2010 Second International Workshop on Education Technology and Computer Science

A Cloud Architecture Based on Smart Home

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***Abstract*—Cloud computing has attracted more and more attentions due to its ability to deliver computing utilities as Internet services. Many industrial companies have successfully applied their Clouds with different technologies and architectures. But the existing Clouds are all computer-based and designed for Web browser. In this paper we propose a Cloud architecture which is based on digital appliances in smart home to provide IT Services that can be accessed and used by appliances users. As the vinculum that links Cloud and smart home, home gateway, which helps smart home merge into Cloud to provide more information services and access services provided by Cloud, plays a significant role in this architecture. Thus this Cloud architecture extends Cloud computing applications to a new domain so that more users could benefit from Clouds. The architecture that we propose in this paper is a conceptual model and more work need to be done to implement it.**

Keywords-Smart Home; Cloud Computing; Home Gateway; Information Service

I. INTRODUCTION

Cloud Computing is a term used to describe both a platform and type of application. It refers to both the applications 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 is called a Cloud [1]. A Cloud dynamically provisions, configures, reconfigures, and deprovisions datacenters and servers as needed. Web applications and Web services could be hosted on these large datacenters and powerful servers to provide applications as services that can be accessed through the Internet [2].

A Cloud, which is reality for delivering computing utilities as Internet services [3], is a pool of virtualized computer resources. It can provision virtual machines or physical machines for deploying a variety of different workloads and monitor resource use in real time to enable rebalancing of allocations when needed [2].

Cloud architecture has high scalability and excellent stability so that it can make enterprises to achieve more efficient use of their IT hardware and software investments [2][4].

All the current Cloud architecture implementations are computer-based, hence there is no exploitation on the computing power of digital home appliances and potential users of smart home.

On the other hand, smart home, which is a conception in pervasive computing, doesn't have a clear and official definition yet. From our points of view, smart home refers to smart space environment built at digital home with pervasive computing algorithms in order to provide more humanized services. In smart home, the key electrical appliances and services, connect with each other, must be remotely controlled, monitored or accessed in order to form a communications network.

Cloud computing and smart home are developing rapidly in their own fields, but currently no research work that combines them with each other has been done. In this work we propose an idea to extent Cloud computing applications to smart home so that more users could benefit from Clouds.

This paper is structured in the following way: Section 2 describes related work. Section 3 introduces the internal structure of smart home and the function of home gateway. Section 4 describes the topological structure of Cloud architecture based on smart home. Section 5 presents the Cloud architecture based on smart home and finally Section 6 concludes the paper.

II. RELATED WORK

As stated, many industrial companies presented their understanding of Cloud computing and also successfully applied it with various technologies [5]. Here are some specific Cloud industry instances and research units. Our present work is built on current Cloud architectures and research works.

A. Google App Engine

Google App Engine allows users to run Web applications written by Python and Java programming language [6]. Google Cloud architecture is based on platform (PaaS). It supports Application Programming Interfaces (APIs), and allows users to create their own applications and access Google data store with these APIs. To realize this Cloud architecture, Google implemented the Google File System, a scalable distributed file system for large distributed data-intensive applications [7]. Furthermore, Google proposed a programming model and an associated implementation called MapReduce for processing and generating large data sets [8]. They also designed a distributed storage system for managing structured data named Bigtable [9].

So far, numerous applications have been stored on Google App Engine and are still on the rise day by day.

B. Amazon Elastic Compute Cloud

Amazon Elastic Compute Cloud (EC2) [10] provides a virtual computing environment that enables a user to run Linux-based applications. The architecture of EC2,

Supported by the National Natural Science Foundation of China under Grand No.60970130; the National Key Technology R&D Program under Grand No.H21001654; the Program for New Century Excellent Talents in University under Grand No.NCET-06-0600

978-0-7695-3987-4/10 $26.00 © 2010 IEEE
DOI 10.1109/ETCS.2010.293

distinguished with Google App Engine, is based on infrastructure. Users can control virtual machines just like they own them. Thus the EC2 has better flexibility and that is the reason why Amazon names their Cloud as Elastic Compute Cloud. However, users feel more difficult in dealing with Amazon cloud computing than with Google App Engine due to this elasticity.

The most important technology used by EC2 is Virtual Machine, with which EC2 allows users to manage computer resource conveniently. The users can either create a new Amazon Machine Image (AMI) containing the applications, libraries, data and associated configuration setting, or select from a library of globally available AMIs [3].

C. *Cloud Computing and Distributed Systems Laboratory*

The Cloud Computing and Distributed Systems (CLOUDS) Laboratory, formerly GRIDS Lab, is a software research and development group within the Dept. of Computer Science and Software Engineering at the University of Melbourne. The lab created several projects/programs in Cloud Computing and has made great contributions to the research on the design and development of different market-oriented Cloud platforms for a range of applications [11].

D. *Open Cirrus*

Open Cirrus™ is a Cloud computing testbed for the research community that federates heterogeneous distributed data centers [12]. Open Cirrus offers a Cloud stack consisting of physical and virtual machines, and global services such as sign-on, monitoring, storage, and job submission.

The existing Clouds and research work have made great contributions to the development of Cloud computing. But the current Cloud architectures are designed only for computer users, but the users of digital appliances in smart home cannot access services provided by present Clouds. Meanwhile, the power of appliances in computing, storage, etc cannot be used by Clouds. We propose a new type of Cloud architecture to improve this situation so that appliances users can benefit from Cloud and Cloud providers can have more potential users.

III. STRUCTURE OF SMART HOME

To achieve the combination of Clouds and smart home, home gateway, regarded as a bridge to link Clouds and smart home, needs to be efficiently and effectively improved. First of all, it is capable of gathering services provided by smart home and submitting all of them to Cloud. Besides, it does search services provided by Cloud, figure out information services suitable to home users, and then store them as the format that can be used by appliances easily.

A. *Smart Home Internal Structure*

For the sake of merging into Cloud, smart home have to meet the following requirements.

- **Interconnected.** It is a must that one of the appliances in smart home should be able to connect with any of others. The protocol of connecting can be various, such as Ethernet, Bluetooth, Wi-Fi and so on. But direct access is not necessary. For instance, by Bluetooth, television could be well connected with printer which also could be linked with cell phone through Wi-Fi, therefore, communication between television and cell phone will be accomplished because of the interrelationships with printer. Fig. 1 shows the network structure of smart home. Home network in this diagram refers to the network formed by the appliances which do not connect with home gateway directly.

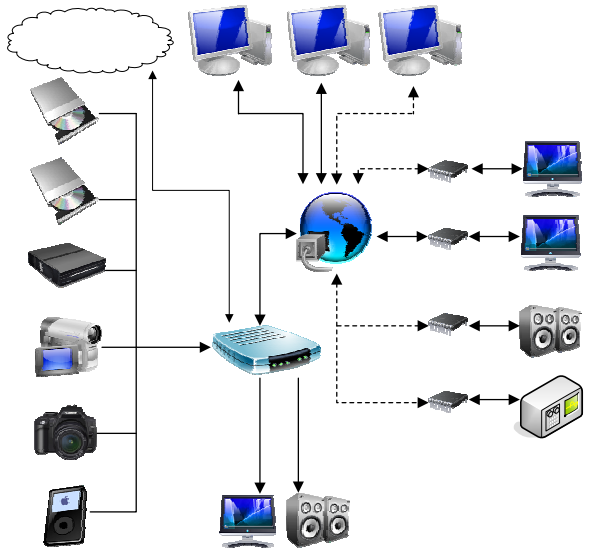

Figure 1. Network structure of smart home

- **Intelligent Control.** Smart home must be able to be controlled remotely. Remotely in this context mean both within the home and from outside of the home. Appliances and services at smart home can be managed and coordinated intelligently, such as auto-discovery and auto-deletion of equipment and services, auto-transformation of data between different equipments and auto-switching of tasks and so on.

- **Uniform Interface.** Not all of the appliances in smart home can be connected outside of smart home. Because there exists a distinction between protocols and devices interfaces, some appliances are inaccessible. Nevertheless, the technology of Web Service makes it easier that uniform interface can be built to meet all needs. Put another way, different kinds of appliances with integrated management are available.

B. *Home Gateway*

Software must be installed on home gateway to virtualize the whole smart home as a virtual resource, just like installing a virtual machine on a computer.

User can share the services provided by their digital home with others under the protection of authority control. Revenue model will also be considered.

The other function of home gateway is searching services out of home and figuring out which services can be used by appliances. Home gateway also stores the services as the format that suits appliances to make the services available.

There are various ways to modularize home gateway architecture, we propose the following plan.

- **Device Manager**

  This module virtualizes every appliance in smart home, which connects each device by interconnected network and interacts with them at lower level.

  Device manager has the ability of controlling all the devices and using them properly. Once a service request from the upper layer is received, Device Manager has the ability to rationally and effectively allocate them to maximizing the efficiency of work.

- **Service Manager**

  Service and device is not one-to-one correspondence, one device can provide several services and one service can be separated into several parts and submitted to different devices.

  Service Manager shields such corresponding relationship to the upper layer, but only provides services, and it interacts with Device Manager to implement the specific executive process.

- **Home Manager**

  This part is the general interface of smart home. It gathers the services provided by Service Manager and informs the Cloud when services added or changed.

  Home manager also stores the services provided by Cloud and register the services that can be used by appliances to Service Manager with the uniform format.

  Home Manager is considered as a node by the upper layer of it. Lots of smart homes gather together to form a cluster which has more powerful computing ability and more services. The cluster so-called Home Cloud, is a part of the whole Cloud architecture.

Open-source Cloud computing system, which can be rebuilt to adapt the needs of smart home gateway, is available now [13]. Some have been proposed home gateway architecture can be referenced [14] [15].

IV. CLOUD TOPOLOGICAL STRUCTURE

The topological structure of Cloud which based on smart home has no essential difference with usual Cloud structure. It is a modification of extant Cloud structure by adding smart home as a kind of infrastructure and integrating middleware into the Cloud management platform so that the smart home resources can be used like computer resources.

A. Enterprise Scale Public Cloud

The enterprise scale public cloud is necessary for the whole Cloud architecture to ensure that the Cloud can work well even without the support of smart home.

In general, the enterprise scale public cloud is provided by appliance manufacturers or vendors to offer after-sale increment service. Thus it must be able to process independently.

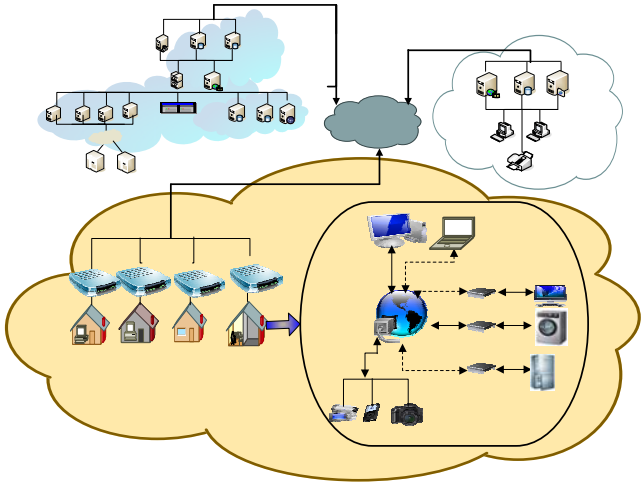

Figure 2. Cloud topological structure

B. Third Party Cloud

Enterprise scale public cloud offers very finite services due to the limitation of energy of appliance manufacturers or vendors. The services provided by enterprise scale public cloud, such as music and video services and auto-detect service are essential and usually necessary.

Therefore the whole Cloud architecture allows third party to create and deploy their own applications for appliance users or just for themselves.

To realize this function, the platform-based architecture, like Google App Engine, can be referred.

C. Smart Home Cloud

At the layer of home gateway, smart home is virtualized as node. Lots of nodes form a cluster which is the component of smart home cloud. Smart home cloud is a part of the whole Cloud architecture similar to other Clouds formed by computer clusters. The difference between computer cloud and smart home cloud is to provide different types of services.

Home gateway plays a significant role in smart home Cloud like computer operating system or virtual machine plays in computer Cloud. To be specific, it controls all of the services and provides methods to allow devices outside smart home to use them, and it also searches resources outside and inform home appliances how to use them.

V. CLOUD ARCHITECTURE BASED ON SMART HOME

The Cloud architecture based on smart home is divided into three parts: infrastructure layer, platform layer and service layer.

A. *Infrastructure Layer*

This layer is the lowest level one in Cloud architecture, which is composed of physical resources and virtualized resources. The virtualization component virtualizes all of the resources that the Cloud can control, including computing power, storage space, network resources and smart home.

B. *Platform Layer*

Platform layer is the most important layer, including resources manage module and security manage module.

The resources manage module is responsible for resource scheduling and detecting system processing status, as well as registering and removing the virtualized smart home.

Security manage component ensures the stability of Cloud processing and protects economic rights of third parties selling their services and the users share their services in a revenue model.

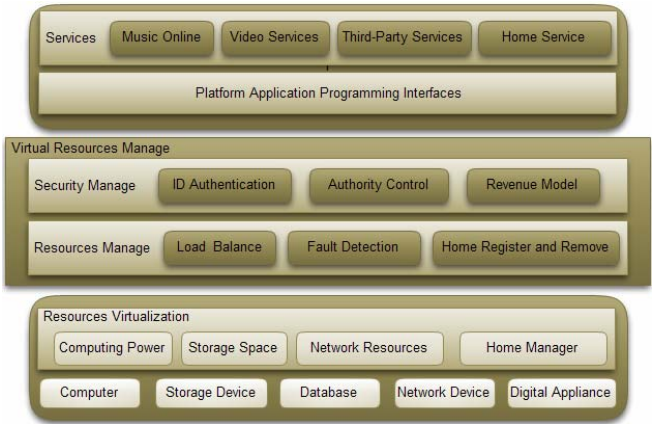

Figure 3. Cloud architecture diagram

C. *Service Layer*

Service layer directly faces the third party developers and the terminal users. Developers can create and deploy their applications and services conveniently using Application Programming Interfaces provided by the cloud platform.

Terminal services can be provided by enterprise public cloud, third party cloud or smart home cloud.

VI. CONCLUSION

In this paper we propose a new type of Cloud architecture: Cloud architecture based on smart home. Thus the Cloud applications can be extended to the domain of smart home so that more users can benefit from Cloud and the Cloud provider can have more potential users. By utilizing gateway technology, this architecture builds a bridge between Cloud and smart home so that smart home can be merged into Cloud to provide more information services and access services provided by Cloud.

The architecture that we propose is a conceptual model and more work need to be done to implement and better it.

ACKNOWLEDGMENT

We acknowledge Ph. D Mijun Kang for his instructive suggestions and Ph. D Wei Zhou for his valuable advice.

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