The research and application of green computer room environmental monitoring system based on internet of things technology

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Abstract: With the rapid development of information technology, the scale of data center increases quickly, and the energy consumption of computer room also increases rapidly, among which, energy consumption of air conditioning cooling makes up a large proportion. How to apply new technology to reduce the energy consumption of the computer room becomes an important topic of energy saving in the current research. This paper study internet of things technology, and design a kind of green computer room environmental monitoring system. In the system, we can get the real-time environment data from the application of wireless sensor network technology, which will be showed in a creative way of three-dimensional effect. In the environment monitor, we can get the computer room assets view, temperature cloud view, humidity cloud view, microenvironment view and so on. Thus according to the condition of the microenvironment, we can adjust the air volume, temperature and humidity parameters of the air conditioning for the individual equipment cabinet to realize the precise air conditioning refrigeration. And this can reduce the energy consumption of air conditioning, as a result, the overall energy consumption of the green computer room will reduce greatly. At the same time, we apply this project in the computer center of Weihai, and after a year of test and running, we find that it took a good energy saving effect, which fully verified the effectiveness of this project on the energy conservation of the computer room.

1. Introduction
At present, our country is in the rapid growth period of information construction, and lots of industries have high demand of the construction of the computer room. At the same time, the development of information technology inject energy to the computer room market constantly, as a result, it also brings larger consumption of energy as the grow of information technology infrastructure. And it is particularly important for the computer rooms to be safe, reliable and efficient operation, but the power consumption of traditional computer room is huge, and energy consumption is relatively high. According to statistics, more than 50% of the electricity are consumed by UPS, air conditioning and other infrastructure for the computer room, and the remaining energy is consumed by servers, storage, network and other IT equipments. Therefore, how to reduce the energy consumption of refrigeration is...
the key factor to minimize the total energy consumption. But at present, some traditional computer rooms don't design the ventilation systems according to the aerodynamic, and the local temperature usually appears to be high, and air conditioning refrigeration did not achieve the desired purpose. As a result, lots of energy is lost, and it looks quite bad on the temperature control effect.

With the high demand of the information technology in all walks of life, it is time to develop monitoring and evaluation system of energy conservation based on Internet of things technology according to the needs of the national energy conservation and emissions reduction. As we know, the data center is usually regarded as the information technology protection infrastructure, and it is particularly important for the data center to run safely, reliably and efficiently. And we can see that the power consumption of the traditional data center is huge, so we must control the energy consumption equipments and realize the goal of energy saving with the new equipment and new technology [1].

2. The internet of things technology

2.1 Concept of Internet of Things
Internet of things is an important part of new generation information technology, it connects all the items in the sensor network and the Internet through the radio frequency identification, sensors, global positioning system and other information sensing devices, so they can exchange and communicate among the information to realize the intelligent identification of objects, location, tracking and monitoring and management. The characteristics of the Internet of things make it widely used in intelligent home, intelligent transportation, industrial monitoring and so on. In short, the Internet of things achieve the acquisition of physical world information based on the existing Internet by sensing technology to realize interconnection between objects and people, things and objects [2].

The architecture of internet of things can be divided into three layers which called information sensing core layer, network layer and application layer, and the information sensing is the basis of Internet of things, the network communication is the reliable guarantee, and the core of the Internet of things is the application processing and the intelligent solutions, and the implementation of the Internet of things need a variety of technology.

2.2 Sensor Technology
Sensors can sense the data which is measured, and convert the available output signal according to certain rules of devices. Along with the rapid development of sensor technology, a variety of high precision, accuracy of the sensors come out. Internet of things have to rely on a large number of various types of sensors to realize interconnection of everything, and the sensor technology can satisfy this requirement. What's more, the continuous development of sensor technology promotes the application of Internet of things in all walks of life.

2.3 Wireless Sensor Network
Wireless sensor network consists of sensor, data processing unit and communication unit. The most main characteristic of the Internet of things is to make an independent wireless network using a variety of sensors and short distance wireless communication technology, such as ZigBee technology [3,4]. It generally provides the exchange of information between the small scope and content, and it is one of the key technologies of Internet of things. The applications of the wireless sensor network include video monitoring, traffic monitoring, air traffic control, robotics, automotive, home health monitoring and industrial automation [5].

3. Design concept
In this system, we use the Internet of things technology to monitor the temperature, humidity, air conditioning operation parameters and other equipment parameters, and show the asset view, temperature cloud view, humidity cloud view and micro environment view using 3D virtual reality technology, so we can learn the temperature and humidity conditions of the microenvironment of the
room [6,7]. According to the monitoring view, we can adjust the air flow, temperature and humidity parameters of the air conditioning system for individual equipment cabinet and room to realize the precise air conditioning refrigeration, thus we can greatly reduce energy consumption of air conditioning refrigeration, as a result, the overall energy consumption of computer room can also reduce to some extent [8].

4. System design
The system uses three layers of B/S structure with the graphical interface operation, and the computer room is modeled according to the actual room condition using the 3D virtual technology. On the one hand, we can grasp the overall computer room environment, on the other hand, we can control over assets and the alarm information quickly [9]. The system structure diagram is shown in Figure 1.

![System Structure Diagram](image)

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**Figure 1.** The system structure diagram.

According to the functional requirements, the system can be divided into four function modules: data collection, three-dimensional display, intelligent warning, remote monitoring. Data collection module is responsible for the data collection of computer room environment, and the data is saved through standardized processing. Three-dimensional display module is responsible for modeling 3D virtual environment according to the reality computer room environment, and show the environmental real-time data on the 3D model. Intelligent warning module is responsible for the alarm of computer room environment temperature and humidity Settings, tracking and combined operation. Remote
monitoring is responsible for the remote control of air conditioning according to the actual situation of monitoring information.

Between the four function modules, the data collection module is divided into two parts, one part is to collect the temperature and humidity of the room, cabinet through the wireless temperature and humidity in the form of a wireless network, another part is to collect parameter data of equipments through SNMP and IPMI protocol in the form of IP network, and the data collection module will store the data in the database, and it will provide data services for other applications. And the 3D display module set the device model by the equipment parameters of the data from the data collection module, and extract the data of temperature and humidity monitoring parameters, and then display the data collected on the device model, so we can get the temperature and humidity monitoring cloud. The intelligent warning module is used to set the parameters of the system, when the monitoring data achieve the warning value, it will began to give an alarm, and shown it in the 3D display system to track the alarm devices, and we can get the current alarm device for detailed information. Remote monitoring will control the alarm information in the 3D display module when we get the alarm from the intelligent warning module. And we can get the detail information and adjust the operating parameters of the equipment information dynamically to cooperate with warning information for the remote controlling of the devices. Four modules correlate between each other together to achieve the monitoring, warning and controlling of the machine room to ensure the energy saving effect of the room [10].

4.1 Data Collection

The type of computer bus is commonly used in the ordinary computer data collection way, in this system, the monitoring data collection using wireless way as far as possible in order to avoid to change the existing room. And we can gather parameter data of equipments through SNMP and IPMI protocol in the form of IP network.

Overall, the system uses the Internet of things technology to collect and process the monitoring data through the wireless and the IP network. The objects which are monitored in the computer room include cabinet microenvironment, computer room environment, air conditioning, server, UPS, etc. Using wireless sensor technology we can collect the temperature and humidity data of cabinet microenvironment, computer room environment through the wireless temperature and humidity sensors. And using the SNMP and IPMI technology we can get the characteristics of air conditioning equipment to obtain temperature, humidity, voltage and other information in order to control and set the air velocity and temperature and humidity of air condition.

Data collection includes both timing acquisition and real-time acquisition. The acquisition of system data is to process and storage the data after getting the data from the third party, and it has nothing to be done with the preparation of the hardware interface. This module includes the data acquisition table and real-time data acquisition table. Among them, the specific function of timing acquisition is that the user can choose the device type and set the acquisition time, and the system can collect the data automatically and set the time of data collection. The specific function of real-time acquisition is that the user give specific orders through a collection instruction of server, and after the response of system, we can get the data by calling the equipment data acquisition interface, and we can feedback the data to the 3D model interface and display it to the user. the Real-time acquisition can be controlled from all the IT equipments, and we can also choose some device type separately [11].

4.2 Three-dimensional Display

The three-dimensional system which uses the Internet of things technology is developed through the unity3D development tools, and it can show the asset view, temperature cloud view, humidity cloud view and micro environment view in three-dimensional effect to realize visualizations of computer infrastructure management. In 3D virtual environment, we can obtain corresponding information through direct clicking on the 3D object in virtual environment, and we can also enlarge, narrow,
rotation, translation the model to realize the dynamic navigation, roaming rooms, searching positioning of alarm devices and other functions.

In this module, there are two basic functions which called intelligent modeling and equipment management respectively. Among them, the main functions of the intelligent modeling is to transform the data in the model database to the 3D modeling of the interface. And in this module, users can manually make the 3D modeling on the system interface, and create the corresponding data model through the transformation of interfaces, at the same time, the data in the database model can be selected to generate the 3D model on the system interface. Between the 3D model and data model, we pay close attention to the model database. This function is mainly used the preliminary stage with the commissioning of the system, and only when adding new device types in the engine room, we will need to manipulate this module. The data table of this module refers equipment type table, equipment property table and equipment instructions table. And the equipment management include display, editing functions. At the front desk, it display it in the form of three-dimensional model, and at the background, it need the support of the three-dimensional model driving program. Devices in the computer room display the models based on the basis data of the related computer room equipment, and the system will show the whole room in the form of 3D diagram, identify the physical location of the controlled equipment, and provide a comprehensive display of all computer room equipment information or the individual equipment information. When the equipment is exception, we can identify the equipment alarm level in the form of the color change or warning light of the equipment, and the equipment alarm status can refresh dynamically. And if we click on the equipment, we can check the related equipment parameters, status and alarm information. The editing functions mainly refer to add, delete and set the equipment configuration information, tow the equipment position and set the automatic memory.

4.3 Intelligent Warning
Intelligent warning mainly include the warning strategy, warning tracking, warning linkage and other functions. This module can customize the alarm level of multiple temperature and humidity, and define the alarm threshold according to the actual situation, and support the phone alarm, message alarm and E-mail alarm. When the alarm occur, users can find the position quickly and accurately through the computer 3D model diagram. For all the alarm we can set up the linkage of the related equipment control to solve the problem.

Among them, in the warning strategy part, users can customize flexible alarm strategy. And the users can customize multiple alarm level according to actual needs, and each attribute of equipment can be defined alarm threshold, and each attribute of the alarm level can be defined multiple alarm level and the response after the alarm. This system support the short message alarm, phone alarm, email alarm and so on, the user can choose one alarm type, and can also choose more alarm type. When the alarm occurs, the system can make the short message, telephone, email and other forms of the police according to the warning strategy of the alarm form automatically.

In the alarm tracking section, when we get the alarm information, the user can get the equipment position quickly and accurately through the computer 3D figure of alarm, and track the alarm which occurs in the system interface automatically. This part mainly pay attention on the 3D model of how to locate the fault equipment position fast according to alarm information of the database which is sent from the system.

In the alarm linkage settings section, we can set up linkage control related equipment for all the alarm. The linkage content can be defined without any driving process, and this part adopt strategy configuration mode which we can realize the linkage settings of alarm freely through the graphical interface.

In the alarm information management part, it shows the alarms and warning level with different color in 3D model of equipment. And it support to query warning information in detail according to the level of alarm, alarm devices, alarm time. And it support to show the equipment parameters level warning positioning combined with the computer room management module in the equipment
management functions.

4.4 Remote Monitoring
The user can set the configuration parameters of equipments from remote monitoring terminal directly, and This module is mainly to realize the hardware instruction which involved in the intelligent modeling module and intelligent early warning module. At the same time, it will interact with the 3D system interface. For example, we can control the air conditioning equipment to transform running state, such as the adjustment of temperature and humidity [12]. Users can control the equipments of computer room in the form of sending command manually to realize the real-time controlling of the air volume, temperature and humidity parameters of air conditioning system for individual equipment cabinet and room in order to realize the precise air conditioning refrigeration [13].

5. System application

5.1 Environment Description
Weihai cloud computing center computer room is built according to the standard of national grade A. The total area of the room is about 1120 square meters, including nearly 400 high-performance server units and 21 PB storage, and for the moment more than 80 million has been invested. The main computer body is divided into three parts: UPS and power distribution cabinet room, IT equipment room and monitoring room, and the air conditioning is deployed as follows: there is one air condition in the UPS and distribution cabinet room, and there are three air conditions in the IT equipment room, and there is one air condition in the monitoring room.

5.2 Application Effect
This system was completed in January 2015, and deployed in Weihai cloud computing center computer room. And then we test the performance of the system for one year. The system shows the asset view, temperature cloud view, humidity cloud view and micro environment view using 3D virtual reality technology, and then we can we can adjust the air flow, temperature and humidity parameters of the air conditioning system for individual equipment cabinet and room to realize the precise air conditioning refrigeration. And the monitoring view of green computer room is shown in the Figure 2.

![Figure 2. The monitoring view of green computer room.](image)

In the 3D system interface of green room environment monitoring system, the first view at the top
is the view of current computer room equipment information. For example, this is the view of the air-conditioning equipment in this article, and when we click on the air conditioning equipment, the system will pop up the current selected air-conditioning equipment operation parameters through the three-dimensional model view of the relevant equipment information.

The second figure at the top is the temperature cloud view of the current room, the current system will collect temperature data of computer room which is used to map to the 3D model view, thus we can calculate the collected data according to the temperature collected, and display the current temperature cloud view according to corresponding color of the temperature scale.

The first figure below is the humidity cloud view of the current room, the current system will collect humidity data of computer room which is used to map to the 3D model view, thus we can calculate the collected data according to the humidity collected, and display the current humidity cloud view according to corresponding color of the humidity scale.

The second figure below is the humidity cloud view of the micro environmental temperature of the current cabinet. And each cabinet set 3 sites, then the temperature data of three layer system will be collected and mapped to the 3D model of the view, so we can calculate the collected data according to the temperature, and show the current micro environment temperature map according to corresponding color of the temperature scale. In this view, we can get each layer of the cabinet microenvironment information by changing the position.

In this paper, the data was compared in three years, and the specific data is shown (Table 1).

| Year | IT Equipment Power Consumption (KW) | Computer Room Total Power Consumption (KW) | PUE |
|------|-----------------------------------|--------------------------------------------|-----|
| 2013 | 71.83                             | 144.79                                     | 2.02|
| 2014 | 72.74                             | 143.21                                     | 1.96|
| 2015 | 72.78                             | 131.42                                     | 1.81|

PUE is the indicator of data center energy efficiency evaluation, and it is ratio of the all energy consumption of the data center and the all energy consumption of IT equipments. The closer the PUE value reach 1, the higher the green degree the data center is. Through the data in the table we can see that thought the ventilation floor was reconstructed in 2013, but the power consumption of IT equipment is 71.83 KW, and the total power consumption of the computer room is 144.79 KW, at this time the PUE value is 2.02, so we can learn that it looks quite bad on the energy saving effect of the room. And in 2014, we increased lots of the servers, thus the power consumption of IT equipment rise, and the total power consumption of machine room has also increased, and at this time the PUE value is 1.96. And in 2015, we deployed green computer room environment monitoring system in the computer room. Through the table, we can see that although we add some IT equipments, the computer room total power consumption room reduce obviously after deploying the system, especially the PUE value dropped to 1.81.

6. Conclusion
The energy saving measures which traditional rooms usually adopted is to choose low energy consumption equipment, select the appropriate power solutions and power supply equipment, choose energy-saving building materials and so on. In this paper, we monitor temperature and humidity of computer room environment through the Internet of things technology more than the traditional methods, and adjust the air flow, temperature and humidity parameters of the air conditioning system for individual equipment cabinet and room to realize the precise air conditioning refrigeration, thus we can greatly reduce energy consumption of air conditioning refrigeration, as a result, the overall energy consumption of computer room can also reduce to some extent, and the energy saving effect is obvious.
References

[1] Zhang, H.; Geng, D. Machine room monitoring system scheme and fitting technology. *Ningxia electric power*, 2010; pp.33-36.

[2] Chan, C. Computer room environment monitoring system based on Internet of things. *Nanjing university of posts and telecommunications*, 2014.

[3] Hou, L. Design and implementation of remote monitoring system based on the ZigBee wireless sensor network. *Journal of changchun college of engineering*, 2015; pp.32-35.

[4] Lu, J. Research and design of equipment room power remote monitoring system of environmental based on the ZigBee network telecom. *Taiyuan university of technology*, 2012.

[5] Cao, C. Analyses the present situation and the development tendency of the development of wireless communication technology. *The management informationization*, 2011; pp.128-129.

[6] Meng, Q. Design of comprehensive data center computer room environment monitoring system. *The data center system design*, 2011; pp.49-52.

[7] Gong, W. Design of the computer room environment monitoring system based on temperature and humidity. *Microcomputer Applications*, 2013; pp.17-18.

[8] Gong, W. Design of computer room environment monitoring system based on temperature and humidity. *Microcomputer application*, 2013.

[9] Chen, W. The design of the machine room monitoring system based on embedded Web server. *Central China normal university*, 2011.

[10] Yu, J. Research of remote machine room monitoring system based on ZigBee wireless sensor network. *Electronic Technology & Software Engineering*, 2013; pp.17-18.

[11] Li, S. Design and implementation of indoor harmful gas on-line monitoring system. *Journal of nanjing normal university*, 2012; pp.74-79.

[12] Zhang, H.; Geng, D. Machine room monitoring system scheme and fitting technology. *Ningxia electric power*, 2010; pp.33-36.

[13] Wu, Y.; Li, W. A kind of RTU based on Dual-MCU for monitoring remote pharos. *Intelligent Information Technology Application Workshops*, 2008; pp.741-743.