An Exploration of System Architecture on Integrating Building Management System in High-Rise Building

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***Abstract*—High-rise building is bloomed into market with a series of evolved requirements. Recently, it is of great interest to adopt the Integrating Building Management System (IBMS) in high-rise buildings. However, the current IBMS architecture solution is far from the satisfaction of performance in integrating level. In the past decade, various system integrations and collaboration technologies have been developed and deployed to application domains. In this paper, we address system sensitive problems and architecture bottlenecks by observing current architectures. We provide a generic set of solutions to support the data access flow, use of information, business systems and collaborative creation. This paper presents a typical scenario for potential system architecture in high-rise building.**

Keywords-Building Management System; Integration; High-Rise Building; System Architecture;

I. INTRODUCTION

In recent years, energy costs and finite energy resource increased energy demand. At the same time, the concerns about global warming have collectively contributed to a global push for energy conservation. Modern commercial buildings have become prime targets for energy efficiency research. Improving energy efficiency in buildings has emerged as an important research area. Commercial building energy already consumes 35% of the total US electricity consumption and is estimated to rise even more[1]. This expenditure constitutes 28% energy usage in residential and 12-13% in commercial buildings. Better understanding of the building processes and designing smarter building management systems that can both maintain occupant comfort while reducing energy consumption and lead to large improvements in building operation[2].

The advent of wireless sensors has enabled buildings to be retrofit for improved monitoring of building processes and energy consumption information. This has led to several "green-building" applications such as occupancy detection[3], plug-load energy metering[4], load-disambiguation[5][6], lighting control[7], and fine-grained HVAC control[8][3]. These sensor-based applications however generate an immense amount of data. Combined with existing building control systems (such as those that run the HVAC), a significant amount of data is being generated. Unfortunately, each of these systems is closed off from each other, and thus the potential for truly interesting data analysis or control applications is lost. In fact, for many industrial systems, the data is not only inaccessible; many times it is simply thrown away.

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Therefore, developing a platform to allow for applications that can span across the multiple systems that monitor and control the building environment can potentially lead to a much deeper understanding of building operations. In terms of high-rise building, as the dimension of distance and time increased, the demand and performance requirement to the building system is increased at the same time. But the lack of a structured and unifying view over the system architecture and component distribution was the main obstacle to undertaking the system design and deployment. Thus, we specifically focus on the underlying architecture and technique in order to achieve the need for performance and scalability.

In this paper, a discovery and analysis of the state-of-art in IBMS solutions is presented. At the same time, we conducted a series of onsite investigations for system architecture usage. It is envisaged that this research will give the readers insights into the critical concepts and issues for consideration in designing the systems in this area.

The remainder of this paper is organized as follows. Section 2 provides a brief introduction and situation summary about IBMS usage in our investigation building. Section 3 offers a detail discussion of IBMS and provides a generic architecture for such systems. Section 4 focuses on the challenges yet to be addressed in high-rise building system including requirements and quality attributes. Section 5 presents our preliminary 4-layers architecture of IBMS.

II. PRODUCTION REVIEW AND ONSITE INVESTIGATION

A. Production Review

We conducted a comparative study on these peer solutions from applications, protocols and architecture based on literature survey. Findings are as follows: 1) Multiple-Layered Architectures are well adopted; 2) Layering strategies may be influenced by product strengths of the provider; 3) Solutions share similar applications but with different focuses; 4) BACNet and Modbus are well supported. Current existing building management systems however greatly limit analysis and innovation potential.

These systems do not usually prioritize storing this data, and thus most of it is simply lost. These systems also tend to be independent from one another. This limits the amount of innovation that can be applied since each system only has information from its own network, and thus control algorithms tend to be simplistic. Typically, data storage and aggregation architecture are different between deployments, and account on a data server to store and later access the sensor data.

B. Onsite Investigation

We have visited a series of modern buildings to identify critical issues of the integration and collect demands from different stakeholders. And we select 4 buildings to present details of system. Brief information of these buildings has listed in Table I. We conducted the summary from 4 aspects: key features, application focus, integration level and limitations as follows. In most of these buildings, limitations and weakness are observed in the current interaction styles used for data and service integration.

C. Conclusion

Based on literature survey and onsite investigation, we have discovered that current solutions are integrated in application layer, which caused limitations and weakness. To consider challenges for high-rise buildings, IBMS performance may suffer from high data sharing demands, such as frequent data acquisition, limitation of communication capability and connection channels, high data exchanging rates across applications and so on. Additional software utilities are needed for the data integration.

III. Challenges in High-Rise Buildings

A. Generic Architecture

Prior to discussing improvements in IBMS in detail, it is instructive to consider BMS in terms of their popular constituent components. A generic architecture for building management systems is presented in Fig. 1. Conceptually, it can be considered consisting three key Layers.

(1) Sensor Layer: Buildings, and the electrical devices and appliances within them, are monitored by a sensor configuration that collects data and parameters.

(2) Computation Layer: Information regarding energy wastage, control and recommendations is then generated by an appropriate combination of algorithmic calculations and statistical analysis.

(3) Application Layer: This layer can be further categorized into two application sub-categories: appliance control and the provision of user feedback across a range of modalities. Implicit within this layer is a management component allowing for system testing and maintenance activities.

B. Architecture Analysis

In order to help the readers get a better understanding of the system analysis, we summarized architecture quality attributes.

TABLE I. Feature Comparison of buildings

Building ID	Key Features	Applications Focus	Integration Level
A 3 floors office	Solar energy system Fire detection system	Generate electricity Connect with Parking system by hardware	Data level
B 16 floors office	Access control system	Check work attendance	
C 32 floors 14 elevators office and classroom	Security system Elevator system	use infrared detection and dynamic cameras display real-time elevator for detection	Data level Service level
E 42 floors 6 elecator hotel	Intelligent elevator dispatching	Integration with smart video engine	Data level Service level

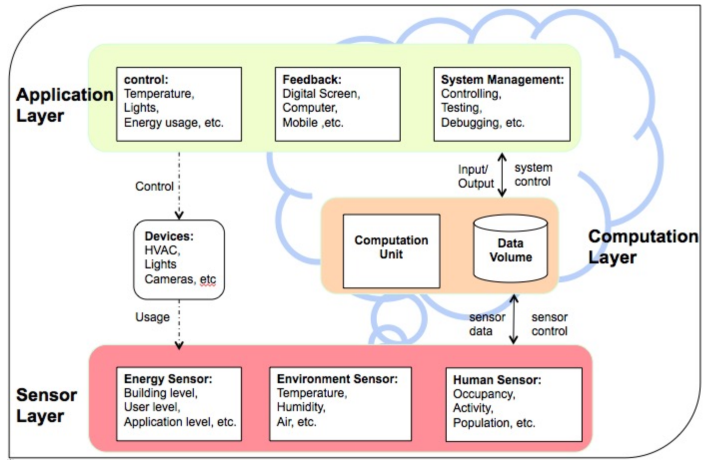

Figure 1. Generic Architecture Layers

This helps us make a profound glimpse in architecture analysis. Secondly, we discovered the potential performance bottleneck evolved if system architecture was applied to high-rise building. All the work above guide us to present an architecture design scenario specific for high-rise building system .

1) Quality attributes: The quality that must be ensured as part of the integration is an important criterion, as well as in high-rise building consideration. Below we identify the quality attributes that we have observed as being the most important and common in architecture integration patterns, especially which being neglected in building requirement considerations. Interoperability assures the connectivity and information interchange among systems. It concerns technology and engineering challenges related to communication, data management. Scalability requires that the integration is scalable across large numbers of systems. Thus, the integration will work correctly if more different systems are integrated.

2) Sensitive points and bottlenecks: In terms of business process analysis, the key problem about the system is reliance on central control in the computational layer. This leads to the constraint that changes in the application functions that affect one step might require changes in the whole process.

The system lacks data level integration. Each application in application layer requests data from the central data storage. The impact of data sharing limitation could dispread when more applications trying to request data from data center.

IV. Architecture Specification

After the architecture analysis in the previous section, we could discover a point that the improved architecture should be data-centric and system-friendly. The integration architecture should satisfy the quality attributes especially performance and interoperability. In this section, we will present our integration architecture scenario.

A. Architecture Description

We find out the current solution for architecture design and system application usage has a great limitation and bottleneck in high-rise building. In IBMS, it requires a high quality for

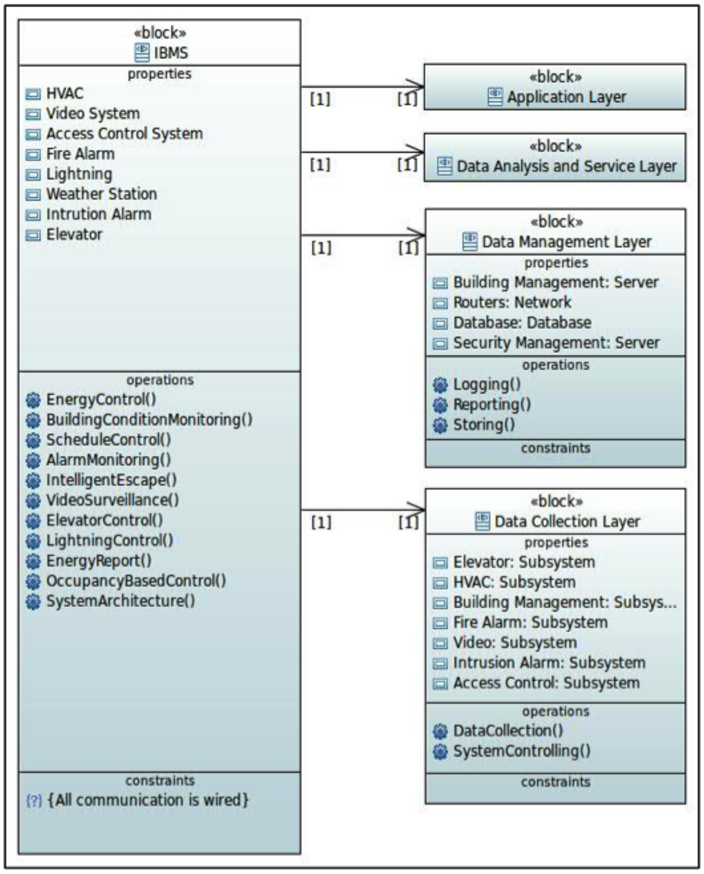

Figure 2. Four Layers of Integration System

system and architecture. Considering the huge amount of data in high-rise building and weakness in current situation, we could foresee the performance would be below the average expectations. So we propose our suggestions in this section especially for the architecture optimization. The architecture and system component is shown in Fig. 2.

- Data collection layer: it collects data from subsystems, for example elevator subsystem, HVAC subsystem and fire alarm subsystem etc.
- Data management layer: it is central storage and management point in the architecture. It takes control on how to store history data and how long the data stored in the database.
- Data analysis and service layer: it provides various service interfaces for applications. In this layer, data mining and information intelligent technology is proposed to data analysis.
- Application layer: it provides user interface for the user. And in this layer the system and program is transparent to the user. This layer integrates different systems and provides system level collaboration.

B. Architecture Improvements

We listed three main improvements respectively in different levels.

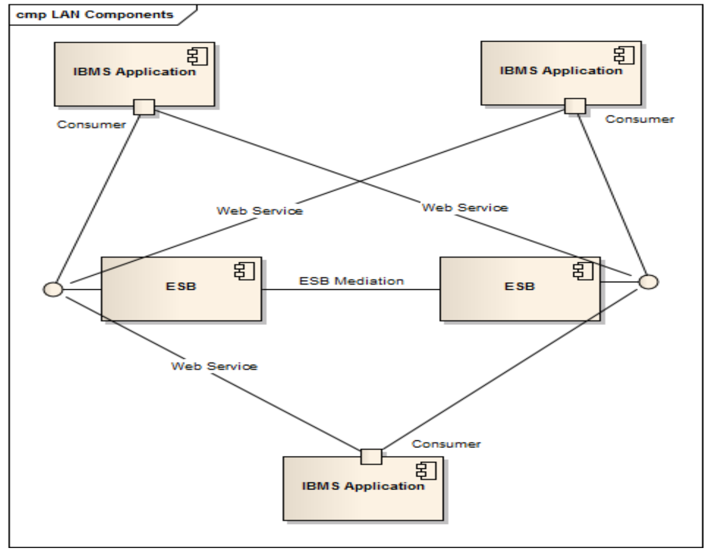

Figure 3. Middleware or ESB component for third party system integration

1. Data level: In high-rise building, the data storage and data transferring are the sensitive points in the system. The performance of them affects the whole integration system seriously. We propose a data-sharing platform. In the platform, we provide a series of data translating utilities. Meanwhile, we build data integration layer. In the integration layer, the system provides data sharing services for data reuse and data encapsulation. Integration in data level optimizes the performance in data transferring and requesting.

2. Application level: In high-rise building, there is a huge demand in application level integration, as well as application collaboration with third party system. The convention collaboration method is providing web service by using XML. To avoid this limitation, the generic architecture designs an enterprise collaboration platform. Event-driven component based architecture could be an option for the system optimization as well as applying service bus in the architecture. The platform provides service reuse and interfaces for third party system integration. The suggestion of component architecture with ESB or Middleware is shown in Fig. 3.

3. System level: This section describes the usability of system level. In the integration system, there should be some utilities and tools for the troubleshooting and debugging work in system. In case the system breaks down, the system should alert the detail information about reasons and point out the reliable solutions. Also, the system should have a surveillance tool on data transferring and correctness about data.

V. Conclusion and Future Work

A. Achievements

This study identified problems and opportunities in the design, construction and operation of IBMS for high-rise buildings. We have designed questionnaires and conducted five onsite investigations to discover the real situation of IBMS. We have studied integration-centric demands, challenges, constraints, environments, contexts and potential patterns. And based on the survey results, we have finished architectural analysis and system modeling to understand architectural issues further.

1) Key Findings: With the study of common applications, networking environment, typical solutions and emerging technologies in IBMS, we have discovered:

- Data conversion and Entity/Object/Device mapping in IBMS for high-rise building need enhancement in system architecture.
- high-rise building IBMS performance may suffer from high data sharing demands; additional software utilities are needed for the data integration.
- Emerging application based on IBMS solution is usually data-centric and event-driven, which should use suitable architectural styles and patterns.
- Demands on cloud platform and intelligent data processing frameworks are strong.

2) Major Outcomes: In this study, we have proposed a four-layered generic architecture as a basis for architectural analysis of high-rise building IBMS, identified quality attributes for IBMS and conducted quality analysis to understand IBMS architecture decision space, analyzed potential adoption of additional platform, service bus, middleware and components to improve integration quality for high-rise building, performed detailed data flow analysis to understand the architectural weakness of one specific use case, and finally explored IBMS architecture decision space from the system level.

B. Future Work

In the next phase of the research,we will make a deeper research on the data flow analysis. We will pick up some practical use cases in system, having a more specific data flow analysis in data collecting and data transferring. Meanwhile, we will explore the brand-new market thus develop some applications with user interaction data.

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