Research and Design of Cloud Architecture for Smart Home

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***Abstract*—Cloud Computing is a recent technology trend whose aim is to deliver computing utilities as Internet services. Many companies have already offered successful commercial Cloud services including SaaS, PaaS and IaaS. But those services are all computer-based and designed for Web browsers. Currently there is no Cloud architecture whose purpose is to provide special services for digital appliances in smart home. In this paper, we propose an additional Model, the smart home Cloud, which not only bases on the present Cloud architecture but also modifies the traditional Service layer to provide efficient and stable services for smart home. In contrast to the traditional Model, we bring Web service and Peer-to-Peer (P2P) technologies to the Cloud. Smart home nodes and Cloud server form a peer-to-peer network, which can help the Cloud server to reduce bandwidth pressure when transmitting higher quality audio/video signals. Smart home gateway describes their services in WSDL and registers them to the Cloud service directory so that other homes can search and consume the service. Peers (smart home) are both suppliers and consumers of services.**

Keywords-Cloud Computing; Smart Home; Peer-to-Peer; Web service;

I. INTRODUCTION

Cloud Computing refers to both the application delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The datacenter hardware and software is what we will call a Cloud [1]. It gives more application providers the choice of deploying their product as SaaS without investing complex IT infrastructure [2, 3], and end users can access the service "anytime, anywhere", share data and collaborate more easily, and keep their data stored safely in Cloud [1].

A Smart Home is a house or living environment that contains the technology to allow devices and systems to be controlled automatically [4] and share a common interface [5]. It provides more humanized services, such as smart home entertainment, remote medical, remote communication and control of smart home for smart home user.

However, the existing Cloud Computing platforms are mainly computer-based and only support HTTP-based applications, end users need a Browser to communicate with the Cloud. This leads to the non-computer electrical appliances in smart home can't enjoy the Cloud resource-on-demand and pay-as-you-go services, and Cloud can't provide non-HTTP applications to meet the demand of the smart home.

In this paper we propose a Cloud architecture based on existing Cloud to support smart home. Cloud can provide more humanized services for digital home appliances in smart home, and smart home nodes can form peer-to-peer network and publish, lookup, use services in the Cloud with it.

This paper is organized as follows. An overview of smart home and current Cloud Computing architectures is introduced in Section 2. The peer-to-peer network structure and technology are described in Section 3. Section 4 presents the architecture of smart-home-based Cloud Computing platform and Section 5 concludes the paper.

II. RELATED WORK

A. Cloud Computing

Clearly, cloud computing is now the most popular topic in the IT industry [3], which is a new and promising paradigm delivering IT services as computing utilities [3]. There are many Cloud industry instances offering commercial services from SaaS, PaaS, to IaaS. Figure 1 shows us that Amazon [8], Google [10, 11], Salesforce.com [12] and Vmware [20] provide SaaS solutions, and Google AppEngine [9], Microsoft Azure [13], RedHat [14], Aneka [19] focus on PaaS solutions. Examples of IaaS solutions are Dell [16], HP [15], IBM [17], Sun [18].

Nowadays, cloud computing customers do not need to own the physical infrastructure, instead avoiding capital expenditure by renting usage from a third-party provider. They consume resources as a service and pay only for resources that they use [6]. In general, Cloud Computing, the long-held dream

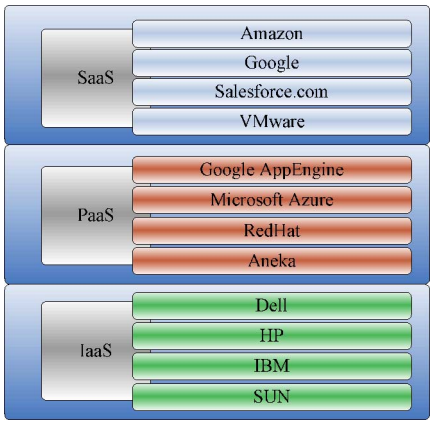

Figure 1. some commercial offerings for Cloud Computing

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of computing as a utility, has the potential to transform a large part of the IT industry [1].

But there are two obvious problems in the present Cloud architectures. First, they are only designed for computer users (e.g. Cloud-based computing, Cloud-based storage), not including ones of digital appliances in smart home. Second, Cloud-based applications are almost HTTP-based and terminal users need a browser to Communicate with the Cloud. As a result, current commercial offerings for Cloud Computing can not provide non HTTP-based services (video streaming, media encoding, remote video) for non-browser digital appliances in smart home, so that smart home could not benefit from Clouds. Unfortunately, currently seldom research works to extent Cloud architecture implementations to smart home.

In fact, Infrastructure as a Service solution (IaaS) provided for users with physical or virtual resources can fit all the requirements of the user applications. But, it is only suitable for the Cloud users (Saas Providers) because end Users could not afford the costs of establishing their own virtual machine. They can only enjoy the existing Cloud services based on HTTP, However, there are a lot of digital appliances unsupported HTTP protocol in the smart home. In this paper, we propose a Mechanism that Cloud could provide more Services based on various protocols for smart home users. Of course, the smart home network also needs further improvement. Digital appliances with different data formats and protocols should be seamlessly networked, controlled, and provide unified format services for users outside-of-house. Fortunately, there have already been mature solutions to this problem in the smart home research filed.

B. Smart Home

Smart homes are becoming increasingly prevalent in today's life. Recently, a lot of research in this area focused on the home gateway. The Open Services Gateway Initiative (OSGi) is one solution of them [4, 5, 7], which aims to create a platform and infrastructure to enable the deployment of services over wide area network to local network and device. In the OSGi architecture smart home, residential service gateway connects various appliances together inside-of-house and bridges the external network such as the Internet into the house network outside-of-house. People can enjoy a better home life experience without overpowering intelligent home appliances with complex technologies and intuitive user interfaces.

However, currently seldom research work focuses on providing stable and efficient Cloud-based services for smart home. Home appliances like digital TVs, air conditioners and digital refrigerators could not benefit Video Streaming, remote control and smart intelligent management services from Clouds. Meanwhile, because of isolated from others, each smart home could not share their home appliances resources like memory and computing power with others.

For this paper, we work on combining Clouds and smart home together so that appliances can benefit from Clouds and Cloud providers can have more potential users. In order to realize our mechanism, we bring the Peer-to-Peer and Web Service technologies to the Cloud Computing and modify the Service Layer of current Cloud architecture.

III. KEY TECHNOLOGIES RESEARCH

With the purpose of combining Cloud and smart home, we need to introduce some new technologies into Cloud. Peer-to-Peer (P2P) and Web service are mature technologies, which can enable Cloud to achieve more special functionality for smart home.

A. Peer-to-Peer networks

Smart home services can be divided into three classes: home entertainment, video communication and video conferencing, which are all based on audio/video streaming. However, traditional client-server Cloud model is limited by the bandwidth pressure when transferring heavy high-quality audio/video signal. In order to solve this problem, we propose a mechanism in which smart home nodes and Cloud server form a peer-to-peer network to reduce the bandwidth pressure on Cloud. Each participant of the network should register some information (such as name, IP) in the Cloud and install a special P2P Software in the home gateway, so that nodes can share the bandwidth pressure and processing power.

Figure 2 shows the network system model. For example, Haier can establish a public Cloud to realize Real-time HD Video broadcast for smart home users. Each smart home with Haier digital TV can join the Cloud and enjoy the special service with the help of residential service gateway. A participant that tunes into a broadcast is not only downloading a video stream, but also uploading it to other participants watching the program.

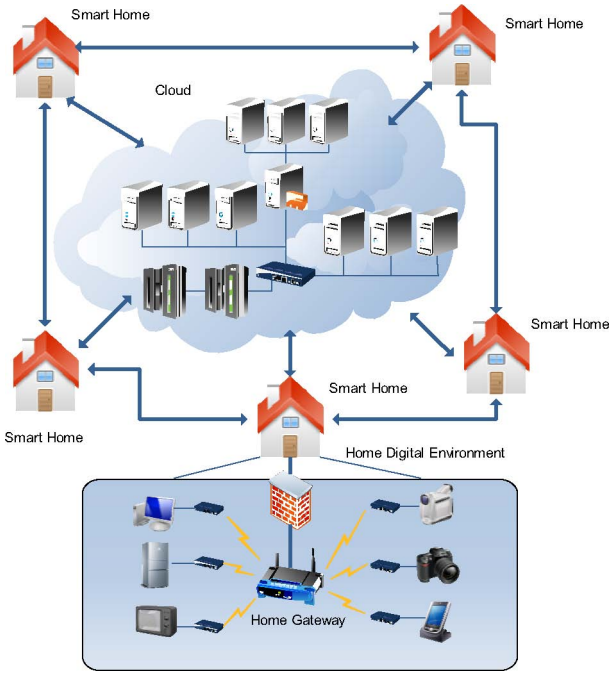

Figure 2. P2P network diagram

B. *Web service*

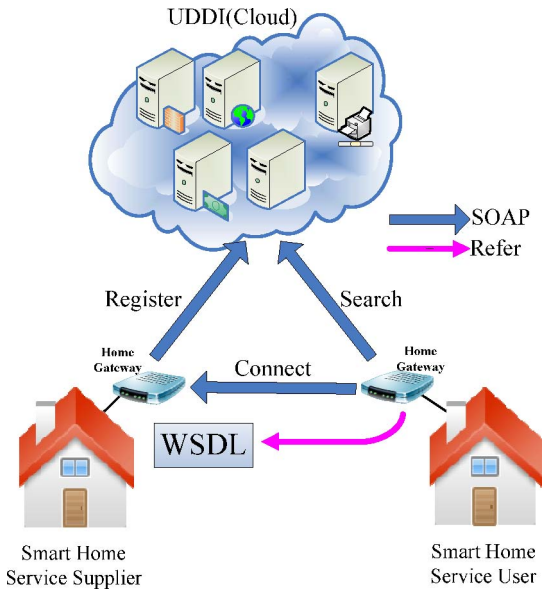

Figure 3. Web service architecture diagram

In this network, Peers (smart home) are both suppliers and consumers of services, in contrast to the traditional client-server model where only Cloud supplies and clients consume. Smart home can share its resources with other homes and benefit from these services.

To realize this feature, we have introduced Web service technology [21], which uses Extensible Markup Language (XML) messages and follows the Simple Object Access Protocol (SOAP) standard. Inside house, home gateway connects and manages all the appliances and various home networks (AV network, PC network, home automation network and wireless network) to form digital environment. If smart users want to share some of their appliance feature with other homes outside of house. They can use the home gateway to describe the services in Web Services Description Language (WSDL) and publish them to Cloud, so other smart home users can search and consume them. Cloud plays a role of UDDI server in the system, which enables service providers (smart home, businesses) to publish their service listings and discover each other and define how the services or software applications interact over the Internet.

Web service in our architecture is showed in Figure 3. For example, there is a printer in smart home A, so the house service gateway can describe the online printing service in WSDL and register it to the Service Directory in Cloud. Other smart home should pay for it when they consume the service, so that smart home A can both make effective use of resources and benefit from Cloud.

IV. ARCHITECTURE OF SMART-HOME-BASED CLOUD

Figure 4 shows the layered design of smart-home-oriented Cloud computing architecture, which bases on the present Cloud architecture but modifies Service Layer to perform as UDDI Registry. The Cloud architecture divided into three parts:

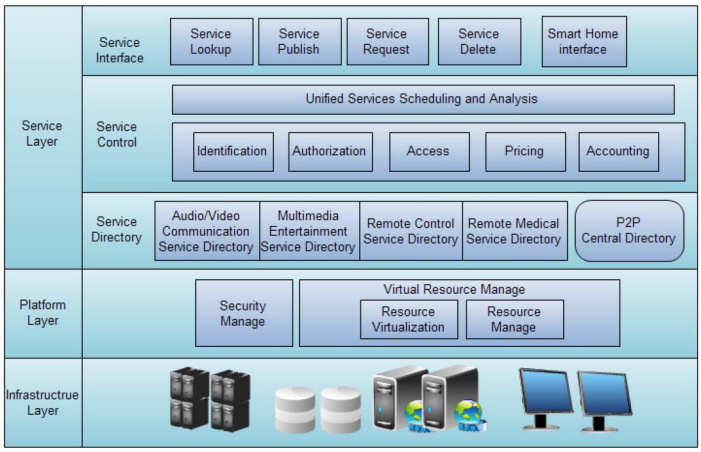

Figure 4. Cloud architecture diagram

infrastructure layer, platform layer and service layer. The platform layer along with infrastructure layer forms the basis for delivering traditional IaaS and PaaS. The topic layer interacts with smart home face-to–face and focuses on application services (SaaS).

A. *Service Layer*

The Service Layer, modified from the present Cloud top layer, is the critical layer on the structure. This part consists of Service interface, Service control and Service directory.

Service interface, which directly faces on the smart home users, offers a simple interface to allow smart home users to publish their service description with easy operations. All the information is converted to XML file and transferred to the Cloud over HTTP/HTTPS protocols. Meanwhile, with the help of service interface, smart home users can search, request and consume any service whose information is listed in the Cloud Service directory (UDDI Server). Besides, smart home interface provides a way to pool smart homes together and harness large amounts of resources, through which, new participants of the Cloud should registry their basic information.

Service control part, brain of the service layer, is responsible for analyzing, processing and responding the user's requests. Figure 5 shows the processing of client request in Cloud. All smart home requests must first pass a filter to check authentication and security. After the safety certification step, XML data is passed to the request parser, which analyzes the data and classifies them into different processors. Request information waiting to be handled is stored in the cache storage

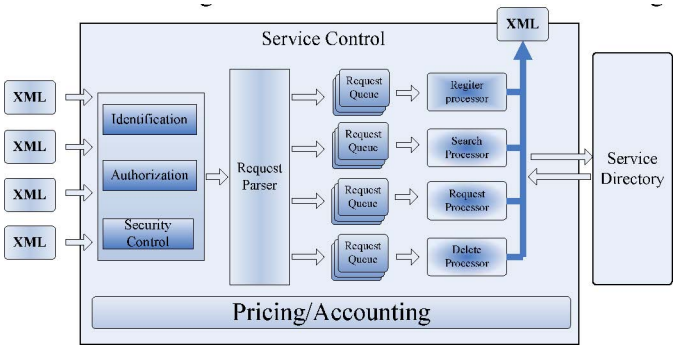

Figure 5. Service Control process diagram

queue. Specific processor deals with the request information and responds to the requestor. The response data is XML format and describes the processing result of the request, according to this information, users can call their needs or confirm services if release successfully.

Moreover, service control part has some nice features like adaptation, self-organization, user authentication, billing, accounting and pricing.

Service directory part acts as an UDDI server, which aims to store published smart home services information. it consists of six directories: Smart Home multimedia entertainment services directory, audio/video communication services directory, Remote control services directory, remote medical services directory, computing and storage services directory and Peer-to-peer central directory, among which, Peer-to-peer central directory contains all the smart home nodes basic information. When the smart home user submit service WSDL to Cloud, Service control part analyze the XML data and register it to the right directory for later operating.

B. *Platform Layer*

This layer is the Core Middleware of the Cloud Model, which is composed of resources manage module and security manage module.

Resources manage component implements the function that resource virtualization and management, such as resource load balance, fault detection, image create, deploy and manage.

The Security manage module ensure the cloud computing security, including restricting user access and certifications, data security and recovery and investigation. It keeps constant vigilance against different forms of attacks not only in the application side but also in the hardware components.

Platform Layer along with Infrastructure Layer capabilities forms the basis for delivering Paas for smart homes. Suppose we build a Cloud to connect all the smart homes in Qingdao together. The Cloud could offer businesses a platform to deploy their specialized services for smart homes. For example, Medical institutions and Shopping can provide telemedicine, Online Video Shopping services.

C. *Infrastructure Layer*

The Infrastructure Layer consists of massive physical resources that are specifically designed for the delivery of cloud services. These resources are transparently managed by the higher level virtualization component that the Cloud can control and provide IaaS Services for smart home users.

V. CONCLUSION

In this paper, we describe the design of the Cloud architecture based on smart home in details. We propose a mechanism that connect the smart home nodes and Cloud server to form a Peer-to-Peer network and introduce Web service into Cloud, so that smart home users can be not only suppliers but also consumers of Cloud services. Cloud applications can also extend to the domain of smart home by providing digital home entertainment and communication services which based on higher-quality audio/video streaming. We aim to combine Cloud and smart home so that more users can benefit from Cloud.

In the follow-up research, more work need to be done, such as, implement our model and Simplify the service interface so that smart home users can interact with Cloud without complex operating.

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