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Smart Home System based on IOT Technologies

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***Abstract*— The idea of applying IOT technologies to smart home system is introduced. An original architecture of the integrated system is analyzed with its detailed introduction. This architecture has great scalability. Based on this proposed architecture many applications can be integrated into the system through uniform interface. Agents are proposed to communicate with appliances through RFID tags. Key issues to be solved to promote the development of smart home system are also discussed.**

Keywords-smart home; IOT; agent; RFID; architecture

I. INTRODUCTION

IOT is an abbreviation of Internet of Things [1], which refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. Radio frequency identification (RFID) is often seen as a prerequisite for IOT. If all objects and people in daily life were equipped with RFID tags, they could be identified and inventoried by computers.

Smart home has been a hot area of research for several years and has attracted attention from academy and industry in recent years. Researches have been focused on design of architecture, infrastructure, intercommunication and realization of smart home system. Research interests from industry also promote the study of smart home, like Siemens exiderdome plan.

Survey of smart home [2], from its definition, current research status, related research projects to the challenges, is provided. As it is mentioned that smart home is "a dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed". The home gateway, which transfers different protocols and connects inner network to the internet, be viewed as a key realization of the smart home in [3]. A solution [4] to smart home system is provided in current situation, which is in a stage that lack of a set of universal standard criterions and interface protocols on domestic smart home network. In [5] the idea of using power line to transfer information is modeled and simulated in LAN, but this method has some limitations and [6] discussed in detail some vital limitations of this kind of data transfer method. An idea of modeling appliances in smart home system as services is provided in [7]. The system architecture is also provided.

It is clear that realization of smart home system needs much research efforts. The following section provides a new approach for the research of smart home, which incorporates IOT technologies into smart home system.

This paper is organized as follows. In Section 2 we will introduce some base conceptions about IOT. In Section 3, a new architecture of smart home is introduced. Section 4 concludes the paper and gives issues that need future investigation.

II. ABOUT IOT

IOT is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things, such as RFID tags, sensors, actuators, mobile phones, etc. which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [8].

IOT can be divided into three layers, which are perception layer, network layer and application layer respectively. Perception layer is responsible for data collection in IOT. It consists of all kinds of sensors, like temperature sensor, humidity sensor, RFID tags and related readers, camera, GPS and so on. Network layer is composed of all kinds of networks, like the internet, the 2G and 3G communication networks, broadcast network. Network layer is mainly used to collect data from perception layer and processing these data for application layer. Application layer is the interface between users and IOT. Many applications including logistics, supply chain, agriculture, industry, public security, urban management, telemedicine, smart home, intelligent transportation, and environmental monitoring, are enabled.

III. ARCHITECTURE FOR SMART HOME USING IOT TECHNOLOGIES

Current situation of home system is that each household appliance works separately. There is almost no cooperation and communication among appliances. Look around our current house, different appliances have different controllers. The idea of integrating all these home appliances into an intelligent system which will bring much convenience for householders is attractive. To realize such integration, architecture of such system should be well considered. The following table 1 describes such architecture of smart home system based on IOT technologies.

In Table 1, the bottom level is resource layer, which includes all kinds of household appliances with RFID tags to identify them. For example television, telephone, air condition, washing machine, oven, automobile, mobile phone and so on. RFID tags are attached on these appliances so that they can quickly be identified and controlled. These resources work coordinately under a centralized controller in a uniform style.

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TABLE I. ARCHITECTURE OF IOT BASED SMART HOME

User Application Layer		
Kernel Layer	Agent Management	Data Transportation
	Authentication and Authorization	State Monitor
Agent Layer	Agents	
Interface Layer	Appliance Specific Service Interface	
Resource Layer (Household appliances)		

The second level from bottom is interface layer. This layer provides different interfaces for all kinds of resources. Through this level, all resources are modeled into different services for its upper layers.

The third level from bottom is agent layer. Agents are producers, consumers and brokers of services provided by interface level. Every resource is controlled by its corresponding agent. For example, TV has TV agent to control it and air condition has its related agent. RFID tags play important role in the communication process between appliances and agents. From view of upper layer, all resources are represented by their corresponding agents. The manipulation of resources can be implemented by sending commands to their related agents. These agents can communicate with each other to fulfill different tasks according to various context and ontologies.

The second top level is kernel layer, which manages agents. It is a vital level in this architecture and mainly includes following functions: Agent Management, Data Transportation, Authentication and Authorization and State Monitoring.

Agent management includes agent registry, agent discovery, agent invocation and agent elimination. When a new household appliance is installed and assigned a RFID tag, an agent will be allocated to it by smart home controller, which will be mentioned in the following part. The smart home controller initializes state of agent and binding it with RFID tag of new appliance, thus information of this appliance can be available to other agents. This is the process of registry. Agent discovery means when a task is to be performed, controller will query all related agents which has been registered, after receiving responses from these agents, controller knows which appliance are available and which are not and why. If an agent reports its related appliance is available, controller will send command to it to fulfill tasks that need participation of its bonding appliance. This is the process of agent invocation. Agent elimination means purposely terminate an agent for some reason. For example, when an appliance is removed from the system and the agent can not contact with its appliance for a given time, then the system will eliminate this agent automatically.

Data transportation means information exchanged between different agents. Through this way, interoperation of agents can be realizable. For example, to fulfill a task, an agent needs cooperation of another agent. It will send command and data to that agent and invites it sharing this job.

Authentication and authorization based on CA (Certification Authority), is popular in IOT. While in smart home system, CA can also be used. Different CA can be built for different home and usually the CA center locates in smart home controllers. When an agent is registered, in initialization process, a certification is issued by CA. The controller also has a certification issued by CA. When an agent is invoked for an operation, the controller or other agents will send their certification to the agent. If the certification is qualified to manipulate the agent, then the agent will send its own certification back to the caller. This is the process of dual checking. The agent will work only if two certifications are both qualified to each other. The controller can make its subordinate agents available to other smart home controllers or agents by means of authorization. The agents or controllers who received an authorization can use related functions. Figure 1 demonstrates this process.

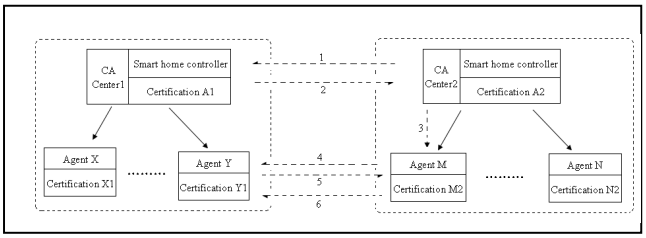

Figure 1. Process of dual checking.

In Figure 1, it is obvious that each smart home system has a CA center, which is responsible for issue certifications for home appliances in its domain. Each certification can be recognized and accepted by agents in the same domain. Systems beyond this domain can ask for a temporary certification issued by the target system's controller. The above six steps demonstrate the entire process, for example person A want to park his car into person B's garage. In Step1, one smart home controller sends a request for the certification to some appliances in another smart home system. This action is often invoked by human not the agent for sake of security consideration. In this example, person A sends his request for a temporary certification of B's garage through his controller, an intelligent mobile phone in this case, to B's controller, a PC for example. B agrees this request and generates a garage's certification, then send back to A in step 2. A passes the certification to the agent of his car in step 3. In step 4 and 5, the car's agent sends the certification to B's garage's agent, and the garage's agent also sends its own certification to the car's agent after it checked out that the certification send to it is a legal one. The process is dual checking. In step 6, the car's agent asks garage's agent to open the garage.

State monitor keeps on touch with agents to get their appliance's state information. This can provide dynamic information to its upper level. The fault diagnosis function is included in state monitor. Through the monitor, causes and location of the fault can be easily located.

The top level is user application interface. In this level, users just need to choose appliance and its functions he or she can access. The entire process of how agents are invoked, how data is transported is totally transparent to users.

Figure 2 demonstrates the architecture mentioned above more clearly.

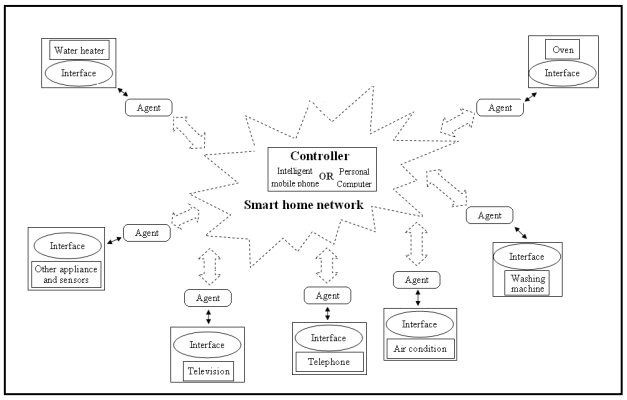

Figure 2. Architecture of smart home.

From Figure 2, we can find that each household appliance, which is identified by RFID tags, has interfaces with it. The interface implements functions of interface layer mentioned above. The controller can be an intelligent mobile phone or PC. Agents are both software representation and manipulator of physical appliances. The kernel layer, user application layer can be integrated into the controller. Information about registered agents, CA, certification and user interfaces are all stored in the controller. Smart home network is the network in home. It can be a wireless LAN, a Bluetooth LAN, GSM or a normal LAN. Smart home network is supporting infrastructure for communication between agents and controller. Outside request information (in form of XML or HTML) can reach the system bridged by internet, GSM or 3G networks. Several smart home systems together consist of a virtual organization to share each other's resources.

IV. CONCLUSIONS

From above two sections, it is obvious that the IOT based smart home has many benefits.

Firstly it is compatible with current household appliances. It doesn't mean discarding current technologies, but to collaborate with them to provide a better life.

Secondly it is scalable. Any new appliance complying with this architecture and protocols can be added into the system. Current appliance can be added into the system through interface.

Thirdly it is convenient to use this system. The control center communicates with users. The agent can interoperate with each other, under constraints of ontology, using service oriented language, which is suggested to be a promising programming language in the next few years.

Although above gives a beautiful blueprint. There is still a long way to go especially in the following three aspects.

The first and foremost issue is protocols. The protocols in IOT still need to be finalized. How to translate the WSDL or RDF, which is XML based specifications, into a way that the appliance, with litter or no memory and calculation ability, can understand

The second issue is context awareness ability. Ontologies defined different applicable rules under different conditions, but how can agents detect different context is still unsolved.

The last but not least is security problem. This includes two aspects, security of user certification and safety of appliances themselves. The certification mechanism and the information transfer method are to be further explored. The safety of appliances requires a set of scientific manipulation rules and a set of fault diagnosis mechanism.

This paper tries to integrate IOT technologies into smart home system. The contribution lies in the proposition of an architecture that integrate IOT into smart home system. The intention of this paper is to draw more interests of these two rapidly developing fields, IOT and smart home system, and expects to do contribution to both.

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