

A Home Automation System Based on Agent Architecture

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Abstract

In this paper, we propose the integration of software architecture and home gateway that makes our home automation system fit to various home environment. This is an integrated, flexible, expandable, and multi user interface for home automation system based on agent architecture. We consider the possible problems and try to find an efficient way to accomplish these problems in the reality home environment. We try to make human live in an intelligent home environment.

1 Introduction

Web browsing is a main home application of computer and network. However, such application does not make full use of the computing capabilities and network bandwidth. It is therefore desirable to provide services to networks in homes, for example, the goal of OSGI [1]. The popularity of residential networking, for example, IEEE 802-11B [3], LonWorks [4], enables the connectivity of home computing devices and appliances. By using a residential gateway as the Internet server of home network, we are able to develop web-based services that provide remote control and monitoring of home devices and appliances. Furthermore, the Public Switched Telephone Network (PSTN) [5] and mobile phone can be used as the auxiliary channels to enhance the personal mobility. In this paper, we attempt to employ the above technologies to develop a home automation system.

A home automation system can be divided into three layers (see [2] for example). At the bottom is the home network layer that employs residential network technologies to connect the computing devices and home appliance. The

middle layer is the service layer that consists of a number of service programs operating on top of the home network layer. At the top is the communication interface layer that consists of various channel for the service programs to communicate with the outside world. In this paper we employ the agent technology [6] to develop the service and the communication interface layers. Agents are programs that can act on behalf of someone. They have cognitive abilities that can work as assistants to users as well as to other agents[6]. We develop several service agents that use wireless technology to control and monitor home appliances. In addition, we develop communication agents that communicate with users using Internet, the PSTN and mobile phone as the channels. The service agents inform or warn the house owner about the situation of home environment and emergency by employing communication agents. If an agent informs the the facilitator to transmit emergency message to house-owner, facilitator will choice the best way to transmit this message. For example, the security agent has detected the temperature of the electric stove that is higher than 100°C, the security agent will inform the facilitator agent. Then facilitator agent will send the message by a telephone call to inform the house-owner.

In the home network layer we use wireless technology to connect home appliances to a home gateway. The home gateway is a computerized device that acts as the server inside the home environment. Technically, the home gateway is an embedded server that is attached to the wide area network to connect external network and the internal network [2]. In this paper, we install an agent platform, OAA [7], in the home gateway for the activations of service and communication agents. Service agents control and monitor home appliances through the home

gateway.

In order to achieve this goal of integration of home electronic appliance and gateway service, we propose an software architecture based on agent concepts that can make them integrate with each other. Each home electronic appliance will not working stand-alone but cooperate with one another, and with the capability to access Internet.

2 Survey of Related Research

2.1 Agent

Agents are programs that can act on behalf of someone. They have cognitive abilities that can work as assistants to users as well as to other agents[6]. The agent has the following characteristics:

- ² **Autonomy:** An agent is free to take actions without constraint. It may be required to explain its reasons and advertise its plans before taking action. Before it tack action, it may be required to ask permission or may not be permitted to take any actions but only to recommend them.
- ² **Delegation:** The agent performs a set of tasks on behalf of a user (or other agents) that are explicitly approved by the user.
- ² **Monitoring:** The agent needs to be able to monitor its environment in order to be able to perform tasks autonomously.
- ² **Capacity:** An agent may be designed to be a complex combination of other agents, or it may be as simple as a threshold switch.
- ² **Self-Knowledge:** Di®erent behavior needs di®erent knowledge, for example, intelligent behavior rquires that the agent be aware of the enviroment, and learning behavior requires that the agent be able to modify its self-knowledge.
- ² **Communication:** Agnets needs to be able to interact with user as well as to other agents for cooperation and competition among agents. The task status and completion can be informed by using agent communication language, such as KQML

2.2 Approaches to Home Networking

There are several approaches to home networking [11], which can be grouped into three classifications: networking solutions that require new wires, those that use existing wires, and those that are wireless, requiring no wires.

² New Wires

Ethernet based Category 5 UTP, Coaxial cable, fiber are options for new wiring. But it has the problems associated with installing new wires in homes. These problems can be solved by install these integrated cabling systems when constructing new homes if requested by the homebuyer. If consider the highest data rates and the reasonably priced, Ethernet solutions will be the best. But it will require additional rewiring and cost, if future changes to romm layouts or use .

² No New Wires

Since the house was built there are two existing wires network, phone lines and power lines . These two home network system provide more convenient and a®ordable alternatives for home users. Home Phone-line Networking Association(HomePNA) [12], utilize phone-line networking uses the same basic transmission technology as traditional Ethernet. The speed for this technology has increased from 1 Mbps to 10 Mbps. Since power outlets are found in almost every romm of the house, equipements can uses AC power lines connect to network PCs that o®ers more °exibility. The data transmission of this technology has traditionally been slow and unreliable. Therefor, industry standards are being created to solve these problems.

² No Wires (Wireless)

Wireless provide a way to enable mobility and convenience. A wireless home networking utilize radio frequency (RF) instead of wires or cables to transmit data. Most house-owner do not want to install the expense and inconvenience of running special cables throughout their homes. Wireless provide the simplify way for home networking.

3 System Design

3.1 System Requirements

System platform plays a key role in integrating remote controller, home electronic appliances, security device and user interface for home automation systems. The traditional approach of building the home automation system is based on monolithic applications. In general, a home automation system must have some requirements, including lighting, appliance control, energy management, security and safety, etc. The followings are the requirements of framework of our home automation system.

2 Interoperation and cooperation

There may be hundreds of agents on the home network. The platform must allow heterogeneous-agent systems to interoperate and cooperate among themselves. While every system-building framework must provide mechanisms of interoperation at some level of granularity, agent-based frameworks face important new challenges in this area. Platform has the responsibility to makes the ability of these systems to successfully execute, collaborate, and learn in a controlled manner.

2 Flexibility

The system must enables dynamic agent ensembles created by different vendors to cooperate robustly and flexibly. Traditional home automation systems lack dynamic agent join policies. You need shut down the whole system and add new agent into system then restart the system if you want join the new appliance into home network. We need a framework that can dynamic add or delete agent at development time and runtime.

2 Good User interfaces

A few years ago, features and reliability were what people noticed about a software application. An application that worked reliably gained a reputation as being more stable, and therefore more desirable. The user interface is the user's doorway to their experience with an application or web site. Designing it well is the key to making that experience a positive one. Designing an easy-to-use user interface seems to be an important thing. Good user interfaces building a bridge from computer to customer.

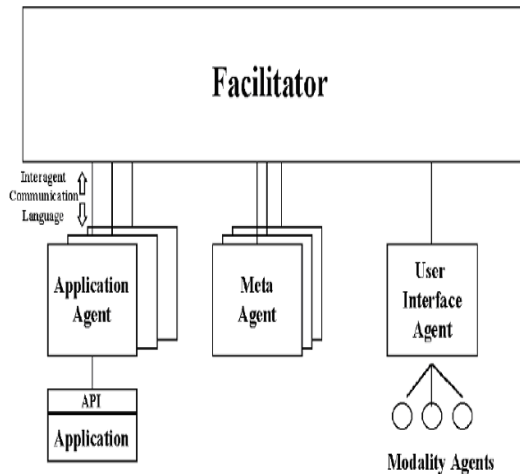


Figure 1: Open Agent Architecture

3.2 Open Agent Architecture

According to our system requirement, we will adapt OAA (Open Agent Architecture) [7] to be our platform. OAA is a framework for integrating a community of heterogeneous software agents in a distributed environment. With this platform, we can develop heterogeneous software agents in different way, but cooperate with each other.

The Open Agent Architecture (OAA), developed and used for several years at SRI International, makes it possible for software services to be provided through the cooperation between agents are brokered by one or more facilitators, which are responsible for matching requests, from users and agents, with descriptions of the capabilities of other agents. The DAI is comprised of the following classes of primitives:

Figure 1 presents the structure typical of a small OAA system, showing a user interface agent and several application agents and meta-agents, organized as a community of peers by their common relationship to a facilitator agent.

3.3 System Architecture

In order to integrate the home network with the home appliances, we will develop several agents in our home automation system. These agents can be divided into four main group agent, respectively, named as facilitator, appliance agent, communication agent and user interface agent. In the following, Figure 2 gives an overview of the system architecture proposed in this paper.



Figure 2: Architecture of home automation system

2 Home Gateway

The home gateway is the node that resides between the public network and the home network, and is the ingress node for the home network. Considering the requirements and the characteristics of the residential gateway, dynamic access from outside the home has to be considered. There, the access can be from anywhere and from any kind of node (e.g. PC or cellular phone). In order to realize easy access from these various environments, we propose to use the Web browser as a client GUI. If the users use the Internet environment from their PC or cellular phone to access the home gateway, then we should consider a firewall.

The home gateway should provide the basic service of network, including web server, firewall, NAT, etc.

2 Facilitator

As we mention in the previous section, the facilitator agent is a specialized server agent that is responsible for coordinating agent communications and cooperative problem-solving. The facilitator agent is the soul of the home automation system. Communication and cooperation between agents are brokered by one or more facilitators, which are responsible for matching requests, from users and agents, with descriptions of the capabilities of other agents. Thus, it is not generally required that a user or agent know the identities, lo-

cations, or number of other agents involved in satisfying a request.

2 Appliance Agent

In the home environment, there are thousands kind of home appliance. But we can divide it into two groups. One is the traditional electronic appliance, we can control it with on and off. The other is the information appliance (IA), we can control it with command. The difference between the information appliances and the traditional electronic appliances is the ability to accept command. If we want to develop an efficient home automation system, we must integrate the traditional electronic appliances and information appliance in home.

2 Communication Agent

For quickly notify the house-owner when the emergency situation is occur, we need communication agent to do this work. For example, the temperature of the electric rice cooker is higher than normal, the appliance agent will send message to Facilitator agent. The facilitator agent will need some way to notify the house-owner. It will send message to communication agent to notify the house-owner. The Communication agent can provide several ways to notify the house-owner. Users can choice the most convenient way to get message when the emergency situation is occur.

2 User interface Agent

Here we provide two main categories of user interface. One is the web browser that user can access the home network in anywhere by PC. Another is telephony technology that user will guide by voice to input their requirement for control home appliance. In order to use http protocol for remote access to the home automation system, we propose the user interface agent based on the Web server, and implementation of the functions of the system by enhancing the Web server functions. There are several ways to realize this, such as using Java servlets, the server side script, and common gateway interface (CGI). But we decided to use CGI to implement our agent, since CGI can easily forward requests to facilitator agent to the appropriate agent to do the appropriate action.

4 Implementation

4.1 Implementation of Agents

Implementation of our home automation system can be divided into four main agent groups, respectively, named as Facilitator, Communication Agents, Appliance Agents, User Interface Agents. The composition of our home automation system is shown in the Figure 3.

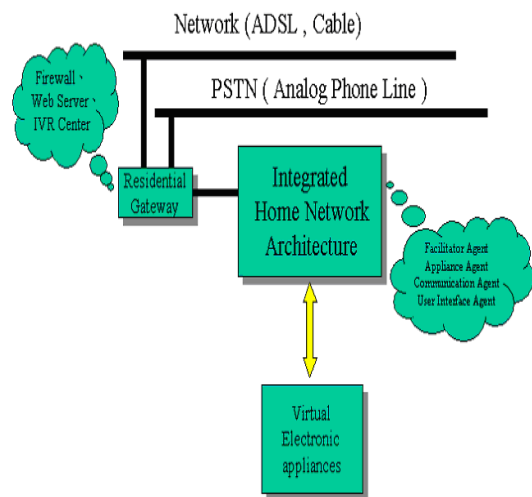


Figure 3: System Implementation

Facilitator

Facilitator is a specialized server that is responsible for coordinating agent communications and cooperative problem-solving. In many systems, the facilitator is also used to provide a global data store for its client agents, which allows them to adopt a blackboard style of interaction. Note that a system configuration is not limited to a single facilitator. Larger systems can be assembled from multiple facilitator/client groups, each having the sort of structure shown in Figure 4.

Communication Agents

Effective communication is essential for the function of home automation systems. While science and technology have greatly improved our capacity for communication, many different and convenient communication ways that we can combined into our home automation systems.

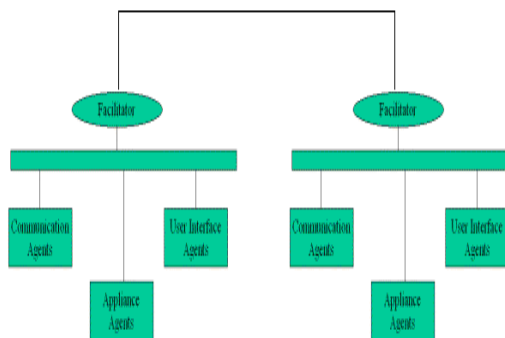


Figure 4: Multi-Facilitator

The mission of the communication agents is to inform the house-owner while the alarm system is been trigger. We have provided several different ways to inform the house-owner as soon as possible.

We built four modules for communication agent. They are telephone, Fax, SMS, and E-mail. We use the telephone line to call the house-owner, then play the voice by TTS(Text To Speech) after user pick up the phone. Fax agent using the WinFaxPro [10] and Modem for sending Fax. Short Message System(SMS) provide a way to send message to the mobil phone. E-mail will send out automatic by using SMTP(Simple Mail Transfer Protocol).

Appliance Agents

There are thousands of different appliances in the home network environment. We can divide it into two main kind of home appliances, one is traditional electronic appliance and the other is information appliance (IA).

2 Traditional electronic appliance

The traditional electronic appliance usually only have two function-On and Off. For example, lighting, Television. Today, the most appliances in the home environment is traditional electronic appliance.

2 Information appliance

The Information appliance has the capability to access the Internet. The difference between the information appliances and the traditional electronic appliances is the ability to access the Internet.

In order to develop an efficient home automation system, we provide a GUI tool to manage

these home appliances. User can use this program to deploy the home appliances and monitor the status of home appliance in runtime in each different home environment. We also propose various kind of appliance agent to apply on various home appliances. In this paper, we assume that every home appliance has ability to be connected to the home gateway whether it is an information appliance or not.

User Interface Agents

Interface design is important for several reasons. First of all the more intuitive the user interface the easier it is to use, and the easier it is to use the cheaper it is. The better the user interface the easier it is to train people to use it, reducing your training costs.

The tough choices come when trying to match the system needs with the available technology options for the best possible result. For example, dial access over the Public Switched Telephone Network (PSTN) is the most widely available physical access technology and is very secure, but cannot provide broadband connectivity when needed. Gigabit Ethernet provides very cost effective broadband access, but is not widely available to every site.

There are two main user interface in our home automation system, include web browser and telephone. User can access the system in anywhere and anytime. Telephone agent using the Dialogic card to handle the user input,DTMF(Dual-Tone Multi-Frequency),for operate the home appliances. It can interact with the user by voice(Text To Speech). Web browser provide a GUI operating system to remote control and monitor the home appliances. It use the CGI(Common Gateway Interface) technology to accept command.

4.2 Appliances Deployment and Management

There are various and heterogeneous appliances in the home environment. We provide a effective tool to manage these appliances in the different home environment. Users can drag and drop their appliances in the home base by WYSIWYG(What You See Is What You Get). The deployment of home appliances can't the virous home environment. The sample of the home appliances deployment is show in figure 5.

Here, we will step by step to demonstrate how to deploy home appliances in the easy way.

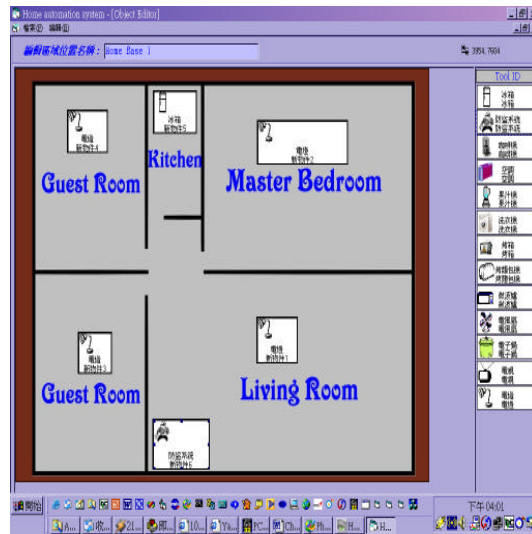


Figure 5: Appliances deployment

Step 1. Draw a base bitmap of home environment in each case.

Step 2. Import home appliances into simulation system.

Step 3. Edit the home appliances ID and it's description.

Step 4. Drag and Drop the home appliance into the home base.

Step 5. Assign the ID to the appropriate appliance.

5 OSGi

The Open Services Gateway Initiative (OSGi), established in 1999, has more than 80 member companies. The OSGi Framework and Specifications facilitate the installation and operation of multiple services on a single Open Services Gateway (set-top box, cable or DSL modem, PC, Web phone, automotive, multimedia gateway or dedicated residential gateway) [1].

The OSGi Specifications provide a set of Application Programming Interface (API) standard for a gateway platform execution environment. In order to conform to the OSGi specification, Open Services Gateways must support these API standards. The following is a high-level summary of the key benefits associated with the OSGi specifications.

- 2 Platform Independent
- 2 Application Independent
- 2 Secure

- 2 Multiple Services
- 2 Multiple Local Network Technologies
- 2 Multiple Device Access Technologies
- 2 Co-existence with other Standards

OSGi can be implemented in this home automation system. OSGi provide a set of APIs between the outside network and internal home network. Using OSGi APIs, edn-users can load network-based services on demand from Service Provider to home appliances. Since we have divided our system into three layers. The middle layer is our service layer, for provide useful programs, in the home gateway. The protocol of the middle layer, which is defined by us, is a closed system for the top layer and bottom layer. The advantage of this system is easy to implement and management, but for provide the common service. So, we can replace the middle layer with OSGi. Then we can provide the more powerful service between the top layer and bottom layer. It is easy to replace the middle layer with any protocol, since we adapted the three layer and Open Agent Architecture concept.

6 Conclusion

In this paper we proposed a home automation system based on OAA. In the proposed architecture, agents can interact each other flexibly using Interagent Communication Language(ICL), and agents can be distributed over home network.

We implement the home networking, by RF module, to connect the home gateway and home appliances. User can through the user interface agent by using the web browser or telephony to access the home automation system. Service Agent can provide the valuable information to user through the communication agent by using telephone, Fax, SMS, and E-mail. Appliances deployment and management tool provide a easy way to deploy and manage the home appliances in the different home environment.

OSGi is consider in the next version for provide the strongly service. More service provider can provide the service to the home appliances for enhance their ability. This system also can be implemented in the large building, such as factory and hospital, to manage the machines and energy. The concept of Intelligent Agent will be implemented in the next version of home automation system to make home smarter.

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