An Intelligent Agent for RFID-based Home Network System

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Abstract. An intelligent agent which is a software component for the efficient home network system is proposed in this paper. The agent consists of six modules such as the Agent Manager, the Data Collector, the Execution Controller, the Data Storage, the Data Queue and the User Interface. The Agent Manager manages the tasks of modules, and the Data Collector collects the data from home appliances through the RFID readers. The Execution Controller determines the operations of home appliances according to the conditions of the home environment and transfers the operations to the appliances through the RFID readers. Moreover, the Data Storage keeps the data which is necessary for the operations of the agent, and the Data Queue temporarily stores the data which is collected from home appliances. Lastly, the User Interface provides the graphical user interface in which an individual can directly control and monitor the home network. The proposed intelligent agent autonomously learns the circumstances of a home network by analyzing the data about the state of home appliances, and provides the best suited environment to the user. Therefore, the user can live in an optimal home environment without effort if he/she performs home networking through the agent.

1 Introduction

The PCs which are connected to the networks become important means for business support according as many PCs and networks connected with them are actively supplied. Moreover, not only wireless home networking which supports the communication between home appliances such as TVs, refrigerators, computers, PDAs and portable phones but also the unlimited communication between home appliances and the outside becomes possible because of the spread of the Internet and the recent rapid technological advances. Accordingly, home networking which binds home appliances is a hot issue in this century. Home networking means the digitalization of information; that is, information which can be processed is supplied to the home. This means that the efficiency of home life can be maximized through the home networking [1].

However, it is difficult to apply various home appliances in the current home network because IP addresses must be assigned to every appliance in the home network. It is too labor intensive to find proper appliances to communicate if a

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wireless LAN is used in the home network. Furthermore, a home network system must be modified in case of the addition of new appliances; it is difficult to implement modules for TCP/IP communication.

To solve these issues, RFID (Radio Frequency IDentification) can be applied to the home network. RFID is an automatic identification technology that replaces traditional barcode technology. It reads and writes information without touching target objects using wireless communication technology. The barcode technology is developed and the price of a barcode is cheap, but they can be identified in close range without any obstruction between a scanner and a barcode because of the use of infrared rays. Moreover, it takes too long to identify a target; several of them cannot be identified at once. The amount of information stored is limited and the security is weak. RFID tags can be identified though there may be an obstruction between reader and tag because RFID uses radio frequency instead of infrared rays, and the tags can be identified at a maximum distance of 30 meters. Furthermore, several targets can be identified at the same time and many more kinds of information can be securely stored and communicated according to the change of time and conditions [2].

Various appliances can be incorporated into a home network because home networking is performed using radio frequency without assigning IP to each appliance if the RFID is applied to the home network. Moreover, a home network system need not be modified much when new appliances are added to the home network. More efficient home networking will be implemented because it is easy to implement and apply the RFID-based home network system.

Therefore, an intelligent agent for efficiently managing the RFID-based home network is stated here. The efficiency of home life at home will be maximized through the home network which has an intelligent agent that learns by itself.

2 Related Works

2.1 Home Network

A home network is a set of components that connects and integrates several appliances which perform calculation, management, monitoring and communication in order to process, manage, transmit and store information in a house. The home network is composed of association of equipments more than two which have the capability to share data and communicate. The structure of a home network is composed of a home gateway which connects the inside network with the outside network, middleware which controls the communication network and information devices in the house, and devices which include the functions for home networking. This is implemented through various networking protocol such as Ethernet, telephone lines, power lines and wireless. It also facilitates the sharing of functions and data, and the remote control between home appliances connected with the network. Furthermore, it offers Internet access, audio/video streaming, and home control applications and services [3].

2.2 RFID (Radio Frequency IDentification)

RFID is a means of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit, and is now being seen as a radical means of enhancing data handling processes [4]. An RFID system has several basic components including a number of RFID readers, RFID tags, and the communication between them. The components of RFID system are represented in Figure 1.

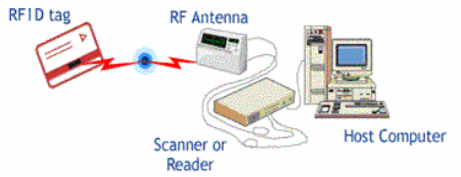

Fig. 1. Components of RFID System

The RFID reader can scan data emitted from RFID tags. RFID readers and tags use a defined radio frequency and protocol to transmit and receive data [5].

RFID tags are classified into three sub-classes, namely passive, semi-passive, and active. Passive RFID tags do not require batteries for operation and are, therefore, inherently robust, reliable, and low-cost. Their construction is relatively simple. A high performance passive RFID tag consists of a tiny integrated circuit chip, a printed antenna, and an adhesive label substrate for application to items. Active and semipassive tags require batteries for operation and, therefore, provide a greater range and throughput than passive (batteryless) tags. The simple addition of a battery to an RFID tag is a necessary but incomplete feature that classifies it as active [6][7].

2.3 RFID/USN (Ubiquitous Sensor Network)

RFID/USN manages information through the network by detecting real time information of objects which attach RFID. It binds itself to anything with not only its sensory information but also the information of its surroundings such as temperature, humidity, pollution and cracks. The ultimate purpose of the RFID/USN is to implement ubiquitous environments. RFID/USN focuses on the RFID which stores data, and sensing capability will be added to the RFID in the near future. Finally, networking capability will be added to the RFID [8][9].

The use of RFID/USN will increase step by step according to the development of sensor technology. RFID tags will become smaller in size and more intelligent while the price of them will decrease. Accordingly, the use of RFID will be expanded in the fields of logistics, distribution, circumstances, prevention of accidents, management of medical care and management of food. RFID will be developed into a smarter micro network sensor by adding sensing and communication facilities. In the future, the RFID/USN will be evolved into the level that can recognize and manage surroundings by multi-functional tags from the current level that recognizes the fixed code of objects, and will be developed into an intelligent USN which has a communication facility [9].

3 Architecture of RFID-based Home Network

Home appliances with RFID sensors which are RFID tags with sensing facillity, RFID readers that read data from RFID tags and write data to RFID tags, and a home server which controls the home network are necessary for the construction of a RFID-based home network. Moreover, mobile devices which can communicate with a home server using wireless LAN are needed in order to control the home network while a user is moving. Figure 2 is the structure of this RFID-based home network.

RFID sensors[7] are attached to all appliances in order to sense the state of appliances in the RFID-based home network. RFID sensors periodically assess the state of home appliances and write the state on to RFID tags. RFID readers read the data from RFID tags and transfer the data to the home server. The intelligent agent of the home server collects and analyzes the data from RFID readers, determines the operations of home appliances in order to maintain an optimal environment for the house owner, and controls the home appliances to perform the operations by transferring them through RFID readers. Furthermore, the agent provides the service that the house owner can directly control and monitor the home network.

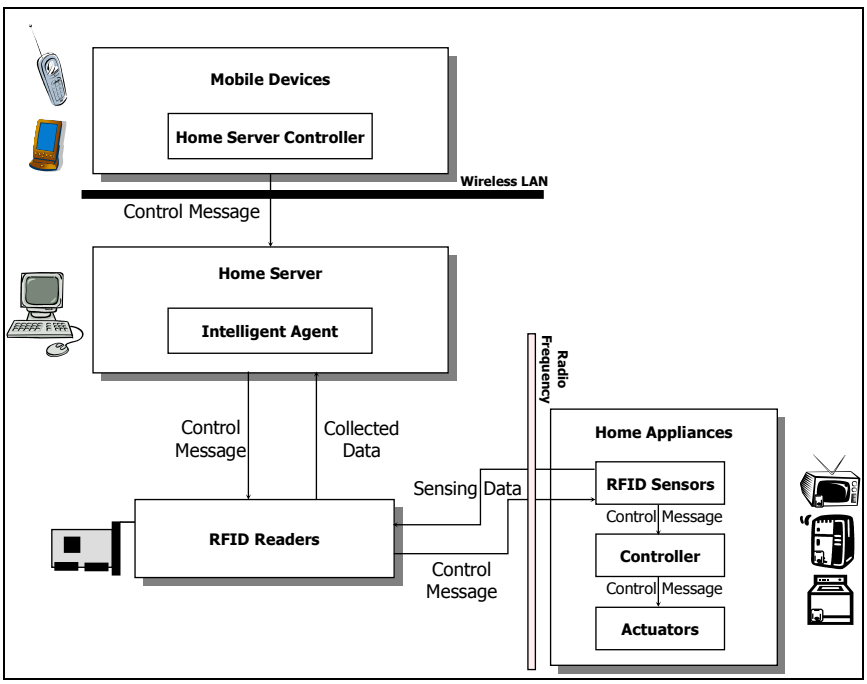

Fig. 2. Architecture of RFID-based Home Network

The following is the process of RFID-based home networking.

① RFID sensors periodically sense the state of home appliances. They sense the current state of appliances, store the state in tags, and transfer the state to RFID readers.

② RFID readers read the state of home appliances from RFID sensors. Not only do RFID readers receive the data transferred from RFID sensors, but also they periodically check the RFID sensors and read data about the state of home appliances.
③ The intelligent agent of the home server collects data from RFID readers, analyzes the data, and determines the operations of home appliances in order to provide an optimal environment to the user of home network.
④ The intelligent agent of the home server sends control messages to the RFID readers after it determines the operations.
⑤ RFID readers transfer the control messages received from the home server to home appliances.
⑥ Home appliances perform operations according to the control messages.

4 Intelligent Agent for RFID-based Home Networking

An intelligent agent which autonomously controls RFID-based home networking is proposed in this section.

The user of a home network must periodically monitor the environment of his/her home network and manage the home network to maintain an optimal home environment for him/her. This is a labor intensive process on the part of the user. Accordingly, an agent that can autonomously control the home network instead of the user is necessary in order to save the effort and the time of the user. This agent must continuously collect the data from RFID sensors, analyze the collected data, and find out the inclinations of the user based on the analyzed information. Moreover, it must continuously monitor and control the home network to provide an optimal home environment according to the desires of the user.

4.1 Structure

The intelligent agent collects data from RFID sensors, analyzes the data, and controls the home network to maintain the most comfortable home environment based on the data. Figure 3 represents the intelligent agent for RFID-based home networking. This agent consists of six modules: the Agent Manager, the Data Collector, the Execution Controller, the Data Storage, the Data Queue and the User Interface.

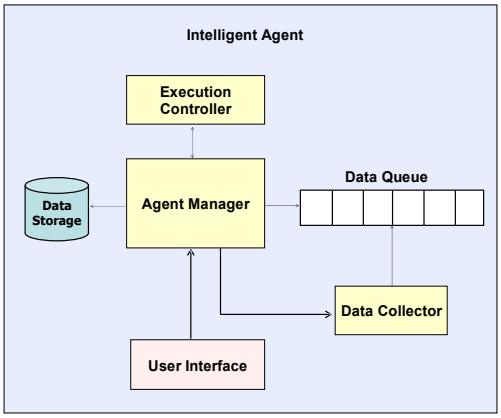

Fig. 3. Intelligent Agent

Agent Manager

The management of intelligent agent and study about the inclination of the user are necessary in order to maintain the best suited home networking for the user.

The Agent Manager manages modules in the agent so that they can accomplish accurately their tasks. In addition, it determines the best suited home networking for the house owner by analyzing the data which is gathered by the Data Collector and stored in the Data Queue.

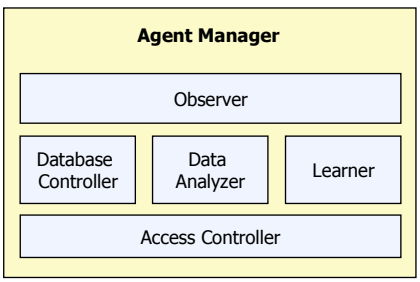

Fig. 4. Agent Manager

Figure 4 represents the structure of the Agent Manager. The Agent Manager consists of the Access Controller, the Database Controller, the Data Analyzer, the Learner and the Observer.

The following is the description of the five modules in the Agent Manager:

* Access Controller: This supervises the access to the agent from the outside. Only authorized users can access the agent in order to directly monitor and control the home network.
* Database Controller: This provides basic primitives for database operations, such as selection, insertion, update and deletion. The manipulation of information in the Data Storage is performed using this module.

* Data Analyzer: This analyzes the data read from RFID sensors. It looks at the data about the state of home appliances from RFID sensors which are attached to the home appliances in the home network and understands the current circumstances of the home network.
* Learner: This component studies the inclination of the user based on the information from the Data Analyzer. It imitates the wishes of the user from the past and current analyzed information about the environment of the home network. The following is the algorithm of the Learner. The Learner studies the inclination of the user based on the data of home appliances during the past 7 days. Every hour it analyzes the data of the same time zone during the past 7 days and understands the inclination of the user based on the repeated data over the setting probability.

```
Define a device which has just on/off information as SimpleDevice.
Define a device which has on/off and additional information as ComplexDevice.

begin
  for i = 0 to (SimpleDevice_Count)
    for j = 1 to 24  // get data of recent 7 days  from SimpleDevice_Tables
      Execute query "Select Count(*), action from SimpleDevice_Tables[i]
                     WHERE datetime = j and user = CurrentUser and date >= CurrentDate-7 group by action";
      count_on := count of on;
      count_off := count of off;
      total_count := count_on + count_off;
      if( count_on >= (total_count*probability) ) then  // probability is a user-defined percentage
        SimpleDeviceInfo[i][j] := on;                   // total_count *probability is frequency of the action
      else if (count_off >= (total_count*probability) ) then
                SimpleDeviceInfo[i][j] := off;
      end if;
    end for;
  end for;
  for i = 0 to (ComplexDevice_Count)
    for j = 1 to 24  // get data of recent 7 days  from ComplexDevice_Tables
      Execute query "Select Count(*), action from ComplexDevice_Tables[i]
                     WHERE date >= CurrentDate-7 and datetime = j and user = CurrentUser group by action";
      count_on := count of on
      count_off := count of off
      total_count := count_on + count_off;
      if( count_on >= (total_count*probability) ) then
        Execute query "Select Count(*), additionalInfo from ComplexDevice_Table[i]
                       WHERE date >= CurrentDate-7 and datetime = j and action = on and user = CurrentUser
                       group by additionalInfo";
        info := most frequent additionalInfo;
        ComplexDeviceInfo[i][j] := on;
        ComplexDeviceadditionalInfo[i][j] := info;
      else if( count_off >= (total_count*probability) ) then
        ComplexDeviceInfo[i][j] := off;
      end if;
    end for;
  end for;
end;
```

* Observer: This monitors the execution of modules in the agent and manages the modules to correctly perform their roles.

Data Collector

It is necessary that the states of home appliances are continuously read from RFID sensors in order to maintain the home environments of the user.

The Data Collector continuously sends messages to the RFID readers, collects new data received from RFID sensors, and stores the data in the Data Queue. It collects the data from the RFID readers if the RFID sensors sense the states of the home appliances and actively sends the data to the RFID readers. In addition, it sends

messages to the RFID readers to read the data from the RFID sensors according to the necessity.

Execution Controller
The proper operations according to the conditions should be determined, and performed by the home appliances in order to maintain the best suited home environments for the user after studying about the inclination of the user.

The Execution Controller determines the operations of home appliances according to the conditions of the home environment in order to maintain an optimal home environment for the user. It also sends control messages to the RFID readers in order to control the home appliances.

Data Storage
The information such as the previous operations and the inclination of the user is necessary in order to autonomously maintain the home environments. For this, the storage which stores the information is necessary.

The Data Storage is the database of the agent. Each module of the agent gets the data for operations from the Data Storage, performs its operations and stores the data which must be preserved in the Data Storage according to the result of the operations. The information about the wishes of the user, which is received by analyzing the data of the home network, is stored in the Data Storage and it is updated continuously.

Data Queue
The data which is periodically read from RFID sensors should be temporarily stored in order to analyze the current home environments.

The Data Queue is temporary storage. The data which is read from the RFID sensors is held here for a short time before it is processed. RFID sensors which are attached to home appliances periodically transfer the data to the RFID readers simultaneously and the Data Collector gathers the data which is transferred from several RFID sensors at a time. Therefore, it is necessary to temporarily store the data so that the Execution Controller can analyze the data and perform proper operations.

User Interface
It should be easy and convenient that the user directly controls the home network.

The User Interface is a GUI (Graphical User Interface). The intelligent agent autonomously maintains the optimal home network environment according to the desires of the user, but the user can control the home network using this interface if he or she wants. Moreover, the user can monitor the home network using this interface.

4.2 Collaborations

The modules of the intelligent agent collaborate with each other as figure 5 in order to control the home network. This collaboration shows that the agent autonomously controls the home network. The user can perform these tasks through the User Interface if he or she wants to directly control the home network.

* The Data Collector collects the data that the RFID sensors attached to home appliances such as an indoor thermometer, refrigerator, TV, lighting and water heater, sense the states of the appliances and send to the RFID readers, and stores the collected data in the Data Queue. For example, the Data Collector gathers the data such as the current indoor temperature, the current temperature of refrigerator and the on/off state of the TV, and stores the data in the Data Queue.
* The Agent Manager reads the collected data from the Data Queue, analyzes the data, learns the wishes of the user of the home network and stores the results in Data Storage. For example, the Agent Manager reads the data about the indoor temperature, air conditioner and water heater, and analyzes the data. As a result of the analysis, the Agent Manager may find out that the user of the home network turned on the air conditioner if the indoor temperature was higher than 25°C and turned on the water heater if the indoor temperature was lower than 20°C. The Agent Manager learns that the user prefers indoor temperature between 20°C and 25°C, and stores the result in the Data Storage.
* The Execution Controller determines the operations of home appliances according to the current circumstances based on the desires of the user. For example, the Execution Controller may determine that the air conditioner should be turned on in order to decrease the indoor temperature if the current indoor temperature is higher than 25°C because the user prefers an indoor temperature between 20°C and 25°C.
* The Execution Controller stores the determination in the Data Storage and transfers it to the home appliances through RFID readers to perform the operations. For example, the Execution Controller stores the indoor temperature and the operation of the air conditioner in the Data Storage if it determines that the air conditioner should be turned on, and transfers the information to the RFID sensor attached to the air conditioner. Then the air conditioner is turned on through its controller.

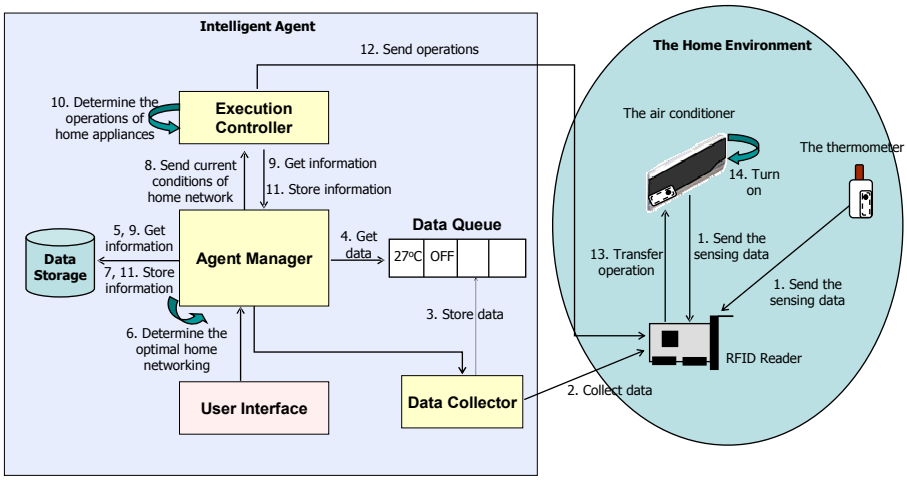

Fig. 5. Collaborations of Modules in the Intelligent Agent

5 Conclusion and Future Work

An intelligent agent for the efficient management of the home network is proposed in this paper. The agent consists of six modules: the Agent Manager, the Data Collector, the Execution Controller, the Data Storage, the Data Queue and the User Interface.

The Agent Manager manages the tasks of the modules in the agent, and the Data Collector collects the data from the home appliances through the RFID readers. The Execution Controller determines the operations of the home appliances according to the conditions of the home network and transfers them to the home appliances through the RFID readers. Moreover, the Data Storage keeps the data which is necessary for the operations of the agent, and the Data Queue temporarily stores the data which is collected from the home appliances. Lastly, the User Interface provides the graphical user interface that the user of the home network can directly control and monitor the home network.

The proposed intelligent agent autonomously learns the circumstances of the home network by analyzing the data about the states of home appliances, and provides the best suited environment for the user. Therefore, the user can live in the most comfortable home environment without effort if he or she performs home networking through the agent.

The proposed intelligent agent will be developed in the near future. Furthermore, a mobile intelligent agent which can control home network that home appliances communicate with each other through RFID will be studied.

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