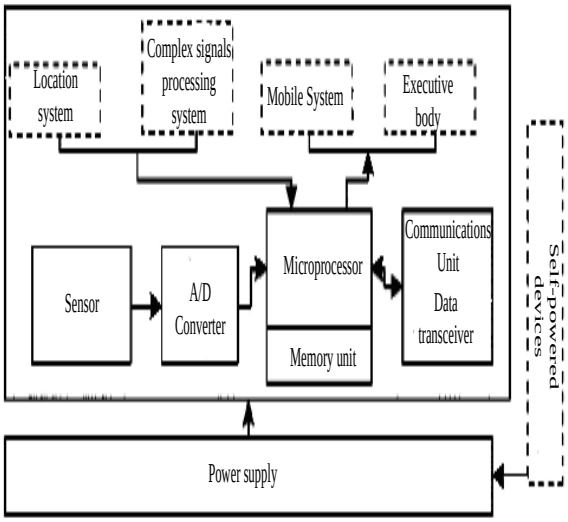

Fig. 2 Constitution of wireless sensor network node

3. System Hardware Design

This design selects high-performance and low-power-consumption microcontroller ATmega32L as main control chip of this system by considering low power consumption. We use wireless module CRM2400CNC as main control chip nRF2401 and FT232BL of FTDI Company as USB interface module for wireless telecommunication part.

3.1 Sensor Node Hardware Design

This system uses modularization ideas. Hardware mainly consists of microcontroller, wireless RF module, sensor module and power module, etc. Of which: Sensor modules mainly include activity quantity sensor, animal heat sensor and sensors of various kinds of environment parameters. Chart of system hardware structure is shown in Fig.3.

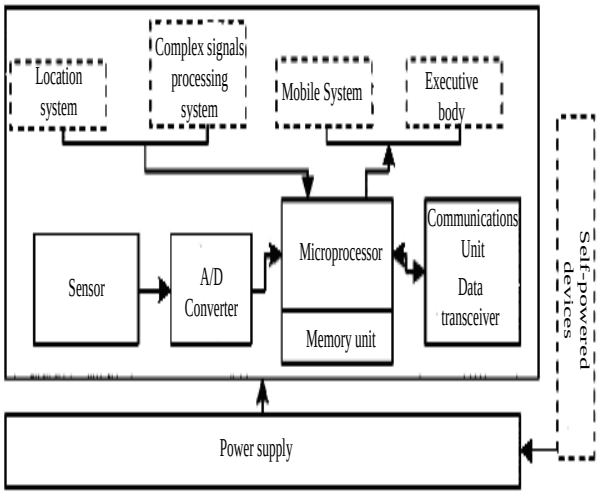

Fig. 3 Wireless sensor node hardware structure in livestock farm

3.2 Cluster Head Node Design

We use wireless signal telecommunication between cluster head node and ordinary node. Wireless information channel frequency is 2.433 GHz. We modulate format by the Minimum Shift Keying (MSK). Data rate is 250 Kbit/s. Cluster head nodes receive data package sent by ordinary node and transfer to Sink network gateway by wire network. We mainly consider following factors during design: 1) Simplify software design and cancel complex routing mechanism. We strive to use single hop principle for transmission of ordinary node signal to cluster head; 2) We use industrial level RS-485 wire network protocol to guarantee stability and reliability of wire network; 3) We use modular design and ordinary node transmission module for wireless data transmission module of cluster head node so as to reduce cost[13].

3.3 Sink Node Design

Sink node is data collection center of the entire system. It is mainly responsible for receiving data transferred from sensor node, dispatching operation of sensor node and connecting wireless network and Ethernet so as to upload acquired data and issue users' commands and establish a telecommunication bridge between users and nodes. Structure is shown in Fig.4. Sink nodes have powerful-function processing modules and large-capacity memory modules besides wireless receiving and dispatching modules of the same structure and function of sensor nodes. Nodes also have Ethernet control modules to connect to remote server. Nodes also play a role of network gateway for wireless network and Ethernet besides data collection and storage function. Municipal electricity replaces battery for power supply to nodes and gets rid of energy supply restriction because of relatively less convergence nodes and fixed positions by comparing with sensor nodes.

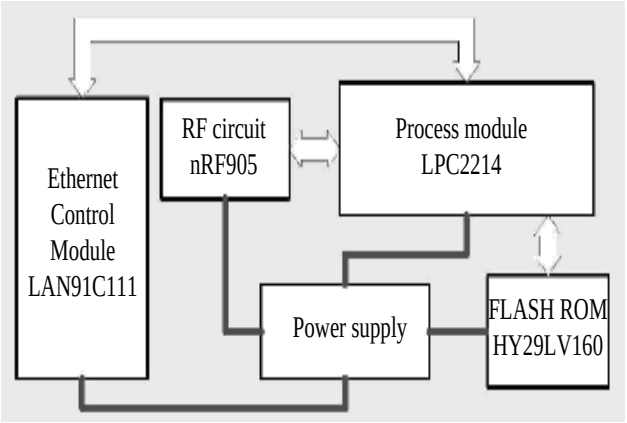

Fig. 4 Structural chart of Sink node

4. SYSTEM SOFTWARE DESIGN

Animal data information is collected to know various kinds of states of animal activities. Tracing target is every animal. We must solve individual identification and positioning problem. Global ID is used for unique expression of individual. We retain this ID for positioning by utilizing memory of sensing node for a long time. We can use GPS, etc but there is a blind zone problem for livestock farm besides super-high cost. Besides, activity scope varies with animal habits and individuals. Thus, we obtain reliable node positioning on the basis of incorrect distance estimate by utilizing precise position information of a lot of "anchor" nodes in sensor network on the basis of "Range-free" positioning algorithm. All "anchor" nodes send information packets which include their own position information to network during algorithm starting stage. Hop count is 0. Other nodes will add 1 to hop count then transfer after receiving above information packet. Finally, all pending positioning nodes will gain position information of every "anchor" node and hop count from this node to anchor node. "Anchor" node will calculate average distance of every hop in the network according to received position information and mutual hop count of other "anchor" nodes and issue to network. Pending positioning nodes will multiply total hop count of them and "anchor" nodes by average distance of every hop to calculate estimated distance from this node to every "anchor" node. We can gain an equation set according to Euclid distance formula. Unknown value is coordinate of pending positioning coordinate. However, above calculation is done after sending to "cluster head".

The system uses PEGASIS routing protocol. It is a kind of power consumption self-adaptation cluster routing algorithm developed on the basis of LEACH. This protocol assumes that sensor nodes which constitute the network are isomorphic and still.

Node sends test signals of progressively decreased energy and determines the nearest adjacent node by detection reply. All nodes in the network can know position relationship in this form. Thus, every node can select "cluster" according to position. "Cluster head" refers to position relationship and optimizes the best link of Sink node. PEGASIS routing protocol in the system saves selection steps of "cluster" for various nodes and "cluster head" for various "clusters"

and simplifies original protocol because “cluster” and “cluster head” nodes have been determined manually. It only knows position relationship by sending test signals. Various “cluster heads” refer to position relationship and optimize the best link of Sink node. Every node in PEGSIS sends data grouping by the minimum power and finishes necessary data merging and saves data flow. Thus, the entire network has small power consumption [14,15].

5. CONCLUSION

This paper establishes a small wireless sensor network in livestock farm. It applies wireless sensor network for scale livestock farm to solve difficult wiring and complete coverage problems in detection zone excellently. It uses high-performance and low-energy-consumption elements. It has advantages such as low cost, fast response, stable and reliable telecommunication and convenient operation, etc and provides test platform for further research of wireless sensor network telecommunication protocol.

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