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Design and Implementation of an Intelligent Operation and Maintenance Management Cloud Platform for Green Buildings Group

Qu Chenfei[1,2,a], Wang Donglin[1,2], Liu Wenxia[1,2],and Zhao Pengcheng[1,2]

[1]Tianjin Architecture Design Institute, 300074 No. 95, Hexi District Meteorological Station Road, Tianjin
[2]Tianjin Intelligent Building Design and Operation Management Control Integrated Engineering Technology Center, 300074 No. 95, Hexi District Meteorological Station Road, Tianjin

[a] Corresponding author: chinaqchf@163.com

Abstract. In recent years, green buildings have developed rapidly in China, but there are still many problems in its operation and maintenance management, it is difficult to meet the requirements of green buildings' operation. In view of the complexity of space, function and management mode, the problem of the operation and maintenance management of green buildings is more prominent. An intelligent operation and maintenance management cloud platform for green buildings of group-company was designed and implemented based on IOT technology in this paper. The platform can significantly reduce the difficulty of the operation and maintenance management of green building groups and reduce the number of operation and maintenance personnel and energy consumption, and reduce operating costs.

1. Introduction

As more and more attention has been paid to the problems of climate, environment and energy, green building has become the focus of international development. The number of green buildings in China has increased rapidly since the green building evaluation and identification work was carried out in April 2008. National green building logo evaluation project has reached 4515 items as the end of September 2016, and the total green building area has reached 523 million m2. Urban development is undergoing a green ecological transformation. Large scale green buildings group will greatly reduce the consumption of buildings and become a new trend of urban construction. [1]

Operation and maintenance management includes two aspects of operation management and maintenance management. Operation management refers to increasing its utilization rate and reducing its operating cost in the whole life period of a building. Maintenance management means to prolong its use as far as possible. In recent years, the connotation of architectural operation and maintenance management has developed into a variety of means for comprehensive management of buildings, aims at providing standardized and personalized services for customers. The information and data of the estate management would be classified, summarized, analysed (qualitatively and quantitatively evaluated) and predicted at the same time.

In the practice of operation and maintenance management of green buildings, the professional and scope of management are more extensive and the content of management is more complex. The

original manual management mode or simple computer management mode has been unable to meet the requirements. There are many problems in the operation and maintenance management of green buildings in China, such as the lack of professional operation and maintenance management platform, lagging behind, extensive management, high maintenance cost and poor energy-saving effect. More than 80% of the energy efficiency of green buildings is not up to standard. This is also an important reason for the current domestic green building which is difficult to obtain the running logo. Many enterprise groups hold a number of regional and large-scale green buildings group, and their operation and management are divided into separate modes of operation and group management. This increases the difficulty of operation and maintenance management. [2]

In response to these problems, some domestic scholars, scientific research departments and enterprises have begun research and exploration in operation and maintenance management of green building and achieved certain results, bringing positive economic and social benefits to enterprises. [3] However, these explorations are more limited to the exploration of operation and maintenance management of single-building. There are no relevant research results and case for the complex situation of multi-space multi-purpose and multi-property of large-scale green buildings group.

The IOT is a highly integrated and comprehensive application of the new generation of information technology. It has the characteristics of strong penetration and rapid development of technology. We propose to operate green buildings group by internet, applying the IOT technology to the intelligent operation and maintenance control cloud platform to solve the problems of operation and maintenance management of green buildings group. The platform was designed and implemented in this paper including architecture design, functional design, and platform implementation and so on.

2. Architecture design

2.1. *Logic architecture design*
The cloud platform uses the fast developing Internet of things (IOT) technology, information technology (IT) and operation technology (OT). It can perceive, analyse and integrate the key information of the green building group, integrate and utilize all kinds of information and data resources to the maximum. [4] The logical structure of the platform is shown in Figure 1, which is composed of the perceptual layer, the transport layer, the data layer, the supporting layer and the application layer.
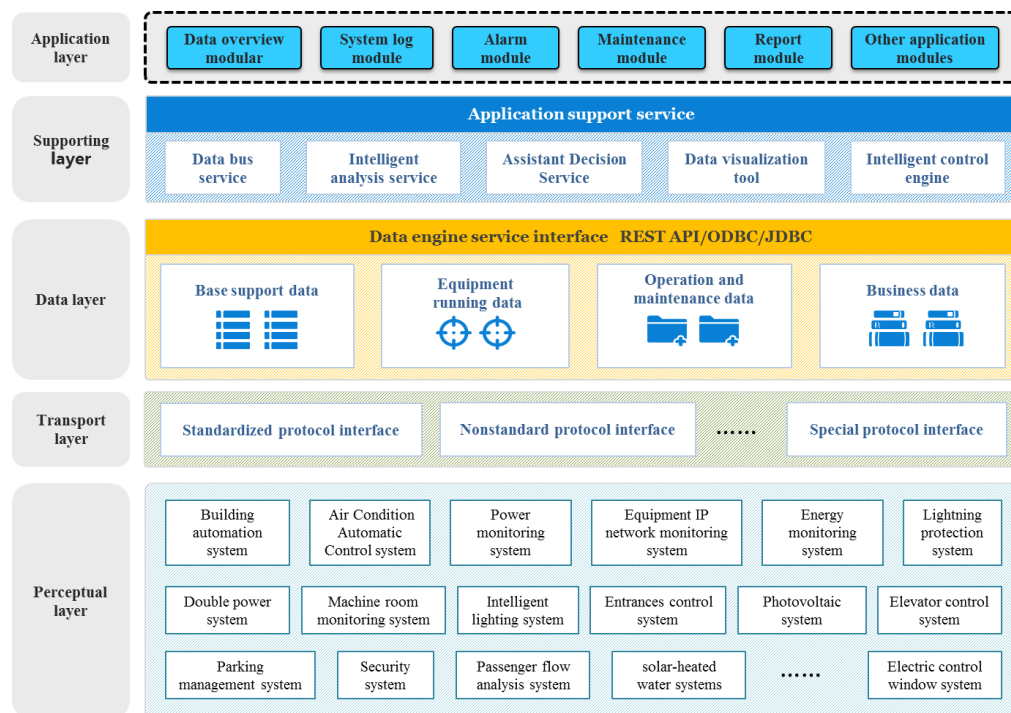
•Perceptual layer: The running images and data of green building (Group)can be collected through all kinds of sensors, meter and other special monitoring equipment, and then be passed through RFID, fieldbus, Zigbee, Bluetooth, infrared and other short distance transmission technology, through the network type equipment such as the field controller, gateway and so on to the network layer .

•Transport layer: In order to realize the communication and interconnection between the intelligent operation and maintenance management cloud platform and the system and equipment of the perceptual layer, the data transmission is carried out through the equipment special network, the wired network, the wireless network, the satellite network and so on. The transport layer has standardized protocol interface, non-standard protocol interface, and special protocol interface and so on. It can include real-time monitoring data interface, database interconnected data interface, video image data interface and other categories.

•Data layer: It includes basic support data, equipment operation data, operation and maintenance data, business data, etc., mainly based on structured data. It provides storage and computing services for other layers through the data engine service interface.

•Supporting layer: It provides data bus service, intelligent analysis service, assistant decision service, data visualization service and so on.

•Application layer: It provides the terminal users with the business processing module oriented to the intelligent operation and maintenance management of green buildings group, including the data overview module, the system log module, the property management module, the maintenance management module, the report management module and so on.
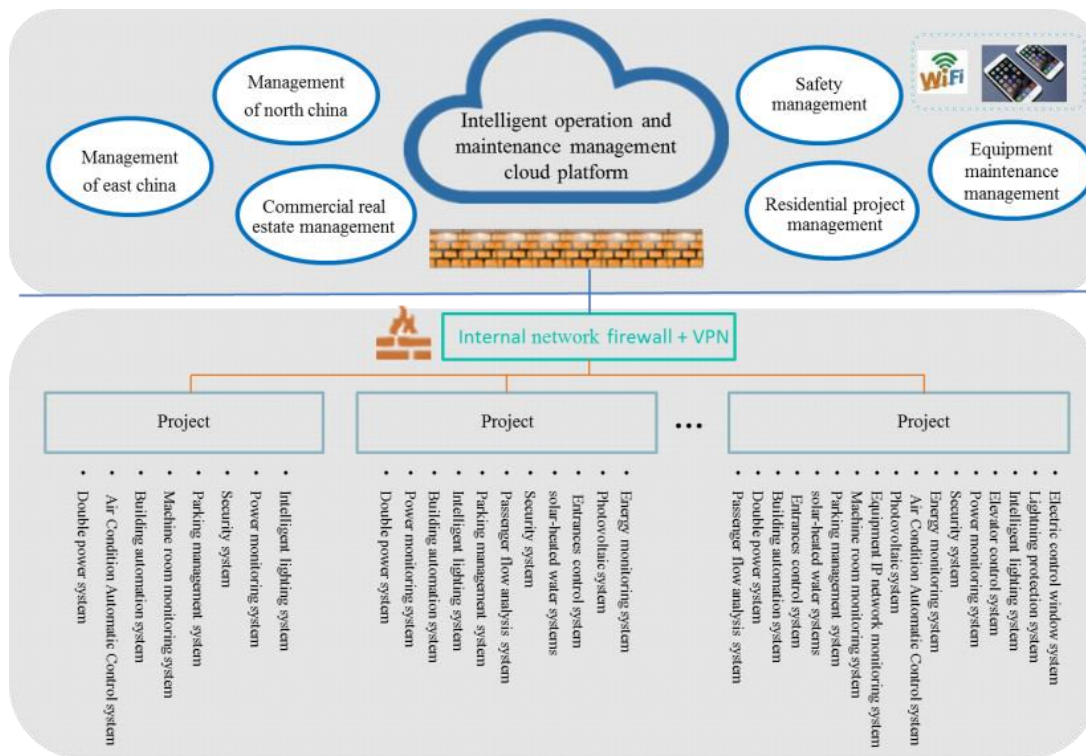
Figure 1. Logical architecture diagram of intelligent operation and maintenance management cloud platform.

2.2. *Physical architecture design*

Considering the operation and maintenance management is divided into management of a single building and unified management of the group, this platform can be implemented on two level platforms, with horizontal and vertical multidimensional management. Each project unified the data to the group intelligence operation and maintenance management cloud platform. Data storage, backup and big data analyses are carried out by group cloud platform, so that all projects can be managed uniformly, as shown in Figure 2.

The intelligent operation and maintenance management platform of each project adopts local deployment. The system and equipment of the project are connected to the platform through real-time monitoring data interface, database interconnection data interface, video and image data interface. Video and data are collected, analysed, transmitted and processed, and the optimal control and decision of the project is realized. The core data of project energy, security, equipment maintenance and operation can be transmitted to the group cloud platform through interface at the same time.

The group intelligent operation and maintenance management cloud platform can choose the mode of public cloud or private cloud deployment according to the actual requirements and conditions of the project, so as to realize the flexible deployment and application of the platform. We can manage massive project data relying on cloud platform's good data processing and analysis ability. We can expand the cloud service resources according to the project construction situation. [5] The group cloud platform uses modular service architecture to provide customized services for different managers in different dimensions, such as regional and vertical (such as the architectural use, management content).

Figure 2. Physical architecture diagram of intelligent operation and maintenance management cloud platform.

3. Functional design

From the view of the service content of the intelligent transportation management of green buildings group, it is not only limited to security, cleaning, warranty and so on, but the comprehensive promotion of the traditional property management service, realizing operation and maintenance digitalization, scientific management and intelligent experience. The platform can ensure the green building mechanical and electrical equipment, power supply water supply, and public facilities and so on are in good working condition. In all circumstances, it can respond accurately, reliably and quickly to deal with and coordinate the work of each system in time, so as to save energy, save people and increase efficiency.

The intelligent operation and maintenance management (cloud) platform can monitor each subsystem, can realize energy management, alarm management, equipment maintenance management, support running log, evaluation analysis, strategy optimization, pattern management, system calendar, report query, user management, lookup management and so on. The specific functions are shown in Figure 3. The intelligent operation and maintenance management cloud platform has a complete user management scheme, which can be customized to generate user pages according to the different dimensions, such as the region and the vertical (such as the architectural use, the management content), according to the user's role and user information. The main functions of the cloud platform for intelligent operation and maintenance management are as follows:

  • System monitoring: with a rich graphical function, the state of the device can be monitored in a graphical software interface. All systems and devices can be controlled by mode control or manual control.

  • Energy management: energy utilization can be displayed in line with line drawings, bar charts, pie charts, energy efficiency labels, data tables, etc. And the platform can carry out trend tracking analysis of key energy consumption and primary energy consumption, and conduct abnormal energy consumption alarm.

•Alarm management: the platform can timely display the fault alarm system, equipment, location, type, level and other information on the monitoring interface when the alarm occurs, and it support the alarm definition, historical alarm query and SMS alarm.

•Maintenance information: the platform can provide the first hand maintenance data for equipment management, mainly including equipment accounts, maintenance management (for example: fault maintenance management, preventive maintenance plan management), work sheet management (for example: the implementation of the work list, the plan of the work list, the record of maintenance), spare parts management and so on.

•Running log: the platform can record the running state information of each intelligent subsystem, record the operation information of the system (such as editing user, defining authority, making mode, switching mode and so on), record equipment control instructions and feedback (such as starting and stopping equipment, modifying equipment running parameter settings, etc.).

•Evaluation and analysis: the platform can dynamically evaluate the performance of the building according to the dynamic changes of the operating performance of the building, and evaluate the performance of the indicators of the green building dynamically, and carry out the evaluation results.

•Strategy Optimization: the platform can combine the system monitoring and evaluation analysis results to realize the dynamic adjustment of the building operation performance, and finally realize the dynamic balance between the building operation cost and the building environment quality,
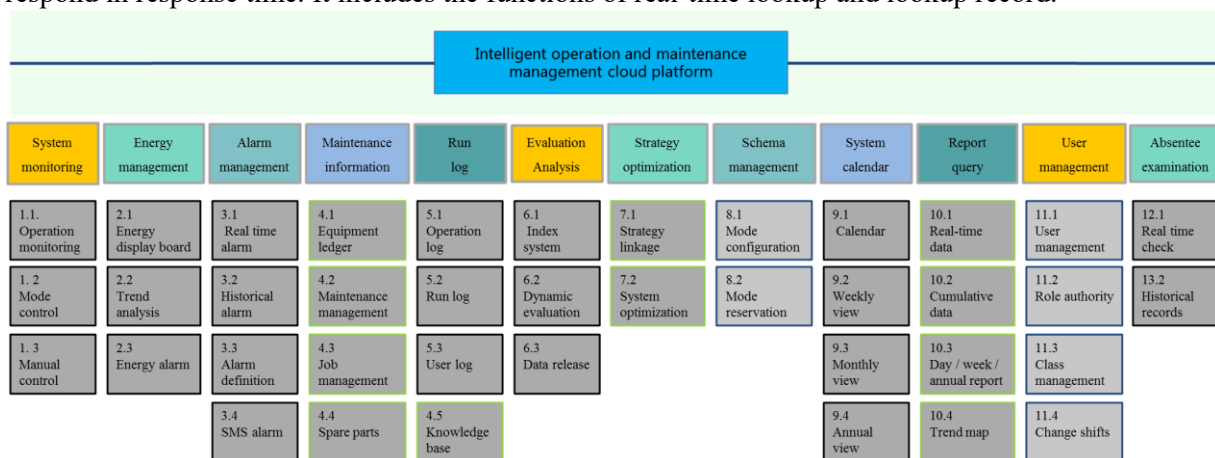
•Mode management: the platform has the function of global one key mode management (manual switching, automatic switching), and the function of mode adding, editing, deleting, batch uploading, batch export and so on.

•System calendar: through the platform, we can presupposition and view the schedule of each subsystem running control mode.

•Report query: the platform is rich in data analysis function, and it is presented to users in the form of various reports. For example, real time data curve, historical data curve, daily weekly monthly report, trend chart, etc.

•User management: the platform can set users according to different categories and roles and give different privileges to realize different categories, roles and users' differential operation to the system, and support class management and handover class management.

•Check Gang: users of group cloud platform can test the operation and maintenance personnel on the platform through the platform, and the operation and maintenance personnel of each project should respond in response time. It includes the functions of real-time lookup and lookup record.

Figure 3. Function diagram of intelligent operation and maintenance management cloud platform.
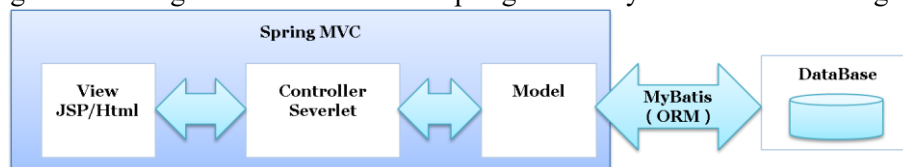
4. Platform implementation

4.1. *Technical method*

JavaEE technology architecture and SQL Server database are used in this project. Internet technologies, internet of things technology, web technology are comprehensive used to develop the platform. The following technologies are adopted in the platform:

•Java language which is cross-platform and open was used to code based on the Eclipse (an integrated development environment).

•SQL Server databases was used in data storage based on structured data storage. MyBatis which is a Java-based persistence layer framework was used in the data access layer, saving a lot of work on JDBC code writing and result set retrieval. Writing SQL statements in XML files makes the system more flexible and easy to be maintained.

• The platform was implemented based on the B/S architecture. The popular SpringMVC framework was adopted which reduces the coupling between business logic and interface presentation. The same data can be displayed in different forms to meet the individual needs of different customers. As a lightweight IoC container, Spring reduces the coupling between invocation classes and implementation classes of various service, making business logic implementations more flexible and easy to be maintained, and enabling different developers to make a reasonable division of work based on their strengths. The integration architecture of SpringMVC+MyBatis is shown in Figure 4.

Figure 4. The integration architecture of SpringMVC+MyBatis.

•The response of the platform to the client's Http request comply with the REST style, so that the same data can be added, deleted, updated and selected by the same controller, making the web service lighter.

•In order to meet the individual needs of different customers, a large number of versatile user interface controls that can be configured and expanded, such as general lists, general forms, and general charts were used in cloud platform development. We can flexibly configure according to meet customer's needs, getting different presentation forms, making the platform more expressive.

4.2. *Case of engineering implementation*

A green buildings group consists of six green building units: science and technology museum, art museum, library, performing arts center, civic activity center, cultural corridor and underground parking lot. Each unit is operated independently and managed by a group. The control-center has the authority to manage all spaces, systems, and functions. Others such as sub-control-center, leadership management terminals, employee service terminals, merchant login terminals, display terminals, alarm front-ends and so on will be assigned different management and query modules according to different permissions, realizing horizontal and vertical multidimensional management of all green building units. The platform is shown in Figure 5.

Figure 5. The intelligent operation and maintenance management cloud platform.

The platform can realize centralized monitoring, rapid response, linkage control and global event management of intelligent system data, and can easily complete energy efficiency analysis, energy efficiency benchmark, energy consumption statistics, energy efficiency ranking and high-energy alarm. It supports equipment file, multi-level alarm management, fault management, preventive maintenance, work order management, operation log, shift management, check and other functions. Part of the platform page is shown in Figure 6-9.

Figure 6. The homepage of the platform.

Figure 7. The system monitoring page of the platform.

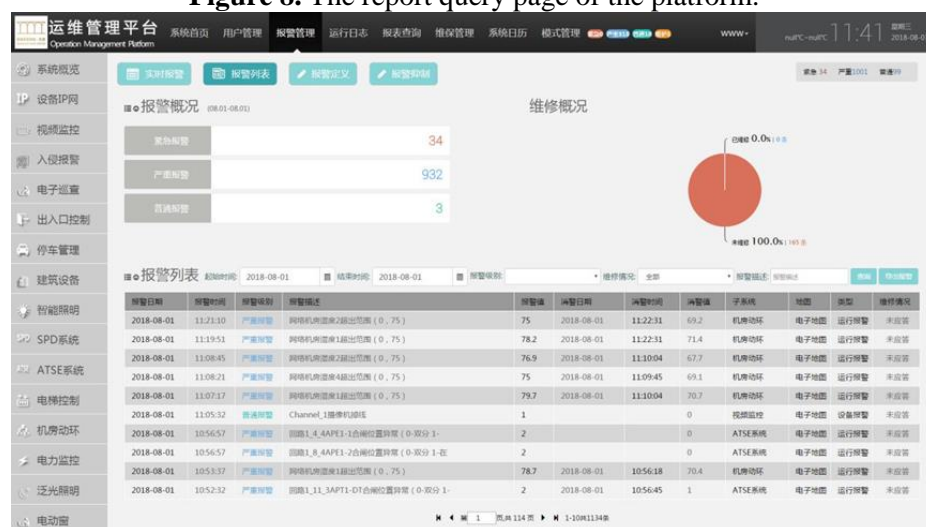**Figure 8.** The report query page of the platform.

Figure 9. The alarm management page of the platform.

The platform was completed and put into use in 2017, and it has been in operation for almost a year. It can be seen from Tables 1 and 2 that the use of the project through the platform (including a total of 6 monomers) can save personnel costs of about 3.8 million yuan per year. According to the National Building Energy Standard, the project is located in severe cold and cold areas. The underground area is about 110,000 m2 (the energy consumption guiding index is about 12 kWh/m2*a), and the above ground area is about 200,000 m2 (the energy consumption guiding index is about 120 kWh/m2*a). The annual energy consumption is estimated to be 25.32 million kWh, and the annual energy consumption during the actual operation is about 18.9 million kWh, which can save energy costs of about 6.42 million yuan per year. It can be seen that the equipment maintenance cost reduced by the platform is still not counted, and the annual operation and maintenance cost of the project can be saved by about 10.22 million yuan.

Table1. Regular Property Watch Staff Table (taking one building block as an example).

	Duty room	Duty time	Duty people	Number of people
1	Fire control room	24h	Three shifts, 2 people/shift	6
2	Security control room	24h	Monday to Friday 8:30~:17:30	6
3	Substation	24h	Three shifts, 2 people/shift	6
4	Plumbing maintenance personnel	12h	7:00~19:00, One person on duty, two people for repair	3
5	Electrical maintenance staff	12h	7:00~19:00，One person on duty, two people for repair (Maintenance personnel share with the cooling room)	3
6	Other auxiliary maintenance personnel	8h		2
7		Total people		26

Table2. Property watch staff table after set up a unified operation and maintenance management platform (taking one building block as an example).

	Duty room	Duty time	Duty people	Number of people
1	Security control room	24h	Three shifts, 2 people/shift	6
2	Plumbing maintenance personnel	12h	7:00~19:00，One person on duty, two people for repair	3
3	Electrical maintenance staff	12h	7:00~19:00，One person on duty, two people for repair (Maintenance personnel share with the cooling room)	3
4	Other auxiliary maintenance personnel	8h		2
5		Total people		14

5. Platform implementation

Green buildings have been widely accepted. Large-scale green buildings which can significantly reduce the consumption of resources become a new trend in urban construction. Traditional operation and maintenance management mode has been unable to meet the requirements of current green building operation and maintenance and there are many problems. The IOT is a highly integrated and comprehensive application of the new generation of information technology. It has the characteristics of strong penetration and rapid development of technology. We propose to operate green buildings by internet. Aiming at the grouping and unified management in green buildings, the two-level platform construction is proposed, and the platform development ideas of horizontal and vertical multi-

dimensional management are carried out, and platform development and project application are carried out. Practice has shown that the intelligent operation and maintenance control cloud platform of green building groups through IOT technology can reduce operation and maintenance personnel, reduce building energy consumption, extend equipment service life, and reduce construction operation expenses.

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