Development of smart home environment based on internet of things technologies

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Abstract

Wireless sensor networks (WSNs) have been becoming increasingly essential in recent years because of their ability to manage real-time situational information for various novel services. Recently, the scope of WSN technologies has been expanded to places such as the home, in order to provide the residents with various intelligent services, such as home automation services or home energy management services. The ubiquitous home network has gained wide-spread attentions due to its seamless integration into everyday life. This innovative system transparently unifies various home appliances, smart sensors/actuators and wireless communication technologies. The ubiquitous home network gradually forms a complex system to process various tasks. The proposed intelligent home control system divides and assigns various home network tasks to appropriate components. It can integrate diversified physical sensing information and control various consumer home devices, with the support of active sensor networks having both sensor and actuator components. We develop a new routing protocol to improve the performance of our active sensor networks. This paper introduces the proposed home control system's design that provides intelligent services for users. We demonstrate its implementation using a real test.

Keywords: home networks, intelligent home control systems, active sensor networks

1 Introduction

Home automation activities are becoming increasingly important nowadays in providing more comfort and security for the home residents. Reports are available in the past concerning the development of devices and units needed for implementing the smart home [1]. Each implementation deals certain aspects of automation satisfying partial requirements of the consumers.

In the last decade, intelligence emerged as the basic component to design modern home and building automation systems [2]. The term "intelligence" implies a provision of automated control over the buildings to solve interoperability is-sues among devices from different vendors, to sense the environment, to provide context-aware services to the residents and to manage safety and security issues. Regardless of how ambitious and diverse the notions might seem, the research community has demonstrated the ability to achieve such goals using pilot projects. In the past few years, energy efficiency has become a key requirement for designing modern buildings and industries. The approaches in this regard not only rely on improving building structures and adopting more efficient appliances but also aim at increasing user awareness towards their energy usage [3].

Modern buildings and houses have started incorporating digital control systems to enable users to take advantage of time-based rates by controlling each device generating or consuming electricity. Direct digital controls for building heating, ventilation, and cooling systems (HVAC) [4-7], and dimmable ballasts are commonly available. Modern building control systems enable optimum start/stop, night purge, maximum load demand, supervisory functions for lighting, sun-blind, energy metering, and many other applications. Standardization of communication protocols and widespread adoption of the BACnet [8-10] protocol enabled the integration of commercial building control products and offered the connectivity among systems made by different manufacturers. BACnet is a communication protocol developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers for building automation and control networks. The acceptance of Powerline for connecting appliances in residential buildings is increasing at a rapid rate. A limited number of connected smart appliances which have been released by General Electric (GE) and other manufacturers, offer time-of-use (TOU) pricing control to a limited extent. However these do not offer an integrated solution involving both utility company and the residential customer.

A number of projects and research have developed ubiquitous home network applications. Compared to traditional home networks, the in-progress ubiquitous home network collects user activity patterns, as well as physical sensing information on the surrounding environment, to support more intelligent and adaptive home services. It has the potential to control consumer home devices used in everyday life. Eventually, users will experience the convenience of performing ordinary activities and increased satisfaction offered by adaptive home services. Several conditions are required to reap advantages from the ubiquitous home network. For instance, computing systems should integrate diversified sensing information to perceive the current situation in the

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home area. Also, they should be able to control various consumer home devices. The home system may become complex, as the number of sensors and devices offered increases. Therefore, home network systems should be designed distributing various tasks into proper computational units to reduce complexity.

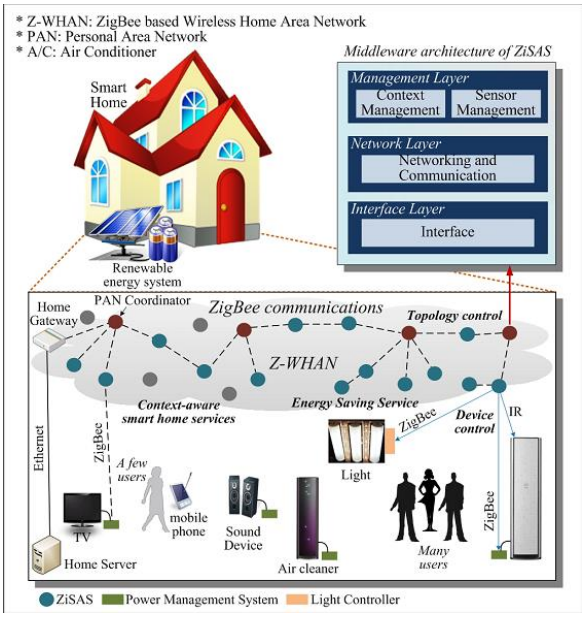

FIGURE 1 Overview of the proposed intelligent home control system based on active sensor networks

In this work, we design an intelligent home control system that can assign tasks to suitable components. Using a wireless sensor network with actuator functionality, our system can automatically gather physical sensing information and efficiently control various consumer home devices. We call this network the Active sensor network. The system can efficiently distribute various tasks related to home network to corresponding components and implement real ubiquitous home services via smart sensors and actuators deployed in home areas. Figure 1 gives an overview of the proposed intelligent home control system. The system, being supported by underlying active sensor networks (i.e., wireless sensor/actuator networks) and additional wired/wireless communications technologies, can control consumer home devices such as lamps, gas valves, curtains, TVs, and air conditioners.

2 Related works

In this section, we briefly discuss the existing system about smart home systems and applications based on the wireless communication technology. Han et al [11] proposed a home energy management system (HEMS) using a ZigBee technology to reduce the standby power. The proposed system is composed of an automatic standby power cut-off outlet, a ZigBee hub and a management server. The power outlet with a Zigbee module cuts off the AC power when the energy consumption of the device connected to the power outlet is below the threshold value. The ZigBee hub collects information from the power outlets and controls these power outlets through the ZigBee module. The ZigBee hub transmits current situation to sever and then a user can monitor/control the current energy usage using the HEMS user interface. Gaddam et al [12] designed a smart home monitoring system for elders based on a cognitive sensor network. It uses selective activity monitoring cognitive sensors network to monitor a home instead of a web-cam based system. Sensors to monitor an appliance, water use, and elders' movement collect information and transmit this to the central server by using the RF transceiver. When an abnormal situation, such as excessive power/water usage occurs, then the system alerts the appropriate people by sending a SMS (short message service) message. Gill et al [13] proposed ZigBee based home automation system that can control and monitor home appliances. The proposed system is composed of a home network device and a home gateway. As an essential part of the system, the home gateway supports interoperability between external networks and home networks. Pan et al [14] proposed a WSN-based intelligent light control system for indoor environments, such as a home for a reduction in energy consumption. In this paper, wireless sensors are responsible for measuring current illuminations and the lights are controlled by applying the concept of user's activities and profiles. Song et al [15] suggested a home monitoring system using hybrid sensor networks. The basic concept of this paper is a nomadic sensor that moves the appropriate location and participates in the network when the network is disconnected. Suh et al [16-20] proposed an intelligent home control system based on a wireless sensor/actuator network with a link quality indicator based routing protocol to enhance network reliability

Compared to existing work, this paper focuses on the so-called active sensor network-based home control system to efficiently distribute home control tasks to appropriate components and automatically manage consumer home devices. It makes home network's configuration and management more convenient and comfortable. Consumer home devices have self-configuration and self-organization features using smart sensors or actuators. We have implemented the ubiquitous home services based on our proposed system with various home appliances, smart nodes and communication technologies.

3 The Proposed architecture

Our intelligent home control system based on active sensor networks consists of various software components as follows.

Service Components: These components represent some ubiquitous home services provided by our system. Examples include services for home automation, home security and home management.

Decision Component: The component recognizes the current home environment via active sensor networks, and enables the service components to select the appropriate service.

Sensing Component: The component gathers sensing data and special event information from the active sensor

networking infrastructure deployed in home environments. This sensing component provides this information to the decision component. The decision component then adaptively selects the correct home services based on the current home state of affairs.

Control Component: The component instructs special control commands to the deployed actuators, such as relay switches or Infra-Reds. These provide methods to control and handle various consumer home devices such as lamps, gas valves, TVs and air conditioners.

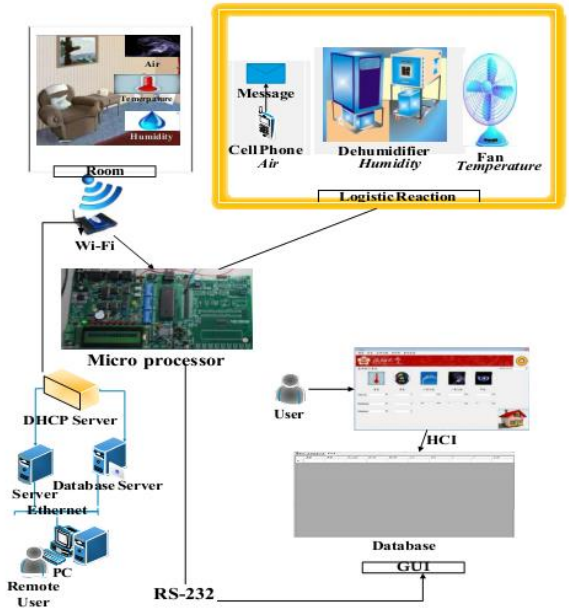

FIGURE 2 Structure of the situation

Interaction Component: The component manages interaction between our home control system (i.e., the control component) behind a sink node and the active sensor networks deployed in a home domain.

Additional Communication Components: These components manage some other networking technologies (beyond the active sensor networks), such as WLAN, Ethernet, RFID and CDMA. These technologies leverage our provided home services to become more effective.

The proposed home automation system is controlled and maintained by the software written in a PC with a specially designed I/O card added to it. The automation system for real time operation has the following desirable features. The regulated visitor entry unit helps checking the visitor through video and admit the intended visitor to flat. This unit has a register to record the visitor's time and date. Maintaining time and displaying in monitor screen would be useful to the resident and also for recording in the visitor register. Remote control of selected appliances of the home by telephone and internet and also local in-home control take care of controlling appliances to meet desired purposes and security. Alternate energy sourcing unit installed involves the following features. Reading the angular position of the solar panel, determining the error in angle and controlling the panel motors towards the direction of sun for extracting maximum solar energy. Periodically reading the direction of the platform and that of the voltage generated from windmill and rotating the platform to the optimal direction. A Home Assistant system which would automatically get activated every morning by referring the data bases and bringing to the screen the activities to be done on the day. An independent intruder detection system which would dial a set of programmed digits automatically to telephone lines and also would give a local alarm.

4 The proposed method

In this section, we address the active sensor network architecture utilized in the proposed home control system. Our active sensor network consists of a number of smart nodes (i.e., sensors and actuators). They may proffer several tasks, such as gathering physical home environment information and controlling various consumer home devices. Although these two types of smart nodes have different functionalities, they both have the computation and RF communication abilities to automatically establish wireless networks. We discuss these smart sensors and actuators in more detail below.

We design the Interaction Component and new routing protocol to interact with our control home system and automatically establish networks. In the following subsections, we describe how smart devices can interact with and be controlled by our home system, and how they can form multi-hop networks wirelessly.

4.1 DESIGN OF HOME MONITORING SYSTEM

Our research in intelligent home environment monitoring system is focus on the intelligent monitoring by using fan, dehumidifier, and the warning messages from cell phone to monitoring temperature, humidity, and the gas at home. On the top of the picture is the center of monitoring system and monitoring network is built by Wi-Fi. The sensor nodes linking to every kind of sensor is built in the room everywhere. Developing the sensor and getting the data in that place you want to know. And then use Wi-Fi module to transmit the data to the user side of home monitoring center by using Dynamic Host Configuration Protocol Server (DHCP server). Database center is including the data of the server and PC side, this platform is in charge of saving the data of the monitoring. Home monitoring center is including the user's interface and database that the users can operate the automatic equipment and monitor the every environment element as shown in Figure 2. Database center is including the data of the server and PC side, this platform is in charge of saving the data of the monitoring. Home monitoring center is including the user's interface and database that the users can operate the automatic equipment and monitor the every environment element.

We have developed the smart sensor nodes that are classified into two different types of a generic sensor and an actuator. Generic sensor typed nodes try either to detect the general physical sensing measurements such as temperature, humidity and light or check for the special events such as gas leaks, human movement and window status detection. Whereas, actuator typed nodes can directly control consumer home devices. In our system,

some actuators are deployed near the consumer home devices and connected to their electronic switch by the relay switch module (which is also developed by ourselves). The control ability of actuator is limited to turn on/off actions, because the relay switch module simply works as an electronic switch. Our actuator typed node utilizes IR (Infra-Red) communication also in order to instruct complex consumer devices such as TV, Air Conditioners and Air Cleaners. This collaboration among actuator nodes and consumer home devices leads an extension beyond traditional wireless sensor networks. Our active sensor network can collect diversified sensing information and control various consumer home devices. The generic sensor and actuator nodes are managed by the Sensing Component and Control Component, respectively.

4.2 DEVELOP WI-FI VIRTUAL IP

The sensor data of this research is transmitted by Wi-Fi wireless network. The sensing circuit with Wi-Fi module needs an IP address which can help it to link to the Internet to transmit the data. We take basic structure mode through DHCP server to cover by the Wi-Fi module and mobility equipment dynamically allocate virtual Internet Protocol (IP). Let the equipment can link to Internet in wireless way. Because home monitoring system needs real-time data from room temperature, humidity, carbon monoxide, smoke and methane, we use Wi-Fi with its high speed transmission and wide wireless network. To make the system miniaturization and cost reduction, we use Wi-Fi module to transmit the data. We use RN-131-EK Evaluation Board as our Wi-Fi module to evaluate and design. We use Universal Asynchronous Receiver/Transmitter (UART) as our interface because we don't need to understand TCP/IP protocol and we can design the applications easily. The module is supports 2.4 GHz IEEE Std. 802.11b and can get IP address by DHCP server assigning dynamically. Data Rate is up to 2Mbps and the network coverage is up to 400 meters. We can design and develop by Microchip high-level microcontroller for network cost reduction and data high speed transmission.

Each smart node should have a special computational entry, which can understand commands transmitted from the home system and recognize its tasks according to its sensing or actuator functionality, to interact with our home system. We develop the Interaction Component on smart nodes as a part of our system for this purpose. Since each node is equipped with special capabilities such as gas detection, relay switching and IR controlling, each node may perform different actions according to its capabilities. Our Interaction Component is design to distinguish these different capabilities and perform adaptive operations. It can respond with appropriate responses to commands transmitted from the home control system.

4.3 EMBEDDED SYSTEM STRUCTURE

In this study will be required for high-speed data transmit sensing system combines Wi-Fi wireless networks, while Wi-Fi has a high transmission characteristics, high transmission distance and high universality do not need multi-hop data transmission, quite suitable provision for monitoring sensor networks. Sensors is depend on demand provisioning of different environmental sensors, preliminary planning to the digital signal processor (DSP) core for sensing data acquisition and data transfer work, the circuit structure, the middle sensing circuit and core DSP, left for the various sensors, the above control systems for the automation facilities, the right interface for the database and administrator. Monitoring sensor is including temperature, humidity, and gas (smoke, carbon monoxide, and methane).

5 The design of smart home

Our proposed system initially instructs some intentional commands to smart nodes. It then receives the physical sensing data of interest, or a special event from the corresponding sensors. These operations are managed by Sensing Component, and the gathered information is forwarded to Decision Component. Decision Component can select the adaptive home service based on these detected physical sensing data and special events. The selected services are operated with the help of Control Component and Additional Communication Components according to the predefined scenarios in Service Components. Figure 3 shows the component architecture in our proposed home control system. In this section, we detail each component's operations.

5.1 SENSING

The Sensing Component is designed to receive and request the physical sensing data and specific events of interest from smart nodes. This component manages the generic sensor nodes in the active sensor network. Our home system handles three packet types: Set-Command packet, Data packet and Event packet. The Set-Command packet is generated either to request the physical sensing data of interest or to configure the special event to the generic sensor type nodes. The packet includes the specific sensor device ID and its requested attributes. The packet is transmitted from the Sensing Component to the smart node's Interaction Component. The Data packet includes the general physical sensing information such as temperature, humidity and light. This information is the response to the Set-Command packet generated from the Sensing Component. The Event packet informs about specific events, such as detecting a person's presence, locking the door and detecting the presence of dangerous gases. This packet is configured by the Set-Command packet that includes descriptions of the specific event as attributes. Both Data and Event packets are forwarded from the Interaction Component on the smart node to the Sensing Component.

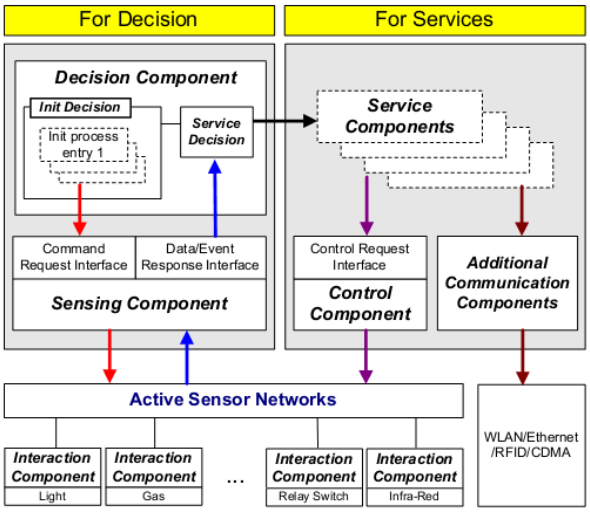

FIGURE 3 A block diagram for the component-based architecture

5.2 DECISION

Appropriate home services are selected by the Decision Component, based on the physical sensing information and events gathered by active sensor networks. The Decision Component is provided the Command Request and Data/Event Response interfaces by the Sensing Component. As shown in Figure 3, it consists of InitDecision part and Service Decision part. The "InitDecision part" is the sum of initial process entries configured by householders. When a householder selects an initial process entry, the selected entry generates appropriate Set-Command packets to the active sensor networks though Command Request interfaces. The corresponding smart node's Interaction Component may return the appropriate Data packet or Event packet to the home control system to respond to the commands. These response packets are forwarded to the "Service Decision part" through the Data/Event Response interface. The Service Decision part receives the physical sensing information and events detected in the current home areas without additional operations. Service Decision part recognizes the current situation, and executes the adaptive home service from Service Components. For example, if the householder selects the initial process entry for the gas monitoring service in InitDecision part, the matched entry generates the Set-Command packet to receive the current gas level from gas sensors. The command packet is forwarded to active sensor networks through the Command Request interface, and the corresponding gas sensor nodes periodically transmit the Data packet including the detected gas level in the house. The Service Decision part performs the gas monitoring service from the Service Components based on the packets forwarded by the Data/Event Response interface.

5.3 CONTROL

Our system can elaborately command and control most consumer home devices, based on the actuator nodes. The Control Component manages these actuator nodes. If a home service selected by Decision Component needs to control the special consumer home device, the corresponding service component requests an appropriate device type and its actions to Control Component through the Control Request interface. On receiving the request from the service component, Control Component searches the special smart node ID to control the corresponding home device. It inserts the searched node ID, its routing path and attributes of interest to the Control-Command packets. The Control-Command packet is a special command to control home device in actuator nodes. It includes descriptions about the consumer device type and its actions as attributes. Thus, the packet is forwarded the special actuator type node, based on our LQIR protocol, and the device is controlled according to the intentions of the service component. In our home control system, all tasks, related to controlling consumer home devices, are handled by Control Component.

One of the goals in this paper is to propose the new ubiquitous home services that offer inhabitants more comfortable environments to perform day-to-day tasks. The Service Components include these home services. The Decision Component selects an adaptive service, and it may be performed using Control Component and Additional Communication Components according to the predefined scenarios. We have designed and implemented seven different kinds of intelligent home services on our proposed system. These services are classified into three types: first, home automation services controlling air conditioners, air cleaners and curtain movements, according to the weather. The second, home security services, detects potential crimes and prevents gas explosions. The last is the home management services via the Internet.

6 Conclusion

The scope of WSN technologies has been expanded to places such as the home, in order to provide the residents with various intelligent services, such as home automation services or home energy management services. The ubiquitous home network has gained wide-spread attentions due to its seamless integration into everyday life. This innovative system transparently unifies various home appliances, smart sensors/actuators and wireless communication technologies. The ubiquitous home network gradually forms a complex system to process various tasks. The proposed intelligent home control system divides and assigns various home network tasks to appropriate components. It can integrate diversified physical sensing information and control various consumer home devices, with the support of active sensor networks having both sensor and actuator components. We develop a new routing protocol to improve the performance of our active sensor networks. This paper introduces the proposed home control system's design that provides intelligent services for users. We demonstrate its implementation using a real test.

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