Home Automation as a Service

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Abstract—Home automation, as a model of pervasive computing, is progressively becoming substantial for people homed in developed societies. With the proliferation in the usage of household electronic and electrical appliances, numerous data and multifarious controls levy a cumbersome burden on residential home automation control units, making it expensive and difficult for the users to autonomously install, control and monitor the home automation system. In this paper, we convey the concept of Home Automation as a Service (HAaaS) based on cloud computing, which assist in shrinking residential computing workload and therefore making home automation more convenient, flexible, energy efficient and less expensive. Furthermore, cloud based HAaaS would readily endow the users the ability to remotely control and monitor their home automation system in real-time, from anywhere, via the Internet. We also present the design, implementation and operation of a cloud connected ad-hoc wireless home automation system as a working example of multi-user HAaaS and thereby infer that HAaaS is indeed fructuous.

Keywords - home automation; cloud; Internet; multimedia; appliances.

I. INTRODUCTION

Home automation is an umbrella term used to describe the use of specific automation techniques in private homes for enhanced convenience, comfort, energy efficiency and security of the residents. Prevalent techniques used in home automation include control of lighting, heating, ventilation, air conditioning, appliances, multi-media home entertainment, security surveillance and other systems. With the vast number of the household electronic and electrical appliances used in modern homes, the undertaking of home automation systems has become extensive and hefty.

Home Automation as a Service (HAaaS) can simplify this scenario by connecting each sub-system of a home automation system directly to the cloud, and thus not only reduce the setup and maintenance cost by eliminating the need of specialized gateway and web server in each household [1], but also enable HAaaS provi dersto deliver advanced automation services to the home automation system. Multi-user HAaaS must necessarily be based on the standard cloud computing model, in which services are made available to the general public over the Internet as long as they use the specified web application programming interface (API). Cloud computing refers to online services provided over the Internet together with the hardware and software infrastructure of the data centers that offer those services [2]. The services offered by existent cloud providers can be broadly categorized as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). In this paper, we discuss about these cloud services and highlight the relation of HAaaS with these services.

To endorse the expediency of HAaaS, we designed and actualized a cloud connected ad-hoc wireless home automation system as a virtuous case in point of HAaaS and tested the Quality of Service (QoS) of different sub-systems working simultaneously. We also devised our own cloud so as to empower the employment of specialized shared resources and demonstrate the upright functioning of the entire ecosystem while calling attention to the advantages of HAaaS over traditional home automation systems.

II. RELATED WORKS

A. Home Automation

The impingement of building automation on people’s lifestyles is as far reaching as that of industrial automation on manufacturing and its benefits stretches over all sections of a society. Building automation is realized by embedding small-scale microcomputers inside various appliances, all of which interact with the user and communicate with other appliances [3]. Home automation is a domain within building automation, focused towards certain automation requirements that are consistent with the domestic lifestyles of the residents. While several systems (such as illumination control, heating and ventilation control, control of doors and window shutters, security surveillance systems, etc.) deployed in building automation are also used in home automation, added functions in home automation can comprise of control of home entertainment systems, plant watering, pet feeding, changing the ambiance and the use of domestic robots. Cutting-edge systems can sense the presence and identity of a person and possibly set personalized illumination, temperature and music. Further refined systems may maintain a portfolio of merchandise, recording their usage through radio-frequency identification (RFID) tags, and formulate a shopping list to order replacements.

Classification of home automation models:

1. Individual Control devices: As the most primitive form of home automation implementation, these appliances (like washing machine, hair dryer, etc.) feature an independent control for themselves.

2. Distributed Control Systems: The most significant characteristic of this type of systems is that the
controllers are not central in location, but are distributed throughout the system and the entire system of controllers is connected by networks for communication and monitoring.

3. **Centrally Controlled Systems**: These systems are controlled by residential computers so as to regulate appliances like heaters, air conditioners, refrigerators, window shutters, cooking systems, etc. Regardless of their current location, residents may connect to the control system from anywhere via the Internet or telephone.

4. **Cloud Controlled Systems**: These systems are made up of embedded devices which are connected to cloud services via the Internet. Similar to centrally controlled systems, residents may connect to the control systems from anywhere, through the cloud, via the Internet.

**B. Cloud Services**

Cloud computing is often defined as a large-scale distributed computing paradigm that is driven by economies of scale (reductions in unit cost as the magnitude of usage levels increase), in which a pool of abstracted, virtualized, dynamically scalable, managed computing power, storage, platforms, and services are delivered on demand to users or customers, over the Internet [4].

Classification of cloud services:

1. **Software as a Service**

   SaaS is a software delivery model in which application software are hosted by a service provider or vendor and made accessible to clients over a network, usually the Internet.

2. **Platform as a Service**

   PaaS is a method to outsource computer hardware, operating systems, data storage and network bandwidth over a network, usually the Internet. PaaS distribution model permits the customer to rent virtualized servers and accompanying services to run application software or develop and evaluate new applications. PaaS is an extension of Software as a service, and offers numerous benefits for developers and designers.

3. **Infrastructure as a Service**

   Software as a service is becoming the dominant software distribution model as core technologies that support web services mature and the use of new developmental methodologies (like HTML5 and AJAX) become widespread. Correspondingly, expansion of broadband services to more areas facilitates user access from around the world.
IaaS is a delivery model in which a business or institute leases the tools used to undertake certain tasks, including computer hardware, data storage, networking hardware and network bandwidth. The vendor possesses the equipment and is responsible for operation and maintenance.

III. HOME AUTOMATION AS A SERVICE

HAaaS refers to the cloud services provided over the Internet together with the household appliances that are automated through those services. We regard HAaaS as a development of PaaS, where computer hardware, operating systems, data storage and network bandwidth are outsourced, while application and data are managed by the HAaaS provider. HAaaS users are in control of their automated home appliances and systems by using the cloud services.

To realize the amalgamation of cloud and home automation, the bridge to link cloud services with home automation systems needs to be efficient and effective. The link is essentially the Internet and the following are the two main approaches to linking:

A. Internet Gateway

Conventionally, smart homes use an Internet gateway to connect to the Internet [5], where the Internet gateway is largely a dedicated computer unit which allows coupled devices to access the Internet. In HAaaS, home automation systems and appliances may also be connected to the cloud through such an Internet gateway. Figure 4 shows how different household appliances can be connected to the cloud by linking to a residential Internet gateway.

B. Internet of Things

The Internet of Things (IoT) refers to distinctively recognizable objects (things) and their virtual representations in an Internet-like structure [6]. In HAaaS, individual home automation systems and appliances may be directly connected to the cloud as distinct objects and as a result avoid protocol conversions.

IV. A WORKING EXAMPLE OF HAaaS

The design of our IoT based home automation system makes it low cost, flexible and easy to install [7][8][9]. We replaced the traditional electrical switch board of each room with our cloud connected board, where each board is a node of the home automation system, as a result creating an ad-hoc
wireless network among all the boards in a household. Using 802.11n standard empowers us to create the ad-hoc network with adequate signal range to operate across a house and concurrently connect each node of the distributed home automation system directly to the cloud over Internet Protocol. Furthermore, we configured one board to act as an Internet gateway, by connecting it to a public HSDPA network of a national Internet Service Provider (ISP) with down-link speed of 7.2 Megabit/s and up-link speed of 1.8 Megabit/s. The wireless network is secured by Wi-Fi Protected Access II (WPA2) and encrypted with Counter Mode with Cipher Block Chaining Message Authentication Code Protocol (CCMP) encryption protocol.

We installed supplementary audio hardware to the cloud based home automation system we had implemented earlier. For audio playback we coupled a High Definition Audio Codec, Realtek ALC272, to the Southbridge, Intel ICH6-M (82801FBM). Featuring dual stereo digital-to-analog converters, dual stereo analog-to-digital converters, legacy analog input to analog output mixing, single stereophonic digital microphone converter, and dual independent Sony/Philips Digital Interconnect Format (SPDIF) output converters, the ALC272 provides a fully integrated audio solution. The ALC272 supports simultaneous analog microphone recording and up to 4 channel digital microphone array recording, and features Acoustic Echo Cancellation (AEC), Beam Forming (BF), and Noise Suppression (NS) for voice applications. The ALC272 CODEC’s power efficient design reduces power consumption when the audio function is not being used and offers jack detection wake-up when the system is in power down state so as to minimize power consumption without sacrificing audio features. The ALC272 CODEC’s digital interface circuitry operates on a 3.3V power supply. An integrated 50mW/20ohm headset audio amplifier for Front-Out and Surround-Out, a 14.318MHz to 24.576MHz phase-locked loop (PLL), and a PCBEEPER generator cut bill of materials (BOM) cost [10]. We also installed a set of auxiliary stereo speakers inside the board, with the option to plug in external speakers over a standard 3.5mm audio port. Along with audio hardware, we also installed audio software to play audio files from the cloud. On the front end, the software application provides control to music playback along with details of currently playing track. The controls are Play, Stop, Previous Track and Next Track. The details include Title, Album, Artist, Year and Album Art. On the back end, the software first decides a protocol on which the audio file is to be streamed and then plays the streaming audio file in synchronization with other boards.

We also installed supplementary security surveillance hardware and software to the cloud based home automation system we had implemented earlier. We installed software based location detection system and an improved infrared camera in each node. The improvement is made by fitting an additional wide-angle (also known as fisheye) lens to the camera [11], so as to have a full 180° view of observation. Since the board is installed on a wall, the camera acquires a complete view of a room. And since we replaced the electrical switch board of every room with our board, we get a complete view of the entire house. An application running on each board detects intrusion by the technique of motion detection [12], captured in the infrared camera. In case of an intrusion event, the application communicates with the cloud in order to notify the user.

Presently, the major functional modules are:

- **Power Management System**: One fundamental objective of home automation systems is to control home appliances remotely. In our project, we control and monitor a home power management system (a vital part of most home automation systems) from virtually anywhere using the central cloud based service.

- **Cloud Audio Player**: In our project, we implemented a cloud based audio player synchronized across the home automation network in all (or selected) rooms of a house, thus delivering a brilliant music listening experience across a household. We also deployed specially fabricated strategies and protocols to synchronize the playing of an audio file from the cloud using minimal network
bandwidth, in order to maintain a virtuous quality of service (QoS) for other components of the home automation network.

- **Intrusion Detection and Burglary Prevention System**: Security surveillance partakes in significant number of home automation systems, deploying digital cameras and sensors to monitor and report intrusion events and thereby reducing damages caused by burglary. Our cloud connected ad-hoc wireless home automation system has en suite intrusion detection and burglary prevention stratagems. Along with an improved infrared camera, each node of our home automation system has devised intelligent algorithms for intrusion detection and subsequently reports any event to a location-aware cloud service in real-time.

- **Location-Aware Advertising in Home Automation Systems**: With internet marketing being a driving force behind the growing internet economy, innovative and efficient ways to reach target markets are being pursued. In this project we designed and implemented an advertising framework which uses cloud connected home automation systems as the advertising platform. Moreover, en suite location awareness of the home automation system aids in effective geomarketing [13].

V. THE HAAAS CLOUD

To construct our cloud, we deployed an Intel Xeon and Windows Server 2008 R2 based system. A SMS modem connected to the cloud server is used for opt-in notifications to the users, in case of technical complications like blackout or network failure. The cloud’s web interface is used to control and monitor the home automation devices. The cloud can be accessed from any Internet enable device over an enforced [14] highly secure Hypertext Transfer Protocol Secure (HTTPS) connection from anywhere in the world. The web interface of the cloud requires password based user authentication. A user in entitle to add any number of board (nodes) to his account, which can also be removed if necessary. After authentication is completed successfully, the user is redirected to this page. The page acts as a dashboard to all the other pages.

![User interface diagram of the cloud’s web interface](image)

Fig. 8. User interface diagram of the cloud’s web interface

**Power Management Page**: Integrated with the home page, this page offers information about the status of different cloud connected boards added to the account. The page also provides the control to the home appliances and an option to add additional boards.

- **Cloud Audio Player page**: This page displays the user uploaded MP3 files’ information. Users can choose to play a file among the list. The page also provides other controls like next song, previous song, delete song, etc.

VI. QUALITY OF SERVICE

As with any real-time process, the process of home automation should comply with good operability and integrity. So, benchmark tests of the network gateway were conducted. The benchmark test result graphs generated by PRTG Network Monitor are shown in figure 10, 11 and 12.

![A graph showing gateway bandwidth usage in power management for duration of 2 hours.](image)

Fig. 10. A graph showing gateway bandwidth usage in power management for duration of 2 hours.
We found the result to be encouraging. On an average, less than 25% of the gateway bandwidth is in use for each home automation network with 5 boards operating simultaneously. This leaves out enough bandwidth to set up Resource Reservation Protocol - Traffic Engineering (RSVP-TE) across the IP network [15].

VII. CONCLUSION & FUTURE WORKS

The use of cloud services in home automation derives many benefits extending from cost reduction to value added services. For further work on the cloud based home automation network, we plan to add a multi-level cloud audio player and many more. On improving the security surveillance system, we plan to add more social integration through social networking sites like Facebook and Google+. With the help of these online social networks, we can easily contact and notify a user’s friends in case of an intrusion event and thus make burglary prevention more effective. We are also developing a socially interactive cloud audio player for home automation systems wherein users can share music on friend’s home automation network.

Apart from services, we plan to device a mechanism to improve the effectiveness of Smart Grids. Already functional in many cities, Smart Grids are a promising answer to a sustainable future. We can make these Smart Grids more efficient than the current model, by processing more specific real-time electricity usage data from the cloud, without causing detriment to user privacy. Moreover, the boards (nodes) used in our power management system can act as smart meters as well as load balancer, at little to no extra hardware cost.

REFERENCES


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