



Virtual Force Coverage Control System of Wireless Sensor Network in the Background of Big Data

Jia Xu^{1,2}(✉) and Yang Guo²

¹ Dalian Jiaotong University, Dalian, China

² Dalian Institute of Science and Technology, Dalian, China
yu2018030211@163.com

Abstract. In view of the low virtual force coverage of traditional wireless sensor networks. A virtual force coverage control system based on wireless sensor network is designed. Hardware design mainly includes network interface, processor, control chip and network coordinator. In the software part of the system, firstly, the virtual force coverage control node is selected. On this basis. The optimal control of virtual force and coverage of wireless sensor networks. The virtual force coverage control system of wireless sensor network is designed under the background of big data. The experimental results show that. Under the background of big data, the coverage of virtual force control system of wireless sensor network is higher than that of traditional system. It has a certain practical significance.

Keywords: Big data · Wireless sensor · Network · Virtual force · Cover · Control

1 Introduction

As one of the basic problems of wireless sensor network. The research of network virtual force coverage control has attracted extensive attention of scholars at home and abroad. A series of effective methods for different coverage requirements are developed. Different applications have different interpretations and requirements for coverage. The coverage control problem can be regarded as the case when the sensor node energy, wireless network communication bandwidth, computing capacity and other resources are generally constrained. Through network sensor node deployment and routing and other means. Finally, all kinds of resources of wireless sensor network are allocated optimally. So as to further improve the perception, communication and other service quality.

Due to the intensive deployment of nodes in most sensor networks. If each node communicates with a certain power, it will increase communication interference and cause coverage redundancy. Therefore, a certain sleep mechanism can not only balance the energy consumption of nodes, optimize the network coverage, but also extend the network lifetime. Aiming at the problem of virtual force coverage control system in traditional wireless sensor networks. A virtual force coverage control system for wireless sensor networks in the background of big data is designed. In this design, the energy constraints and coverage requirements of wireless sensor networks are taken into account. Combined with antenna theory, the coverage control problem of wireless sensor networks is reduced to a multi-objective nonlinear programming problem. Thus, a mathematical model of multi-objective nonlinear programming problem is derived and established. The

experimental results show that. Under the background of big data, the virtual force coverage control system of wireless sensor network is designed. The coverage of the control system is higher than that of the traditional system. It has a certain practical significance.

2 Overall Architecture

The virtual force coverage control system of wireless sensor network is designed. In order to solve the problem of low coverage of network virtual baggage, the overall framework of the design is shown in Fig. 1:

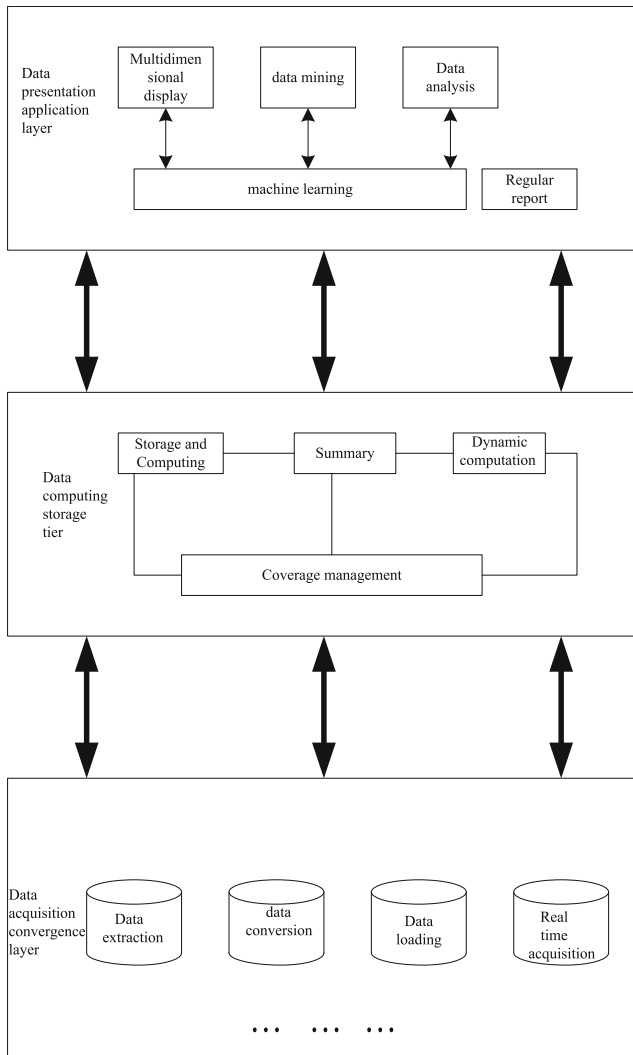


Fig. 1. Architecture of virtual force coverage control system in wireless sensor network

The whole technical architecture is divided into three layers: Data acquisition convergence layer. Wireless sensor network is adopted. As the main collection tool of real world perception data. Gather other big data collection tools [1]. Collect different information of various kinds of sensing devices, and provide data aggregation and storage for the upper layer. Data storage computing layer adopts the current information technology industry. More mature distributed storage and computing framework. To meet the need of virtual force coverage in wireless sensor networks, and to support the increase of hardware nodes, the expansion of data storage space is completed smoothly. All kinds of algorithms required for data presentation application layer and integrated data analysis are encapsulated into analysis modules required for various scenarios. Both terminal app and personalized data analysis application can be built quickly through various components.

3 Hardware Design

The design of system hardware circuit is based on processor. Including network interface design, processor design, interface circuit design, network coordinator design, the following is a specific introduction.

3.1 Network Interface Design

The FPGA processor of Xilinx company is used to control the driving control of the whole network interface. It is connected with network interface chip [2] AX88180 by bus. The internal register of AX88180 is configured by the network driver to realize the transmission and reception of Ethernet data, so as to realize the data communication between the system and the network. The connection between AX88180 chip and 88E1111 chip adopts Gigabit Ethernet media independent interface (GRMII) mode. The function of network interface layer in TCP/IP protocol architecture is realized, including link layer protocol and physical layer protocol. 88E1111 is connected with RJ45 network interface to realize the transmission and reception of bit stream on the network cable. It includes chip selection signal, read enable signal, write enable residence, address bus, data bus, interrupt signal, clock signal, reset signal, read clock signal, write clock signal, etc.

The network interface chip AX88180 reset [3] adopts the combination of power on automatic reset and manual reset, and the frequency of external crystal oscillation circuit is 12 MHz. P1 port line, INTO and VSE are used for network data acquisition. The P1 port is an 8-bit network data acquisition bus, INTO is the network data acquisition interrupt control, VSE is the control signal line of the network data acquisition channel. Because the network interface chip AX88180 has only 1 K bytes, it can not meet the requirements of the system. Therefore, 32 byte HM156 is used to expand the system. The P0 port line is address data multiplexing, which is used for low byte address locking. The P2 port line outputs high byte address.

3.2 Processor Design

Control part of virtual force coverage control system in wireless sensor network. With DSP as the core, DSP processor is connected with FPGA. Connection signals include: address bus, data bus [4], chip selection signal, bus hold signal, clock signal, preparation signal, interrupt signal, read signal and write signal. The control signal of SRAM chip is generated by FPGA chip, and its read-write operation is controlled by DSP chip and FPGA chip respectively. When receiving data, FPGA writes human data to SRAM, and DSP reads data from SRAM. When sending data, DSP writes data to SRAM and FPGA reads data from SRAM. The DSP processor uses DFHEF45 as the interface chip, DFHEF45 is an embedded chip launched by CYPRESS. The chip can communicate with wireless sensor as well as wireless sensor. The chip provides 8 bit wide data bus and interrupt support, which makes it easy to connect with microprocessor, microcontroller and DSP. Internal 256 byte RAM, two sets of parallel registers support ping-pong operation. By controlling pin AO, address and data can be distinguished, and address auto increment mode is supported. The working voltage is 3.3 V, and the interface is compatible with 5 V level. The functional module diagram is as follows (Fig. 2):

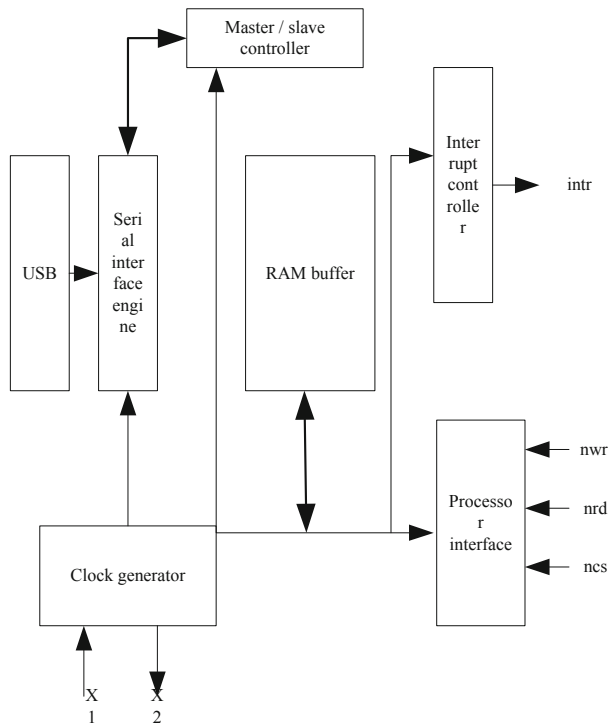


Fig. 2. DFHEF45 functional module diagram

DFHEF45 interface chip is characterized by low cost, low power consumption, high performance, strong reliability, fast instruction execution speed, flexible addressing mode and high efficiency. ARM microprocessor is widely used in embedded system development. Because of its high speed and good compatibility, it is widely used in industrial control, network technology, video acquisition and other fields.

3.3 Control Chip Design

The control chip used in this system is CC2430. It is an on-chip wireless sensor network control product complying with IEEE802.15.4 standard. It integrates ZigBee RF front-end, memory and microcontroller on a single chip [5]. It uses an 8-bit MCU (8051), 128 KB programmable flash memory and 8 KB ram. It also includes an analog-to-digital converter (ADC), four timers, a watchdog timer, a 32 kHz crystal oscillator sleep mode timer, a power on reset circuit, a power down detection circuit, and 21 programmable I/O pins. CC2430 only needs a few peripheral components. Its peripheral circuit includes crystal clock circuit, RF input circuit and output matching circuit. The local oscillator signal of 151 chip can be provided by either external active crystal or internal circuit. RF input and output matching circuit is mainly used to match the input and output impedance of the chip, and provide DC bias for PA and LNA inside the chip. The following figure shows the hardware application circuit of CC2430 chip (Fig. 3).

The control chip uses an unbalanced antenna to connect the unbalanced transformer, which can improve the antenna performance. The unbalanced transformer in the circuit is composed of capacitance C341, inductance L341, L321, L331 and a PCB microwave transmission line. The whole structure meets the requirements of RF input and output matching resistance (50 Ω). R221 and R261 are bias resistors [6], and R221 mainly provides a suitable working current for the 32 MHz crystal oscillator, A 32 MHz crystal oscillator circuit is composed of a 32 MHz quartz resonator (X1) and two capacitors (C191 and C211). A 32.768 kHz crystal oscillator is composed of a 32.768 kHz quartz resonator (X2) and two capacitors (C441 and C431). The voltage regulator supplies power to all pins and internal power supply which require 1.8 V voltage. C241 and C421 are decoupling capacitors, which are used to realize power filter and improve the stability of the chip. For the design of analog part, in order to reduce the interference of other parts and improve the RF performance, anti-interference measures need to be taken. For example, add magnetic beads or inductors at the input end of the analog power supply; separate the analog ground and the digital ground, and ground them at one point. In order to reduce the influence of the distribution parameters, the ground should be paved as large as possible, and holes should be punched properly. The capacitance used for filtering should be close to the chip as much as possible.

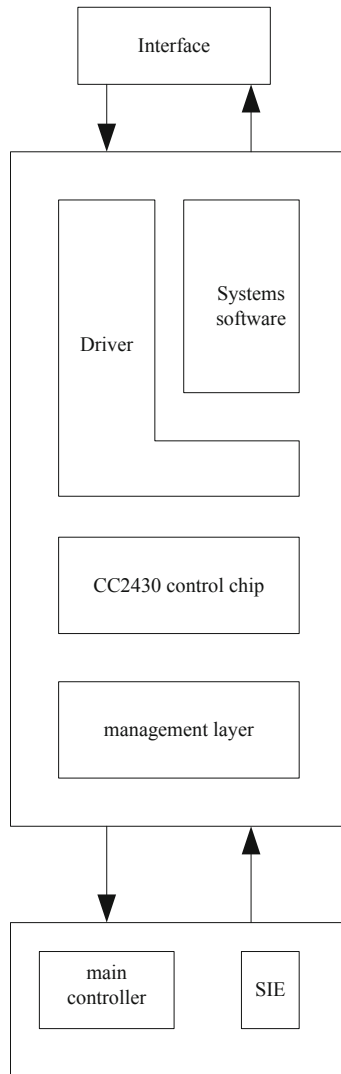


Fig. 3. CC2430 control chip

3.4 Design of Network Coordinator

The network coordinator needs to display the current network status, so the network coordinator is composed of CC2430, serial port, key and LCD. The circuit block diagram is shown in Fig. 4. RFD node and ROUTER node are composed of CC2430, photoresist, serial port expansion interface and street light dimming control circuit.

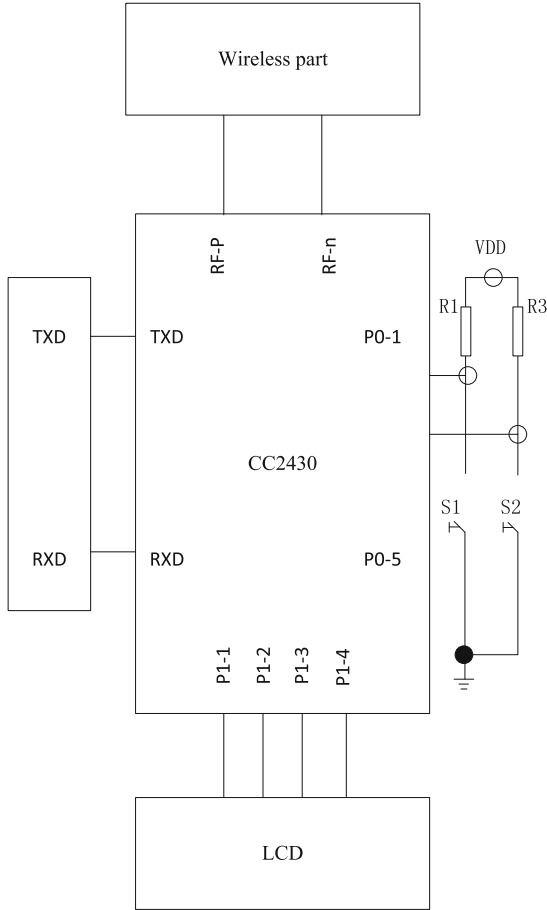


Fig. 4. Circuit diagram of network coordinator

The network coordinator uses the I/O port of CC2430 to control the LCD directly, and outputs the data and debugs the program through the serial port. S1 and S2 are used to control the switch status of the whole network street lamp. It also monitors the key at any time. If the key is pressed, it will send data to each street lamp control node through the network and display the current power switch status of the whole network. RFD node and ROUTER node can also detect their own current light conditions, and determine whether to turn on the street lights by judging the light conditions, so as to achieve energy-saving control.

The network coordinator first initializes CC2430 and LCD [7], then initializes the protocol stack and opens the interrupt. After that, the program starts to format a network. If the network format is successful, the physical address of the corresponding network coordinator, the network ID number and channel number of the established network will be displayed on the LCD screen.

4 Software Implementation

4.1 Selection of Virtual Force Coverage Control Nodes in Wireless Sensor Networks

Before selecting the virtual force coverage control node in wireless sensor networks, a perception model is established to achieve the goal of path planning. The decision tree algorithm is used to consider whether the node is a candidate work node or not according to the node energy, the number of unselected work nodes and the number of neighbor nodes. When the nodes switch states, the energy information of their neighbors is introduced to make decisions, which makes the energy consumption in the network more balanced.

The virtual potential field method is used to simulate the movement of charged particles from high potential point to low potential point in the electric field. Each sensor node in the network is regarded as a virtual charge, and the target and obstacle are regarded as low potential point and high potential point respectively. By using the force of potential field on the node, the node moves to the target, and at the same time, all kinds of obstacles in the moving process can be avoided. When each node in the wireless sensor network is affected by the virtual force of other nodes, it spreads to other areas in the target area, and finally reaches the equilibrium state, that is, to achieve the full coverage state of the target area. Or the uniformity of network coverage is taken as the goal, and the non-uniformity of node deployment is regarded as the obstacle. Using virtual potential field to realize network redeployment [8], the network coverage area can be maximized.

In the virtual force model defined, the virtual force of a sensor node is represented as follows:

$$D = \sum_c hF_d + df \quad (1)$$

In formula (1), D is the sensor node, $\sum_c h$ needs the resultant force of the virtual gravity of the coverage area, F_d is the sensor node at the obstacle, df the resultant force of virtual repulsion (Fig. 5).

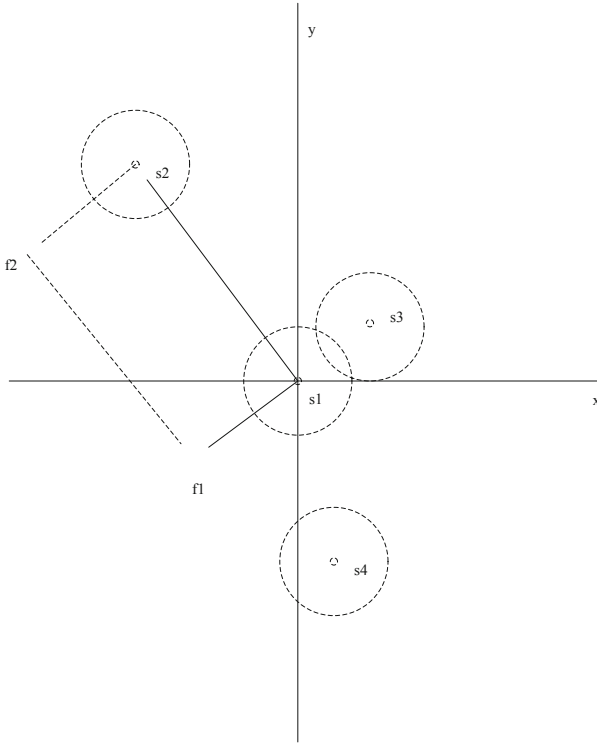


Fig. 5. Example of virtual force action of four sensor nodes

From the above analysis, if the value is set artificially, the monitoring area can be covered according to a certain density, or the coverage intensity of the detection area can be adjusted. However, on the one hand, energy saving is not considered; On the other hand, the density of the final layout depends on the critical distance from the definition. When the distance is too small, the layout of wireless sensor nodes is too close to ensure the coverage requirements; When the distance is too large, the sensor nodes are sparse, which is easy to form a blind area. In order to solve this problem, we will optimize the virtual force coverage control in the next step.

4.2 Optimization of Virtual Force Coverage Control in Wireless Sensor Networks

Based on the selection of virtual force control nodes in wireless sensor networks, the control optimization of virtual force coverage [9] in wireless sensor networks is carried out. At the same time, before optimizing the virtual force coverage control of wireless sensor network, the network model is established. The sensor nodes in the network are randomly and evenly deployed in the two-dimensional square area with side length L , and the node density is large enough, if all nodes are in working state, the whole area can be completely covered, it is assumed that the network has the following properties:

First, the coverage of each node is far smaller than the whole network area.

Second, all nodes will not be moved after deployment, without human maintenance.

Thirdly, each node has a fixed sensing radius. The nodes in the sensing range can receive the information sent by the node, while the nodes outside the sensing range can not receive the information.

Fourth, all nodes are isomorphic and have the same initial energy.

Fifth, the time synchronization between nodes in the network reaches second level.

Assuming that the minimum power [10] that can detect and decode the signal correctly, i.e. the minimum value of G is J , the minimum transmission power of the transmitting node is:

$$X = \frac{D(VN)^T}{JH * J^2} \tag{2}$$

In formula (2), X represents the relationship between transmission power and distance, JH represents the minimum power consumed by the whole network, J^2 represents the minimum power consumed by the whole network, $X D(VN)^T$ represents the balanced power consumed by sensor nodes.

Therefore, the energy saving optimization target model can be expressed as follows: assuming D is the monitoring target area and N sensors are used to cover the nodes, the coverage matrix is as follows:

$$\begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_r \end{bmatrix} = G * \begin{bmatrix} z_{11} & z_{12} & \dots & z_{1f} \\ z_{21} & z_{22} & \dots & z_{2f} \\ \vdots & \vdots & & \vdots \\ z_{r1} & z_{r2} & \dots & z_{rf} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_r \end{bmatrix} \tag{3}$$

In matrix 3, A_1, A_2, A_r respectively represent the coverage area of sensor nodes. Constraints x_1, x_2, x_r can ensure that there is no blind area in the coverage area, constraints G can ensure the connectivity of the network, and take wireless interference into account. Based on the above mathematical model, the energy-saving wireless sensor network coverage control problem is reduced to a multi-objective nonlinear programming problem.

On this basis, the method of setting objective optimization function and using artificial fish swarm algorithm to solve the coverage control problem is to simplify the coverage problem into a function, find the solution of the extreme value of the function and the corresponding extreme value, so as to correspond to the node working state of the sensor coverage problem. The problems related to covering optimization are integrated into a function, which is called optimization objective function. The process of target optimization is as follows (Fig. 6):

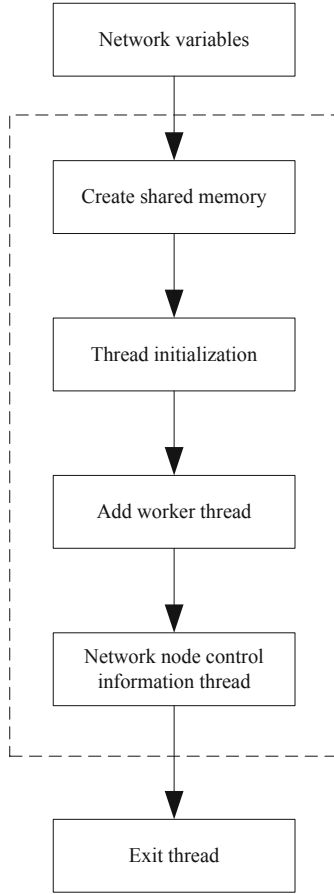


Fig. 6. Objective optimization process

The above is the calculation process of network coverage, and the specific calculation is shown in the following formula:

$$D = RF \frac{df}{\sum_s fD * GH} \tag{4}$$

Among them, D is the total number of sensor nodes, RF is the number of working sensor nodes, $\sum_s fD$ represents the global energy balance coefficient, GH represents the remaining energy in the network nodes, df represents the coverage of the monitoring area.

When the target area is completely covered by the sensor’s sensing range, it is easy to have unnecessary repeated coverage. Adopting the optimal deployment strategy of nodes can save energy consumption, and also provide a good topology structure for

information fusion processing, hierarchical routing and other follow-up technologies. In this scheme, virtual force acts between sensor nodes, which can be expressed as:

$$NF = \frac{V}{\sum_a c \Rightarrow v} \quad (5)$$

In formula (5), NF is the distance between the two sensor nodes, $\sum_a c$ is the square of the sensing radius of the two nodes, v is the sensor area dimension of the node, v represents the node value of the minimum energy consumption in the point, V represents the weight coefficient of the two sub targets.

5 Experimental Comparison

This design is to prove the effectiveness of the virtual force coverage control system of wireless sensor network under the background of big data designed above, and to ensure the preciseness of the experiment, the traditional virtual force coverage control system of wireless sensor network is designed. Under the background of big data, the virtual force coverage control system of wireless sensor network is compared, and the virtual force coverage of the two systems is compared.

5.1 Experimental Platform

The experimental system is composed of three small mobile agents driven by two wheel differential as the experimental platform, as shown in the figure below (Fig. 7):

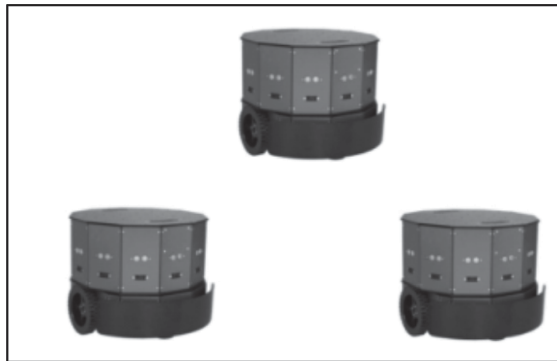


Fig. 7. Small mobile agent

The wireless communication system is based on cc2430zigbee control chip. The communication between the wireless communication system and the control system adopts serial port communication mode. The control system is composed of upper computer and lower computer. The upper computer is developed based on VC. It is mainly used to receive wireless communication information, obstacle distance information, and real-time calculation to get the motion control information of the agent. The main controller of the lower computer is the 2000 series DSP chip of TI company, with the main frequency of 40 MHz, It is mainly used to collect ultrasonic information and encoder information, and control the left and right driving wheels of the agent according to the control instructions issued by the lower computer.

This system is based on IOS 5.1 system to realize the augmented reality client. Therefore, during the test process, an iPhone 4 mobile phone running IOS 5.1 or above system version is needed to watch the experiment. The server is developed in Python, so a web server supporting Python language is also needed. In addition, the iPhone 4 mobile phone should have WiFi or 3G network environment for communication with the server. The experimental platform is designed as follows (Fig. 8):

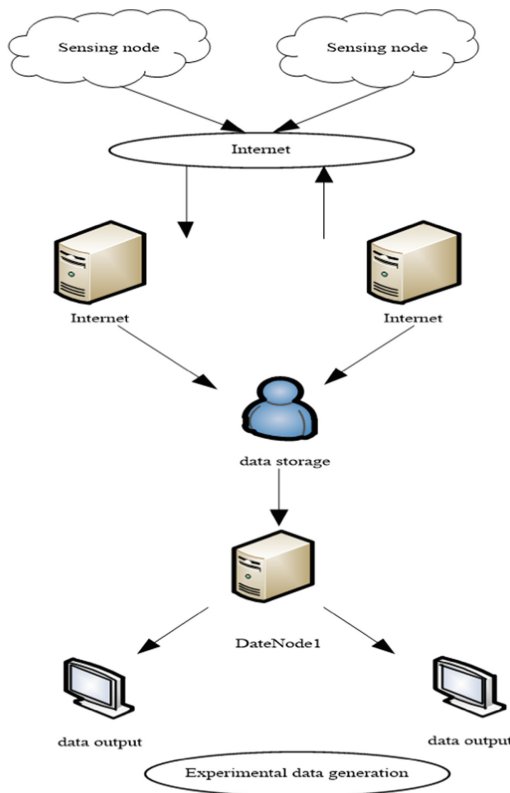


Fig. 8. Experimental platform settings

On the basis of the above experimental environment design, the experimental scheme is designed. In the square monitoring area with side length of 100 m, 100 sensor nodes are randomly and evenly deployed. Supposing that the virtual cell is divided into square areas with side length of 20 m, in order to ensure that the nodes of adjacent cells can communicate with each other, the communication radius and sensing radius of the nodes are respectively 45 m and 13 M. At the same time, it can be assumed that the initial energy of all nodes is 50 J, the energy consumed by each round of nodes elected as cluster heads is 1 J, the working time of each round of cluster heads is certain, there is no energy consumption under the node sleep state, the energy of the center of mass is 50 J, and it will not change with the operation of the network. Because there are 4 nodes in each cell, and each node will die after 50 rounds of cluster heads are selected, the total number of rounds of cluster heads selected in each cell is 200, and the lifetime of the whole cell is the product of the number of rounds of cluster heads selected by all nodes and each continuous working time. In the initial stage, the sensor nodes are randomly and evenly deployed in the whole monitoring area. The above is preparation for the experiment.

5.2 Analysis of Experimental Results

Compared with the coverage of the traditional system and the designed system, the experimental results are generated by the same energy model as LEACH protocol. The specific experimental results are as follows (Fig. 9):

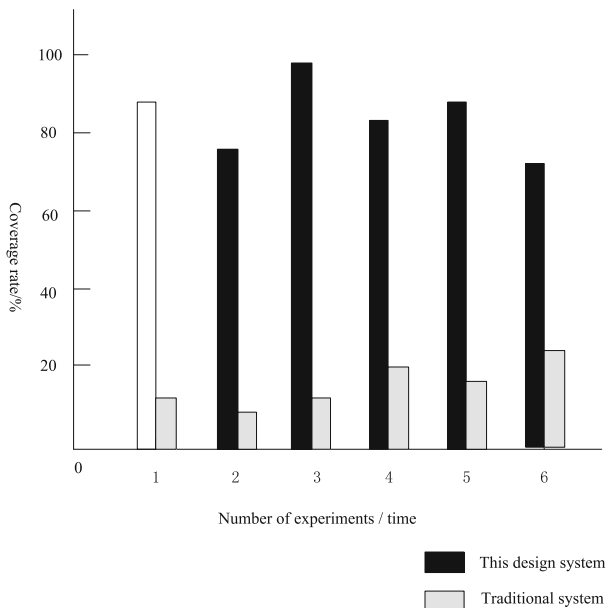


Fig. 9. Comparison of experimental results

Analysis of the above comparison figure shows that in the five experiments, under the background of big data, the virtual force coverage of the wireless sensor network virtual force coverage control system is higher than that of the traditional system. In the second experiment, the difference between the two is the largest.

Therefore, through the above experiments, it can be proved that under the background of big data, the coverage of the virtual force coverage control system of wireless sensor network is higher than that of the traditional system, which proves that under the background of big data, the effectiveness of the virtual force coverage control system of wireless sensor network has a certain practical application significance.

6 Concluding Remarks

In view of the low coverage of the traditional virtual force coverage control system in wireless sensor networks, a virtual force coverage control system in wireless sensor networks is designed under the background of big data. The design of the system is completed from two aspects of hardware design and software design. The experimental results show that under the background of big data, the virtual force coverage control system of wireless sensor network is higher than that of traditional system. The system has good convergence and universality to solve the multi-objective nonlinear programming problem. It can meet the coverage control requirements of wireless sensor network, maximize the life cycle of the network, and improve the performance of the system.

There are still some deficiencies in this design, which need to be improved in the future practical application to meet the virtual force coverage requirements of wireless sensor.

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