Integrating Building Automation Systems based on Web Services

Bai Jianbo*, Hao Yuzhe, Miao Guochang
College of Mechanical and Electrical Engineering, Hohai University, Changzhou, Jiangsu, China
baijb@hhuc.edu.cn

***Abstract*—It is of great advantage to integrate building automation systems (BAS) in intelligent buildings using networks (LAN or WAN).This paper addresses three technical issues in the integration of BASs. One is the integration between BASs and existing enterprise applications. The second is the integration of BASs which adopt different international standardized protocols. The third is the integration of building automation subsystems. The "intelligence" of intelligent buildings is still more of a promise than a reality. As a new generation of Internet communication technologies, Web Services are becoming an increasingly popular middleware technology, which provides new solutions to overcome above problems. The paper analyses the development history and current problems of the BAS industry, proposes that Web Services based on XML, SOAP, WSDL and UDDI are the best answer in solving the integration problems of BASs. The framework model and realization principles of BAS based on Web Services are also described. The technologies have been used to develop a building management system (BMS) for a real intelligent building successfully.**

***Index Terms*—Building automation system, intelligent building, Protocol, Web Services, System integration**

I. INTRODUCTION

A building automation system (BAS) is designed to monitor and control the mechanical and lighting systems in a building. With the development of computer technology, digital communication technology and control technology, BAS industry has got great success in past two decades. But nowadays most building automation systems are isolated islands of information; it is difficult to realize the integration between building automation systems 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 of building automation systems which adopt different communication protocols, and BAS subsystems can't work together conveniently. Web Services which are emerging IT technologies give us a new way to solve the above problems. The international experts of BAS industry have paid more and more attentions to the Integration technologies of BAS based on Web Services [1-3]. Web Services technology will bring forth BAS industry new innovation and development.

Now there are two international organizations to promote the development of Web Services in BAS domain. One is the Organization for the Advancement of Structured Information Standards (OSAIS), and the other is the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE).

In May 2004, OASIS announced the formation of an Open Building technical committee (oBIX). The purpose of oBIX is to "develop a publicly available Web Services interface specification that can be used to obtain data in a simple and secure manner from HVAC, access control, utilities, and other building automation systems, and to provide data exchange between facility systems and enterprise applications."[4] Comprised of representatives from the entire spectrum of the buildings systems industry, oBIX includes professionals from the security, HVAC, building automation, open protocol and IT disciplines. In 2002 September, ASHRAE's Standing Standards Project Committee 135(SSPC135) which is responsible for the BACnet's (A Data Communication Protocol for Building Automation and Control Networks) technical support and update announced the formation of BACnet-XML working group, the earlier work of the group was to define the XML application of the BACnet systems. At present BACnet has made stripe towards the integration with Web Services [5].

In October 2004, ASHRAE SSPC135 announced that "BACnet Web Services Initiative Goes to Public Review", the proposed draft was the addendum C to standard 135-2004 of BACnet [6]. The new addendum is divided into two parts. The first proposes an Annex N to BACnet that defines the BACnet Web Services interface (BACnet/WS). This has been accomplished by defining Application Program Interfaces (API) to read and write the common elements of BAS such as values, schedules, trend logs, and alarm information. The second part of the addendum contains an addition to BACnet's Annex H, "Combining BACnet Networks with Non-BACnet Networks", which prescribes the gateway mapping specifically to and from BACnet messages.

In the paper, Web Services are used to develop a new generation of building management system (BMS). 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. The proposed BMS has been applied to an intelligent building whose BASs are all within a BACnet network [7].

The rest of the paper is organized as follows: Section 2 presents the development history of BAS

Manuscript received October 1, 2009; accepted October 15, 2009.
*Corresponding author. Tel.: +86 519 85191992. This work is supported by the Training Programme Foundation for Youths by Changzhou Municipal People's Government and Hohai University Doctor Startup Fund (08B007-003).

doi:10.4304/jsw.6.11.2209-2216

communication protocols. Section 3 describes the current problems of BAS industry and the corresponding solutions. Section 4 presents the principles of Web Services technology. Section 5 describes the framework and realization of BAS based on Web Services is. Furthermore, an example applied to a real intelligent building is presented. Finally, conclusions are presented in Section 6.

II. THE DEVELOPMENT HISTORY OF COMMUNICATION PROTOCOLS OF BAS

In the early 1980s, microprocessor-based direct digital controllers began to be used in the products of HVAC-related equipment. The earliest of these controllers were designed to be stand-alone, and they didn't have communication functions. With the network demand for BASs, many equipment manufacturers began to add communication functions to their stand-alone controllers, and then a few communication protocols began to appear in BAS industry.

In the beginning, these communication protocols were proprietary to the equipment manufacturers. With the demand for serial communication ports in the mechanical and electrical equipments of building automation systems, a few common protocols became the communication standards, e.g. Modicon's MODBUS and OPTO22's OPTOMUX. Later a few companies recognized the need for common protocols as good business opportunities; they developed their own protocols (e.g. Bosch's CAN and Echelon's Lonworks) and supporting products to supply to the industry.

Nowadays there have been several international standardized protocols which were defined by some industry standard bodies; these protocols (e.g. ASHRAE's BACnet, OPC foundation's OLE for Process control (OPC) [8], and so on) could be available to be deployed without licenses or royalties.

Initially the data structures of these common protocols were flat. In a flat data structure, each data's information is stand-alone. With the wide application of the object-oriented method in computer and communication domains, the object-oriented communication protocols appeared. The object-oriented communication protocols adopted the object-oriented data structures. For example, in a object-oriented data structures the temperature value unit and the name of sampled area would be grouped into a temperature object. Also multiple objects can be grouped into another object in a hierarchical structure. These object-oriented communication protocol's typical representations were BACnet, LonMark and KNX. At present, the three protocols have been widely accepted and used in BAS industry.

III. THE PROBLEMS AND CORRESPONDING SOLUTIONS OF BAS INDUSTRY

BACnet, Lon Mark and KNX protocols have got great success and development in past one decade, and they play more and more important roles in BAS industry. But the development procedure of BAS industry has puzzled the industry experts. They wonder if BAS industry is toward the right development direction or not. A few problems about BAS industry were put forward in followed paragraphs.

At first, in the early 1980s, there was none protocol which could satisfy BAS industry's needs. But nowadays, there have been several protocols which can meet needs of building automation systems. In the market, BAS manufacturers always need to develop the products which support one or more of the standard protocols that are available. But it is often difficult for BAS to integrate the products which adopt different protocols. We can bridge these products using special gateways, but it is complex to develop these gateways and will waste manpower and material resources.

The Second, at present building automation systems are often separated from Information Technologies (IT) systems, and BAS is an isolated island of information. Now most of building owners, facility managers and tenants hope to integrate BAS with their own enterprise application systems [9], and then BAS become one part of the enterprise information systems. In order to realize the goal, BAS manufacturers pay more attentions to develop the products which can support TCP/IP network protocol. For example the BACnet/IP technology of BACnet [10] and the DDE technology of Lonworks [11] can realize interconnection and interactive operation between BAS and desktop applications. Compared with other network applications, building automation systems confront with many obstacles in TCP/IP networks, e.g. Routers, firewalls, security and compatibility. Also the traditional integration of building automation systems emphasizes particularly on interactive operations among the systems. So the system's coupling is strong, and then the infrastructure of the system is apt to fragile. It is far away from the goal of real-time and seamless integration in BAS industry.

The third, from the appearance of the first Intelligent Building (IB) in 1980, the concept of IB is always discussed by people[12], but the goal of intelligent is far from us with the twenty years development yet, one of the fundamental reasons is the absence of cooperative work ability among BAS systems. The products of HVAC system, lighting system, security system and fire alarming system may adopt different protocols or be produced by different manufacturers, these products are always incompatible, they can't be connected each other. Also it is relevant with that BAS systems can't be integrated with enterprise applications conveniently.

The fourth, while BAS industry is still developing, the development step of IT moves faster than BAS and the gap between them becomes larger than ever. From the 1970s, the infrastructure of IT systems has experienced several evolvements. From the earliest host disposes concentratively, and then the infrastructure developed to the distributed processing network. Originally the structure of the distributed processing network is Client/Server(C/S) mode. In the C/S mode calculation tasks are processed by client and server separately. Then the structure of distributed processing network comes to

three layers mode (Browser/ Application Server/Database Server - B/S/S).In three layers mode, the functions of client in C/S mode are acted by Internet Explorer's thin client and application logics which runs in Application Server side. The structure of three layers mode is easier to maintain, upgrade and extend to Internet environment than the structure of two layers mode. With the development of Internet technologies in recent years, Web Services technology becomes the developing trend, where calculation develops to service and the relation between client and server develops to the relation between client and network. Web Services will be the certain tendency of the next generation of network calculation because of the special technology advantages and concepts [13]. Now the Web Services has got successful application in Enterprise Application Integration (EAI) and Electrical Business (EB) domains.

Web Services bring us new solutions to overcome upper problems. Web Services make it easier to integrate enterprise application systems with building automation systems and integrate BAS subsystems which adopt different standardized protocols than ever before. The experts of BAS domain come to one opinion that the convergence of BAS industry and IT industry will be the certain tendency [14-17]. This mean that BAS and its integration technologies based on Web Services will bring forth BAS industry new flight and developing chances.

Web services are the newest research achievement in distributed calculation domain; Web Services are based on some open IT standards which include eXtensible Markup Language (XML), Web Services Description Language (WSDL), Simple Object Access Protocol (SOAP), Universal Discovery Description and Integration (UDDI), Web Services Flow Language (WSFL) and so on. The openness, extendibility and security of Web Services are better than former Web technologies. The fundamental notion of Web Services is to realize interactive operations among heterogeneous configuration systems which use IT platform standards, e.g. Hypertext Transfer Text (HTTP) and so on. Web Services have many advantages including platform-independent, transparent to users and easily traversing fire wall, it is an ideal calculating model to realize the integration of heterogeneous-configuration systems. Introducing Web Services into BAS domain will change the infrastructure of building automation systems and the mode of BAS's data access and inter-operation, realize seamless and real-time integration among BAS subsystems, between building automation systems and enterprise applications, among building automation systems which adopt different communication protocols.

BAS and its integration technologies based on Web Services have followed advantages:

- It can realize seamless and real-time integration between enterprise application systems and building automation systems;
- It can realize the integration of BAS systems which adopt different standardized protocols without additional gateway facilities;
- It can realize the cooperative work among HVAC system, lighting system, security system, fire alarming system and enterprise application (e.g. Hunter management system),It can make building automation systems more intelligent than ever;
- Web Services are supported by all of the major Enterprise Software vendors, including Microsoft.NET, IBM WebSphere, Sun Microsystems, HP Web Services platform and so on.
- Using the interfaces provided by Web Services all kinds of users can develop their own applications suitable for themselves;
- Web Services have made great success in Enterprise Application Integration (EAI) and Electrical Business (EB) domains, and it is the certain development tendency of IT industry.

IV. THE PRINCIPLE AND KEY TECHNOLOGIES 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[18]. 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.

The architecture and protocol stack of Web Services

A Web Service can be considered as a kind of object which is deployed on the Web. It describes interfaces of the object's operation sets, and then we can use the interfaces to access the object in the network by standardized XML message. A Web Service realizes a special task or a set of tasks. A Web Service is described using a standard, formal XML notation, call its service description that provides all the details necessary to interact with the service, including message formats, transport protocols and location. The interfaces hide the implantation details of the service so that it can be used independent of the hardware or software platform on which it is implemented, and independently of the programming language in which it is written. This allows and encourages Web Services based applications to be loosely coupled, component-oriented, and cross-technology implemented. A Web Service can be used alone, and also it can be used in conjunction with other Web Services to carry out more complex tasks or business transactions.

Web Services are based on a "Service-oriented" architecture. Three distinct roles are present in the

architecture: Service Provider, Service Requestor and Service Broker (Fig.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 Requestor 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.

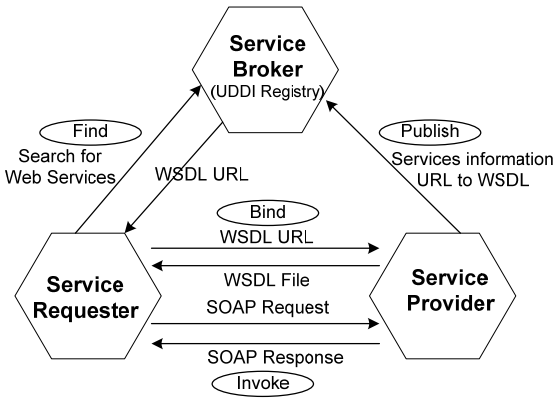

Figure 1. Web Services architecture

There are three main tasks involved in creating and using Web Services:

Publish: The service provider creates a service and registers it with a registry; the service is then advertised by the registry. The most registry scheme is UDDI.

Find: The service requestor searches the registry and finds corresponding services. A service description document can then be retrieved, which provides information on communication protocols, service location, input/output parameters and so on. This document is often defined in WSDL format that defines the service and binding information in an XML document.

Bind: The service requestor can write the client access code to locate, contact and invoke the service according to the binding details contained in the service description document.

Web Services have followed advantages:

1) Good encapsulation

Web Services can be considered as an object which is disposed on the Web, the object has good encapsulation. What users can only find are the functional lists provided by the object.

2) Loose coupling

The realization details of a Web service are not relevant with the programs which will invoke the service. A Web Services can be accessed by the APIs and invoking mechanisms provided by it. A Web Services don't care who will use it.

3) Findable

There is an important role "Service Broker" in Web Service architecture. The Service Broker provides a mechanism which is convenient for the Service Provider to publish services and for Service Requester to find these services.

4) Using standard protocol criterion

Standard IT protocols are used by Web Services to realize service description, transport and data coding. Clients can use Web Services conveniently.

5) High capabilities of integration

Simple and understandable standard Web protocols are adopted by Web Services as the rules of component interface description and cooperation description; it can shield the differences among different software platform completely. Whatever Common Object Request Broker Architecture (CORBA), Distributed Component Object Model (DCOM) or Remote Method Invocation (RMI) can use the standard protocols to operate among each other; it reveals high capabilities of integration.

Web Services are realized by standardized Internet protocols. These protocols include Transfer Control Protocol/ Internet Protocol (TCP/IP), HTTP, XML and other existing Internet protocols, and they also include SOAP, WSDL and UDDI specialized for Web Service technology. Table 1 gives actual architecture of Web Services protocols stack in heterogeneous architecture. It reveals the fundamental of openness and standardization of Web Services adequately. The protocols stack contains the key technologies adopted by Web Services. Somewhat similar to the Open System Interconnection (OSI) model, the upper protocols of Web Services are based on the capabilities which the lower protocols provide.

TABLE I.
ARCHITECTURE OF WEB SERVICES PROTOCOLS STACK

The name of technology	Layer location
WSFL	Service Flow layer
Static->UDDI	Service Discover layer
Direct->UDDI	Service Publication layer
WSDL	Service Description layer
SOAP	XML-based Messaging layer
XML Schema	Data Modeling layer
XML	Data Presentation layer
HTTP,FTP,SMTP	Network Transport layer

A. *XML*

XML plays an essential role in Web Services, which sometimes is also called XML Web Services. XML is the universal format for structured documents and data on the Web. Unlike HTML, XML isolates the data structure from the presentation mark-ups. It represents content in a textual format that is platform and language neutral. Thus it is suitable for defining upper layer standards used in Web Services.

XML acts as Data Presentation layer in the architecture of Web Service protocol stack. It provides the description of data and information for all of Web Services upper protocols.

XML provides a method to describe structured documents and data. HTML is all about what content looks like, unlike HTML XML is about describing the content so it can be manipulated online... XML uses a set of marks to describe data element. Every element may encapsulate simple or complex data.

XML is simple and not relevant with platform. Compared with HTML, one of the advantages of XML is that it can separate user interfaces from structured data. It makes it possible to integrate the data which is from different areas. XML document has followed specialties:

1) Extendibility
   User can define own data marks;
2) Structured data
   Data structure can model any complex things;
3) Validity
   Data can validate the correctness of the structure.

B. SOAP

Simple Object Access Protocol (SOAP) is a XML based lightweight protocol for exchange of information in a decentralized, distributed environment. SOAP defines a mechanism for expressing application semantics by providing a modular packaging model and encoding mechanisms for encoding data within modules. This allows SOAP to be used in a variety of systems ranging from messaging systems to Remote Procedure Calls (RPC). SOAP provides a built-in extension mechanism that allows additional functionality, such as security and transactions, to be added to the basic transport. One of important advantages of SOAP is that SOAP can traverse fire walls. A SOAP message contains three XML elements: a SOAP envelope, a SOAP header, and a SOAP body. SOAP is composed of four parts as follows:

1) SOAP envelope: a mechanism which uses XML envelope to describe the content of information;
2) SOAP encoding rules: SOAP defines an encoding mechanism to exchange data whose type is defined by application program;
3) SOAP RPC representation: SOAP defines a convention which is used to represent remote process call and response;
4) SOAP binding: SOAP define a convention which uses lower transport protocols to exchange SOAP envelopes among nodes.

C. WSDL

Service Description layer (WSDL) provides detail methods for the call of Web Services in the architecture of Web Services protocols stack in table.1. WSDL has been submitted to the World Wide Web Consortium (W3C) for consideration as a recommendation [19]. It provides an abstract description of what a Web Service can do where it resides and how to invoke it. Officially, WSDL is an XML format for describing network services as a set of endpoints operating on messages containing either document-oriented or procedure-oriented information. Informally, a WSDL document provides the access information for the service consumer such as the method signature, the protocols to be used, the network address, and the data format. The document can be logically divided into two parts: an abstract definition of the service being provided that is called the port type, and concrete endpoint binding information for the Port Type.

D. UDDI

Universal Discovery Description and Integration (UDDI) protocol provides a standard discovery mechanism for Web services. UDDI provides pointers to the WSDL document that describes a service and the access point of a service implementation. UDDI, like yellow pages, provide a registry of businesses searchable by the type of business. UDDI uses WSDL to describe interfaces to Web services. To ensure most platforms can access UDDI's services, the UDDI directory exposes a set of APIs in the form of SOAP based Web service. UDDI provides an open, platform-independent service architecture framework that enables businesses for publishing services, discovering businesses offering services and integrating business services over Internet (or Intranet) along with a registry with publicly listed information. The UDDI XML schema defines four core types of information which provides basic information on using Web Services: business information, binding information (information pertaining to the address of contact with a Web Service), and information about specifications.

E. WSFL

Web Services Flow Language (WSFL) is the standard of Service Flow layer in the top-level layer of the Web Services protocols stack. WSFL is different from the other protocols of the protocols stack, and it mainly aims at business flow model and working flow. WSFL is used to describe how Web Services work together in the working flow and how to deal with the communication and cooperation among services. A Web services can be one part of Web Services, also it can be added to working flow dynamically. WSFL has the capability of spanning technology boundaries as well as across business boundaries. The business process model is represented with the WSFL flow model which defines a series of activities and their execution. Once the flow model establishes the processing flow between activities, the WSFL global model specifies how the Web Services involved in the process should interact with each other.

V. BAS SYSTEM AND INTEGRATION TECHNOLOGY BASED ON WEB SERVICES

The most important advantage of Web Services is the good integration capability. At present Web Services technology is one of the most advanced integration methods for enterprise application and it has been widely accredited. Act as an ideal integration tool, this standard–based technology enables different Web Service to

communicate with each other regardless of hardware and operating system. The integration of Web Services allows applications to be integrated more easily and less expensively than ever before. With Web Service technology, enterprises and users can find, describe and use these sharable services. Web Services can be integrated into legacy application conveniently, and then we can develop new kinds of IT solutions. Web Services can also help us to realize the seamless and real-time integration between building automation systems and enterprise applications, among BAS subsystems which adopt different standardized protocols or have different functions.

The integration technology based on Web Services can be classified into four types:

1) User interface integration;
2) Data integration;
3) Business flow integration;
4) Function or method integration.

A. *BAS system and EAI*

Most of building's owners, facility managers or tenants hope to integrate BAS systems into their own enterprise applications; the problem belongs to EAI (Enterprise Application Integration) research domain. The integration of BAS based on Web Services is closely relevant with the integration technology of EAI based on Web Services.

EAI based on Web Services can realize the interaction and communion of information between building automation systems and existing enterprise application systems according to the needs of enterprise business.

Fig.2 gives a sketch map of the integration between building automation systems and enterprise applications 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 BAC subsystems which adopt BACnet protocol, Lontalk protocol or other types of protocols. The third is the integration of different functional building automation systems (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.

The integration between building automation systems and enterprise applications and the integration among BAS subsystems always use the function or method integration mode. This type of integration is the mode of Application-to-Application (A2A) among programs and it adopts synchronous pattern which is based on the request-response mechanism between client (request program) and server (response program).

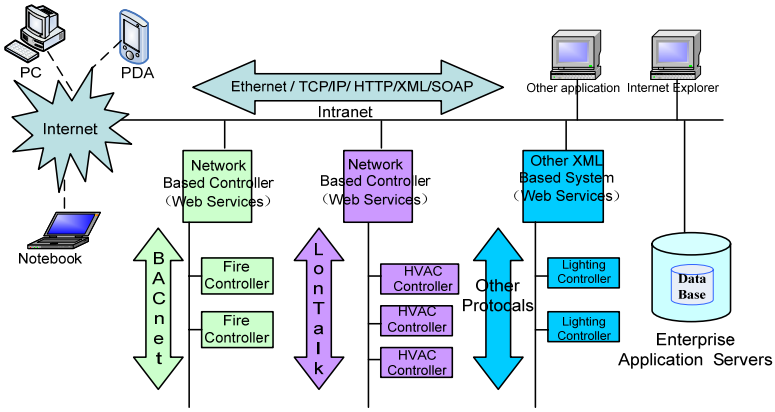

Figure 2. Integration between BASs and enterprise applications based on Web Services

B. *The realization research of BAS based on Web Services*

BAS based on Web Services is not to replace BACnet or LonTalk protocol, it uses existing Internet/Intranet infrastructure and field bus networks to realize the seamless integration between existing enterprise application systems and building automation systems or among BAS sub systems.

1) *System functions*

According to the draft put forward by BACnet-XML-WG group which belongs to the ASHRAE's SSPC135 committee, BAS based on Web Services has following functions [20]:

- "Basic Web Services" must support remote read, write and Find Device capabilities;
- "Advanced Web Services" must support alarm notification, error handling and file transfer;
- Combine existing standardized protocols (e.g. BACnet, LonTalk and EIB) with the integration technologies of Web Services;
- Web Services must be compatible with standard IT security mechanisms;
- Web Services may enhance the functions of services where appropriate;
- Web Services must support the connection of systems through Network Address Translation

(NAT) devices and firewalls, SOAP based on HTTP or FTP can meet the needs [21].

2) System architecture model and system realization principles

In order to use existing Intranet/Internet infrastructure to realize building automation systems based on Web Services, Fig.3 gives the sketch map of BAS architecture based on Web Services, Fig.4 gives preliminary scheme of BAS internal structure based on Web Services.

In Fig.3 UDDI is a virtual registry center and is realized in the server side. UDDI is responsible for the publication of service description and support the function of service find. In BAC, all of the nodes which provide public UDDI registry service are generally called as the UDDI registry center. The UDDI registry center is a whole in logic, but it is realized by distributed control network in physics. All of the nodes are connected by peer-to-peer network infrastructure. So we can access the UDDI registry center when we access any nodes in the network. The interfaces of UDDI include query APIs and publish APIs. The query APIs are used to locate candidate business entities, Web Services and its details of invoking rules and relevant message. The publish APIs are classified into saving APIs and deleting APIs.

BAS describes services content in WSDL documents, these services contain remote read, write, find device, alarm indication, fault processing capabilities and so on .Then the services will be sent to the UDDI registry center for publish. When user requests for services, the request is direct to the UDDI registry center practically. When the detail services are found, client will be bound up and linked with server, and then the client begins to accept the services. The integration mode is the function and method integration type.

The client used by users may be a common PC, a Notebook or a Personal Digital Assistant (PDA). The client application may be a browser or a common Windows desktop program, even another Web Service.

In Fig.4, the client program inside the Intranet queries the Web Services registry center by the medium of UDDI APIs, or gets Web Services location and bind the WSDL document by intercommunicating information with the business partner's technician. Users who traverse the firewall and login into the system need to be checked permission. After being authorized users can query the location of needed Web Services and WSDL description which reside in the UDDI registry center. Then the WSDL description document will be loaded automatically to own developing platform, thus the corresponding interfaces come into being. At the same time, by using XML Schema the client application catches hold of data structure required by the interactive operations quickly, then users can interact with the Web Services by introduction of the interfaces and data structure generated by the developing tool.

A SOAP client can interact with multiple SOAP servers just in real-time, and bring new generative data into a XML file. Once the XML file is transferred to the client application, the analyzed data can be edited and operated locally. On the other hand, after the data has been transfer to the client. Also local users can change the client application's configuration, and choose different realization method.

Web Services application server (Service Provider in Fig.3) of BAS is divided into two layers in logic: business logical layer and data service layer. Business logical layer is responsible for the interactive operation with users and analyzing the request, then operate with the background data source. The data source can be the real-time acquisition data from the field bus networks, the data source can also be traditional relational database or real-time database, and then the distributed network can be formalized. At last, the response in XML format is return to the requester.

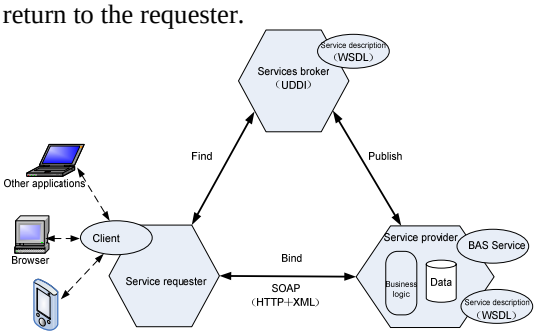

Figure 3. BAS architecture based on Web Services

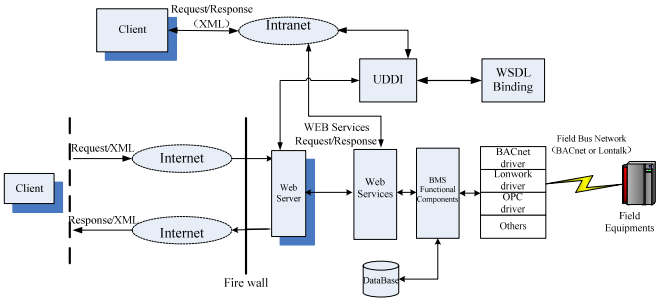

Figure 4. BAS internal structure sketch map based on Web Services

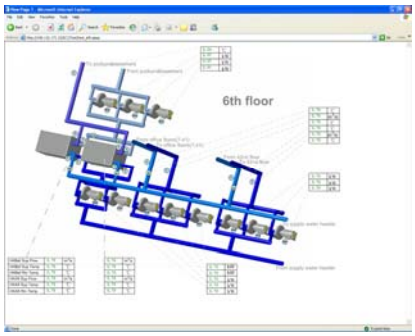

Figure 5. A user interface of web-based BMS based on Web Services

C. Example：A web-based BMS combining Web Services technologies and Ajax

A web-based BMS combing Web Services and AJAX is applied to a real intelligent building, in which BASs using 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

[22]. 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.

Fig.5 presents a user interface of the web-based BMS applied to a BAS based on Web Services, the BMS is designed to monitor and control the HVAC systems in the intelligent building located in Hong Kong.

VI. CONCLUSION

In over two decades, BAS industry and IT industry all get huge 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 building automation systems 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 building automation systems and enterprise applications, among BAS subsystems which adopt different standardized protocols or have different functions , but also it can save the user's investment and help user enhance utility of building automation systems in great measure.

Introducing Web Services technology into BAS domain will change the situation that BAS is an information island, and realize the convergence between BAS industry and IT industry. The application of Web Services in BAS domain will be the certain trend.

The paper describes integration technologies, framework model and realization principles of BAS based on Web Services, which has been applied to develop a web-based BMS in an real intelligent building successfully.

ACKNOWLEDGMENT

This work was supported in part by the Training Programme Foundation for Youths by Changzhou Municipal People's Government and Hohai University Doctor Startup Fund (08B007-03).The authors are grateful to the anonymous reviewers for their valuable recommendations.

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Bai Jianbo was born in 1974 in Changzhou city, Jiangsu province, China. He received the B.Eng. and M.Eng. degrees in heating, ventilation and air-conditioning engineering from Huazhong University of Science and Technology, Wuhan, China, in 1997 and 2000, respectively, and the Ph.D. degree in heating, ventilation and air-conditioning engineering from Southeast University, Nanjing, China, in 2007.

He worked as a research associate with the Hong Kong Polytechnic University, Hong Kong, China, in 2007. He is currently an associate department Chair of Thermal and Power Engineering department with Hohai University, Nanjing, China, where he has been an associate professor since 2009. His main research areas include HVAC control systems, building automation systems and the application of new energy.