Design of a Web-based Building Management System using Ajax and Web Services

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Abstract-As a new generation of Internet communication technologies, Web Services are becoming an increasingly popular middleware technology used to integrate heterogeneous building automation system (BAS) on the Internet. Ajax technology, with which web applications can retrieve data from the server asynchronously in the background without interfering with the display and behavior of the existing page, has gained popularity recently. The article aims to present a web-based building management system (BMS) based on Ajax and Web Services for realizing real-time monitoring and control of BAS on the Internet. The BMS is applied to a BAS within a BACnet network. Some public Web Services methods, which can read and write BACnet data points from the BACnet network, are developed based on a BACnet protocol stack. These Web Services methods can be invoked by other applications to realize BAS integration and interoperation with enterprise applications on the Internet. By invoking the Web Services to get real-time data in the BACnet network, Ajax, which can provide a rich-client browser application, is adopted to design the web GUIs of the BMS.

Keywords-Building management system; Building automation system; Web Services; Ajax

I. INTRODUCTION

With the development of computer technology, digital communication technology and control technology, building automation systems (BAS) industry has got great success in past two decades. But nowadays most BASs are isolated islands of information; it is difficult to realize the integration between BASs and existing enterprise applications. At the same time there are several standard international protocols in BAS industry; so it is also difficult to realize the integration among BASs which adopt different communication protocols. Web Services which are emerging IT technologies give us a new way to solve the above problems. Recently, international scholars have paid more and more attentions to BAS integration based on Web Services. In 2006, Wang proposed a framework combining OPC (OLE for Process control) and Web Services to ingrate data and services of BAS on the Internet [1].In 2007, Neugschwandtner discussed oBIX, a new standard for representing and accessing BAS data via Web Services [2]. In 2008, Malatras presented a service-oriented architecture for building services integration based on Web Services [3].

In intelligent buildings, building managements systems (BMS) are used to monitor and control building facilities in BASs. Web-based BMSs have been developed and tested in BAS domain [4-6]. However, conventional web-based applications require the user to submit a request to the server, wait for the server to process the request and generate a response, and then wait for the browser to update the interface with the results. This request-wait-response-wait pattern is extremely disruptive and lowers productivity. Asynchronous JavaScript and XML (Ajax) is a standards-based programming technique designed to make web-based applications more responsive, interactive, and customizable—in short, to recreate the seamless user experience of most other desktop applications.

In the paper, Web Services and Ajax are used to develop a new generation of BMSs. Web Services support Extensible Markup Language (XML) message-centric approach, allowing us to build loosely coupled and highly distributed systems on the Internet, such as BASs. Ajax uses HTTP-based XmlHttpRequest protocol for the message transfer. Since Ajax and Web Services are XML-based structure, they can leverage each others strength. This enables application developers to easily integrate Ajax based browser applications into Web Services.

The proposed BMS is applied to an intelligent building whose BAS is within a BACnet network. A set of Web Services methods, which can read and write BACnet data points from the BACnet network, are developed based on a BACnet protocol stack. These Web Services methods can be invoked by Ajax easily. Ajax technology, which can provide a rich-client browser application, is adopted to design the web GUIs of the BMS.

The rest of the paper is organized as follows: Section 2 presents the description of the architecture of BAS integration based on Web Services. Section 3 describes the development of web-based BMS using Ajax and Web Services. Furthermore, the application of the BMS is presented. Finally, conclusions are presented in Section 4.

II. WEB SERVICES FOR BAS INTEGRATION

A. Principle of Web Services

Web Services are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web. The main objective of Web Services is to build a technical layer which is independent of platforms and programming languages in existing heterogeneous configuration platforms, depending on the technical layer the applications of these different platforms

can implement the interlink age and integration between each other.

Compared with traditional Web application technologies, Web Services are intended to be used by other programs or applications, not by a human user. It is a network accessible interface to application functionality, built using standard Internet technologies. It acts as an abstraction layer, separating the platform and programming language specific details form how the application code is invoked.

Web Services are based on a "Service-oriented" architecture. Three distinct roles are present in the architecture: Service Provider, Service Requester and Service Broker (Figure 1).

The Service Provider is the owner of the service. From an architectural perspective, this is the platform that hosts access to the service. It is responsible for creating, publishing, and providing the service.

The Service Requester is the party that requires certain functions to be satisfied. From an architectural perspective, this is the application that is looking for and invoking or initiating an interaction with a service.

The Service Broker is a searchable registry and is responsible for advertising service. Most services registries provide classification schemes allowing users to look up services. Some registries even provide a set of APIs for programming access. Service requestors can find needed services and obtain binding information from the service descriptions either at development time or run-time.
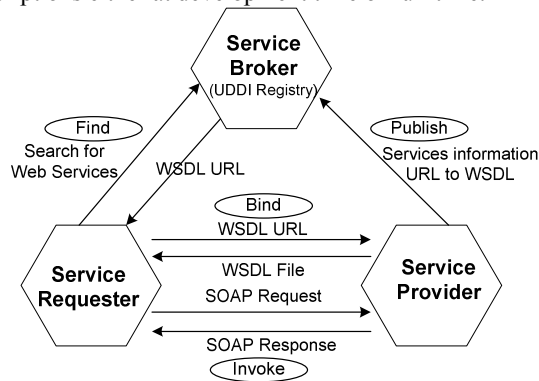

Figure 1. Web Services architecture

B. Web Services-based architecture for BAS Integration

Figure 2 gives a sketch map of BAS integration based on Web Services. The sketch map includes three types of integration. The first is the integration between building automation systems and existing enterprise applications. The second is the integration among BASs which adopt different protocols (e.g. BACnet, Lontalk or KNX). The third is the integration of different functional BAS subsystems (e.g. HVAC system, fire alarming system, light system and so on). Web Services can be installed in the controllers which have strong network control functions. In mini field-bus controllers or sensors, we can still use standardized communication protocols (e.g. BACnet, LonTalk or KNX). BAS based on Web Services is not to replace the standardized protocols which have been widely used in field

bus networks. However it adopts most of existing filed bus networks and standardized communication protocols to realize higher level integration than ever.
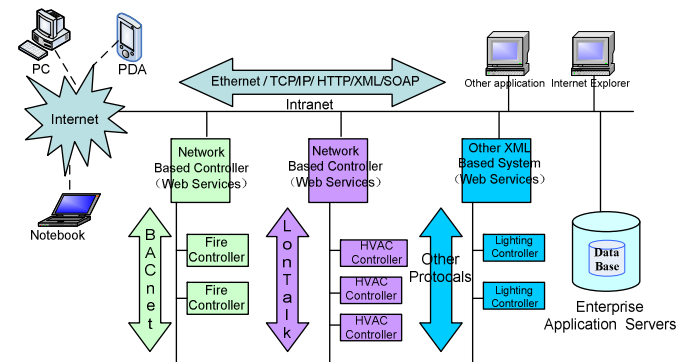

Figure 2. Sketch map of BAS Integration based on Web Services

Figure 3 illustrates the software architecture for BAS integration. BMS functional components resort to protocol drivers to communicate with field equipments in the field bus networks, realizing real-time data access, historical data access and alarms and events process functions. These functions are wrapped with public Web Services methods. Here the web server is not mainly for web page storage and access. Instead, it is used for HTTP protocol parser since the transportation method for Web Services adopted here is the HTTP protocol. It is responsible for parsing the Web Services request from HTTP messages and forwarding the request to the Web Services applications.
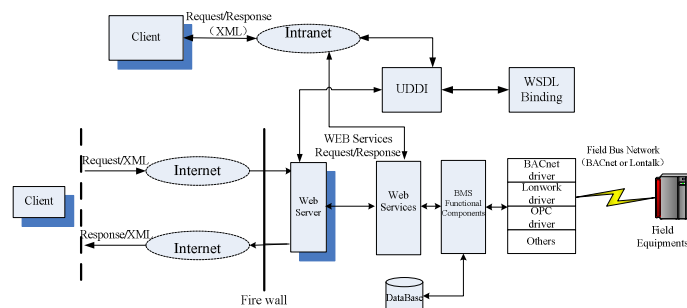

Figure 3. Web Services-based software architecture for BAS integration

These public Web services methods are designed to make it easy for other applications to access data in BASs on the Internet. The data model is intentionally designed to be generic, allowing Web Services to be used with a wide variety of data sources, including control systems that do not communicate using the same protocol. The data access services are also generic, allowing the Web services client to read and write simple data values (integers, real numbers, strings, dates, etc.).

III. DESIGN OF WEB-BASED BMS USING AJAX AND WEB SERVICES

A. A brief description of Ajax

Ajax is the shorthand for Asynchronous JavaScript and XML. That is a web development technique for creating interactive web applications. Ajax use JavaScript to construct the XmlHttpRequest object to communicate with server components asynchronously and update the source of HTML page based on the resulting XML/Text response dynamically. Web communication based on Ajax is different from traditional web communication model (Figure 4). In traditional web communication model, the client sends the request to web server, and the server returns the response to browser one by one. On the other hand, Ajax-based Web applications make web pages more responsive by exchanging small amounts of data with the server behind the scenes, so that the entire web page does not have to be reloaded in each time when the user makes a change.

Ajax incorporates the following features:

- Standards-based presentation using Extensible Hypertext Markup Language (XHTML) and Cascading Style Sheets (CSS);
- Dynamic display and interaction using the Document Object Model (DCOM);
- Data interchange and manipulation using Extensible Markup Language (XML) and Extensible Style sheet Language Transformation (XSLT);
- Asynchronous data retrieval using XmlHttpRequest;
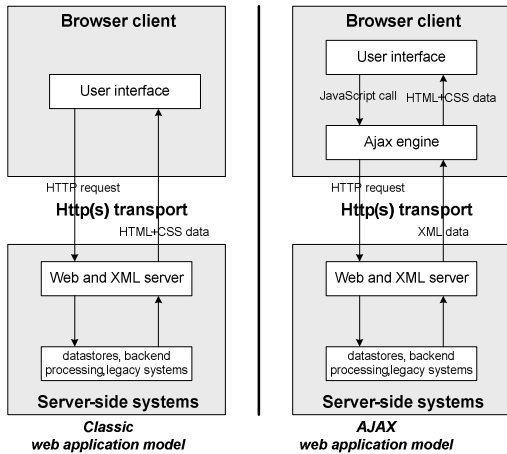- JavaScript to bind everything together.

Figure 4. Comparison between classic web application model and Ajax web application model

B. Invoking Web Services with Ajax applications

Figure 5 shows the architecture of invoking BAS Web Services with Ajax application, it is also the architecture for realizing web-based BMS based on Ajax and Web Services.

In the figure, the browser makes a request to the Service Broker, which in turn makes a request to the Web Services by using web services client stubs. The response from the

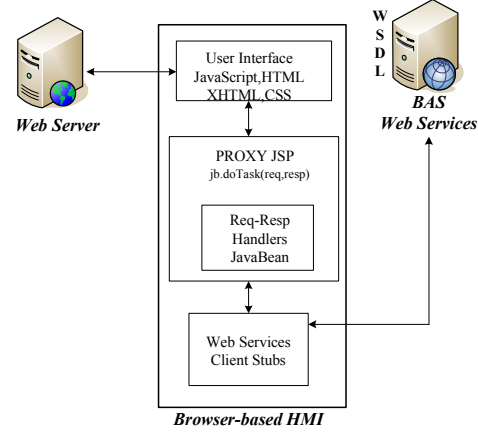Web Services is then transformed by the Service Broker, and presented to the browser.

Figure 5. Architecture for Invoking BAS Web Services with Ajax applications

Proxy.jsp includes an intermediary server page to capture request (HttpServletRequest) and response (HttpServletResponse) objects coming from the first page via XmlHttpRequest protocol. The first page includes some JavaScript, XHTML, CSS and JSP to capture the user given parameters ("req" and "resp" parameters) and to display the return result on the screen.

"jp.doTask" is a java class object which handles creating appropriate requests by using its request-response handler. The handler deals with receiving and parsing response object coming from Web Services. After having received response from the Web Services, "jp.doTask" object sends the returned result to XmlHttpRequest object in the first page.

C. Application of web-based BMS combining Ajax and Web Services technologies

The BMS is applied to a BAS within a BACnet network. At first, public Web Services methods, which can read and write BACnet data points from the BACnet network, are developed based on a BACnet protocol stack provided by Cimetrics Company [7]. The main tasks of Ajax are invoking the Web Services to get real-time data from the BACnet network and displaying results on the web browser. The process of obtaining the data runs asynchronously with the web server and ensures high efficiency. After the required data is retrieved, the document content is modified through the Document Object Model (DOM). As a result, the application is more responsive than classic web applications, since the amount of data exchanged between the web browser and web server is significantly reduced and reloading of the page is not necessary.

Figure 6 presents a user interface of the web-based BMS applied to the BAS, which is designed to monitor and control the heating, ventilation and air-conditioning (HVAC) systems in a building located in Hong Kong.
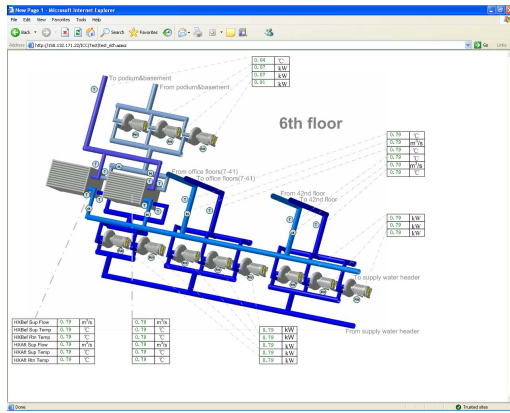
Figure 6. A user interface of web-based BMS based on Web Services and Ajax

IV. CONCLUSIONS

In over two decades, BAS industry and IT industry have got great success and development in technology and market. By now, we find what IT industry has passed is far away from BAS industry. With the appearance of multiple international standardized protocols, there are problems in the BAS internal integration and the integration between BASs and existing enterprise applications, the problems will hamper growth of BAS industry.

With the development of Internet technologies, as a new and powerful model for creating applications from reusable software models in distributed calculation area Web Services will help us solve upper problems. Using Web Services in BAS industry will not only realize the seamless and just-in-time integration between BASs and enterprise applications, among BAS subsystems which adopt different standardized protocols or have different functions , but also it can save users' investment and help users enhance utility of BASs in great measure.

Ajax is a group of interrelated web development techniques used for creating interactive web applications or rich Internet applications. With Ajax, web applications can retrieve data from the server asynchronously in the background without interfering with the display and behavior of the existing page. It is rapidly entering mainstream, rich interface, thin client applications.

In the paper, by using Ajax and Web Services, we propose a generic architecture for realizing a new generation of web-based BMS which can real-time monitor and control BASs on the Internet. Since Ajax and Web Services are XML-based structures, this enables developers to easily integrate Ajax-based browser application into Web Services. The BMS has been applied to a typical BAS within a BACnet network successfully.

ACKNOWLEDGMENT

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