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S-mote: SMART Home Framework for Common Household Appliances in IoT Network

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Abstract

SMART home is one of the most popular applications of Internet-of-Things (IoT) technologies, which is expanding in terms of range of applications. SMART home technology provides convenience at home by connecting household appliances to a single network, control, and management. However, many general home appliances do not support the network functions yet; hence, enjoying such convenient technology could be difficult, and it could be expensive in the beginning to build the framework. In addition, even though products with SMART home technologies are purchased, the control systems could differ from device to device. Thus, in this paper, we propose a SMART home framework, called an S-mote that can operate all the IoT functions in a single application by adding an infrared or radio frequency module to general home appliances. The proposed framework is analyzed using four types of performance tests by five evaluators. The results of the experiment show that the SMART home environment was implemented successfully and that it functions appropriately, without any operational issues, with various home appliances, including the latest IoT devices, and even those equipped with an infrared or radio frequency module.

Keywords

Infrared Module, Infrared Signal, IoT (Internet of Things), Radio Frequency Module, Remote Control, SMART Home, S-mote

1. Introduction

The devices that humans use on a daily basis are getting smaller in size, have better connectivity and simply prove convenient in our lives. These advances are a part of a new technological framework, called the Internet-of-Things (IoT). The IoT technology has taken the spotlight in era of the 4th industrial revolution. IoT refers to the concept of interconnecting computers with various smart devices [1]. This enables devices to interact with each other over the internet, and to be controlled remotely.

With the advent of the IoT era, the focus is currently on the SMART home framework, as one of the most interesting IoT technologies in the market. The term ‘SMART Home’ was first officially used in 1984 by the American Association of House of builders. Ever since then, it has evolved into a 21st century system, where servers running all the functions of the house are networked and contribute to the integrated management of various technologies. The SMART home is expected to make home appliances easily operable and develop into a system that will help make life more convenient through straightforward

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control and the ability to handle the various home appliances remotely [2]. The SMART home is controlled by home appliances connected to a central hub, called a "gateway" [3]. This gateway allows all smart home appliances (smart devices) to be grouped together and controlled.

Although many people want to build the SMART home framework based on IoT technologies, it is difficult to apply the latter to existing analog-based home appliances because these do not support IoT functionality. Generally, the current SMART home framework aims to provide a stable environment by only supporting products with the latest technology or communication. Therefore, this requires purchasing products with the SMART home technology; hence using this technology can be expensive at first [4]. As a result, building a SMART environment that can simultaneously control analog-based and newer, technology-based, home appliances is vital. If various appliances were currently used in a home, it would be best if they were controlled by the one device regardless of their type.

In order to implement this idea and readily build the SMART home, we propose a framework, called S-mote that can operate all the IoT functions as a single application using an infrared module or adding a radio frequency module to general home appliances. An S-mote controller plays the role of the "gateway" used in SMART homes, replacing existing remote controls with a single application. Appliances can be used in SMART homes if they are equipped with infrared modules or radio frequency modules. By applying S-mote, on can readily control home appliances that do not support any IoT functionality, with radio frequency modules. In addition, it is possible to control various products that have publicly available APIs, or are equipped with infrared modules or radio frequency, using one device. Furthermore, it may be possible to control products using a smartphone application.

The remainder of this paper is organized as follows: Section 2 discusses current research trends. Section 3 introduces the S-mote framework in detail. Section 4 provides the f results of the S-mote framework. Finally, Section 5 concludes this study and suggests future work.

2. Current Research Trends

As smart devices become commonplace in our lives, studies on developing SMART home frameworks are conducted in various research fields.

From a technical perspective, various techniques have been suggested for designing and configuring a SMART home, combining wireless communication technologies, evaluating performance of the SMART home controller, controlling IoT devices through voice or multimedia [5,6]. In particular, since the purchase cost of IoT devices is higher than that of general home appliances, various approaches are underway to integrate standard home appliances into the SMART environment [5,6].

From an energy management perspective, novel approaches or frameworks have been proposed to monitor the operational loads of devices according to total power consumption, peak power consumption, and the impact of weather or atmospheric conditions. Eventually this leads to an attempt to manage energy efficiently utilizing the emerging technologies of IoT and big data in the residential, commercial, and industrial sectors [7,8].

From a security and privacy respective, structural frameworks have been proposed to equip SMART homes with enhanced security and privacy systems, using data encryption techniques or minimizing network usage. The current generation of IoT devices is vulnerable to a variety of attack, and it is difficult to find definite solutions to make IoT devices safer or more secure. Thus, many researchers have focused on this issue and suggested elaborate solutions. In particular, they studied network-level security and a privacy control technique, a security authorization scheme for IoT devices, a secure data uploading methodology, potential threats caused by malicious third parties to reveal sensitive information [9,10].

3. S-Mote Framework

In order to build a SMART home, the proposed framework focuses on making all products communicate in a SMART home environment, including non-IoT appliances. There are two methods for supporting IoT functionality and inter-device communication for non-IoT home appliances. The wireless communication technologies embedded into home appliances can be used directly, or additional modules can be attached to home appliances to enable wireless communication. There are also two types of wireless communication technologies: infrared communication through light and electromagnetic waves communication through protocols such as Wi-Fi and RFID.

Traditional home appliances are mostly operated by remote-controlled units at a short distance using infrared. This study aims to clone these infrared signals and apply them to SMART homes without replacing the existing appliances. Those devices that do not support infrared remote control could also be integrated into SMART homes using radio frequency (RF) signals. Thus, S-mote provides a framework that can operate all functions in a single application by adding an infrared or RF module to generic home appliances. The following section details the functions and techniques used in the S-mote framework.

3.1 Structure for S-Mote

The whole structure of the S-mote framework is presented in Fig. 1. It consists of four parts: infrared modules, RF modules, controller, and Wi-Fi modules. As shown in Fig. 1, Part 1 includes home appliances equipped with infrared modules. Generally, appliances using remote controls are based on infrared communication and they have built-in infrared modules. These modules are used as a connection point to communicate with other devices. Part 2 includes home appliances equipped with RF modules. While the latest appliances usually support IoT functionality, existing and previously released home appliances still do not support IoT functions, which is one of the important considerations when constructing a SMART home. For these appliances, RF modules are attached and used as a connection point to communicate with other devices. The module has benefits in that it is very inexpensive and its available frequency can be set as desired by users, compared with modules supporting other wireless communication technologies. Part 3 is the controller operating the home appliances wirelessly. The controller plays the role of a gateway communicating and managing the appliances in a SMART home. It includes infrared modules (transmitter and receiver) and RF modules (transmitter) to communicate with the home appliances. Moreover, it may be possible to communicate with IoT devices equipped with a Wi-Fi module if the API of the devices is publicly available. Part 4 includes IoT devices equipped with a Wi-Fi module. The latest smart devices with a Wi-Fi functionality belong to this category. Through the S-mote framework, all of the home appliances are easily connected to each other and operated though one controller.

3.2 Connectivity and Interoperability in S-Mote

The S-mote framework provides connectivity and interoperability using wireless communication modules. Home appliances supporting infrared communication are controlled though infrared transceivers, while those without infrared communication support are controlled through radio transceivers and relay modules. In addition, the latest IoT devices are controlled through Wi-Fi modules.

An infrared receiver handles the infrared signals used in each home appliance. The receiver is equipped with the S-mote controller. In order to control the appliances with infrared modules, their dedicated remote-control information is first registered and stored in the S-mote controller, or the infrared signal data can be downloaded from each home appliance website and registered into the controller.

An infrared transmitter controls home appliances using infrared signals that are stored/downloaded by users. The transmitter is equipped with the S-mote controller, and hence can control home appliances with infrared modules through the S-mote controller, without a need for the dedicated remote controls of the home appliances. When the user sends their input to the S-mote controller, the signal corresponding to each button on the remote control is sent through the infrared transmitter of the S-mote controller to control the power or function of the appliance.

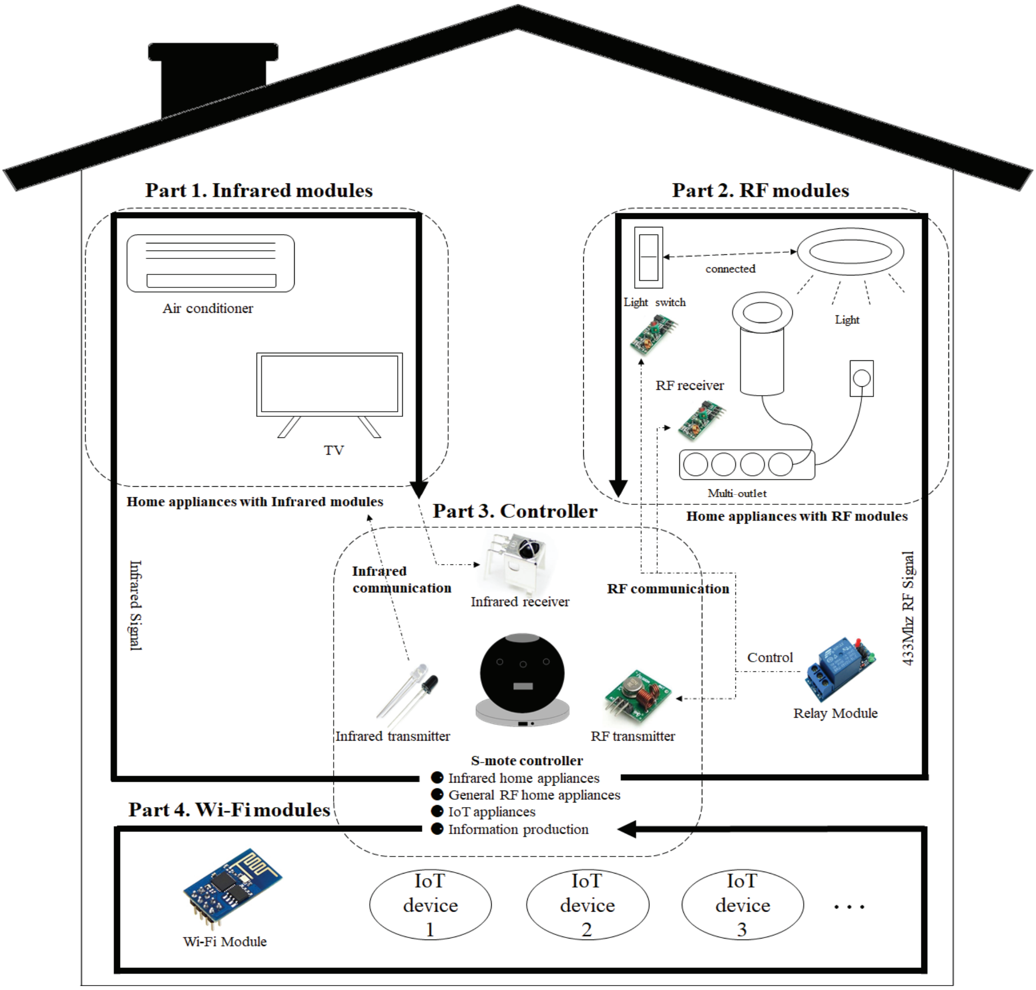

Fig. 1. Overall S-mote framework.

An RF transmitter is used to provide auxiliary control over household appliances that do not use infrared signals and transmit stored signals through the RF module. The transmitter is also equipped with the S-mote controller. This enables the controller to communicate with the home appliances using the RF receiver.

An RF receiver is used to provide remote control over home appliances that do not use infrared modules. It allows control of the appliances with RF modules when it receives an RF signal from an RF transmitter. Because the RF receiver is required to control home appliances with RF modules, it should be attached to each appliance, not the S-mote controller.

Finally, a relay module is a chip that is required to perform RF communication. It is directed by the RF receivers, and is also responsible for issuing commands to the RF transmitter.

3.3 Communication Control Techniques

In order to construct and implement the S-mote framework using wireless communication modules, the following three points are required.

The Linux Infrared Remote Control (LIRC) is a Linux-based open-source package that can decode, store, and transmit many commonly used remote control signals. LIRC can be applied to almost any infrared remote-controlled device and can be controlled by transmitting remote control signals by converting the key on the remote control into program-specific commands and replacing the remote control. This package can be used either by directly registering the remote-control signal or by downloading the remote control registered in the LIRC.

In addition, 433Utils is an open-source package for communication using 433 MHz of RF. Both Arduino and Raspberry Pi are utilized. The 433 MHz signals can be encoded to transmit various data, from binary integer data to string or voice. The signals received can then be decoded and converted to data to support communication.

The S-mote controller is a SMART home gateway designed to control appliances that do not even support infrared communication, by equipping them with an infrared transmitter, an infrared receiver, and an RF transmitter. A 433-MHz radio module is also installed for home appliances that do not support infrared communication. Through the S-mote controller, it is possible to control all of the home appliances remotely.

4. Feasibility Analysis

This section presents a feasibility analysis of the proposed framework. In order to construct the SMART home environment, several appliances are chosen for our analysis: (1) a television and an air conditioner with infrared modules and (2) a multi-outlet and a light switch with RF modules. Because the multi-outlet and the light switch do not support IoT functionality, an RF module is inserted into them, as shown in Figs. 2 and 3. In Fig. 2, An Arduino Pro Mini (5 V) and a microcontroller unit are attached to the multi-outlet. In addition, the relay module used an SZH-EK082 to control the external power and the 433 MHz RF receiver used an MX-05V to receive signals. In Fig. 3, the appearance of the light switch was made by a 3D printer, and the switch was operated from a 110° angle to a 170° angle by a motor. The software in the RF receiver was implemented using RC-Switch in Arduino Sketch.

The S-mote controller is manufactured as a gateway for the infrared and RF communication in the proposed framework. As shown in Fig. 4, the controller applied a Raspberry Pi 3 Model B. The infrared receiver used the KSM-913TE5N model. An infrared LED was used for transmission. The radio transceiver was produced by applying an MX-FS-03V to the 433 MHz RF transmitter. The appearance of the S-mote controller was obtained through a 3D printer.

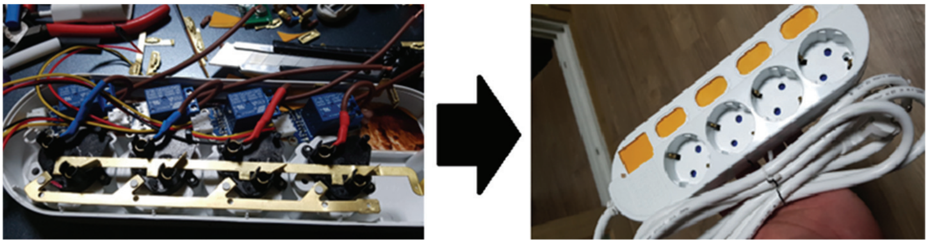

Fig. 2. Multi-outlet with RF modules inserted, inside (left image) and outside (right image).

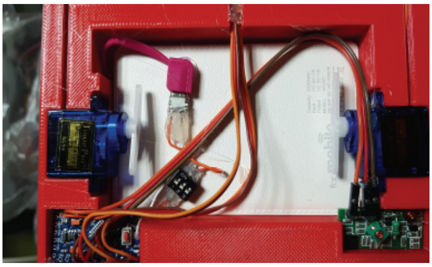

Fig. 3. Light switch with RF module inserted.

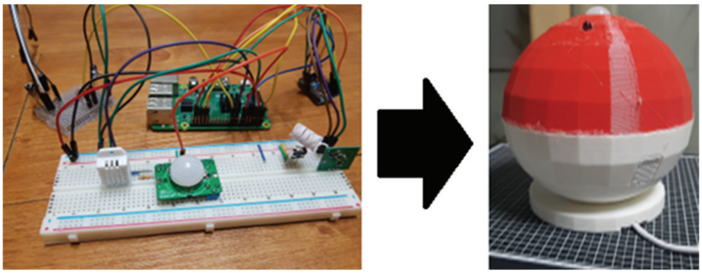

Fig. 4. S-mote controller, inside (left image) and outside (right image).

Finally, the interface for operating these appliances through the S-mote controller is implemented as a mobile web application using HTML, CSS, and Java Script. Through this application, all of the home appliances are controlled remotely from one smartphone device communicating with the S-mote controller.

The proposed framework is analyzed from various perspectives, as follows:

- Test A. Does S-mote ensure that appliances with infrared communication work normally?
- Test B. Does S-mote ensure that appliances with RF communication work normally?
- Test C. Does S-mote bring convenience to users?
- Test D. Is there a spatial or distance limit for S-mote?

The tests were conducted with five evaluators. For Test A, a television and an air conditioner with infrared communication were controlled by S-mote and tested in a 10 m^2 room. For Test B, a multi-outlet and a light switch with RF communication were controlled through S-mote and tested in a 10 m^2 room. For Test C, five evaluators checked S-mote and manipulated the mobile application to investigate satisfaction. For Test D, the operation between the controller and the home appliances was conducted by changing the distance from 10 cm to 10 m, which was assumed to be a typical room size.

The final testing results are presented in Table 1.

Table 1. Feasibility tests

	Testing results
Test A	In terms of the results of the testing on the television and the air conditioner with infrared communication capability in a 10 m^2 room, both operate satisfactorily without problems if infrared communication is possible. In addition, their operational response time is identical whether using dedicated remote controls or a mobile application of S-mote.
Test B	Concerning the results of the testing on the multi-outlet and the light switch with RF communication capability in a 10 m^2 room, both operate satisfactorily without problems if RF communication is possible. Although they do not have remote controls, they are easily controlled by the mobile application of S-mote.
Test C	In order to investigate the convenience of the S-mote environment, a survey is conducted after its use. The results from the five evaluators are: 10, 9, 8, 9, and 9 points (0 to 10). The convenience is estimated on average at 9 points, and the evaluators point out that S-mote can recognize, utilize, and operate the devices readily, promptly and accurately.
Test D	In terms of the results of the testing on the television, the air conditioner, the multi-outlet, and the light switch in 10 m^2 room, all operate satisfactorily without problems when their distance to the S-mote controller is changed from 10 cm to 10 m at intervals of 50 cm.

5. Conclusion

In order to build a more cost effective and straightforward SMART home environment, this paper proposes the S-mote framework, which can operate generic home appliances from a single mobile application by using an infrared module or adding an RF module. Home appliances with infrared communication capability can be directly controlled without any additional work (e.g., programming or attaching modules). In addition, regarding existing home appliances without any communication function, these can be controlled similarly to the latest IoT devices through RF modules. The feasibility test was performed on the proposed framework with five evaluators, and the results show that the framework successfully configured the SMART home environment and worked satisfactorily, resulting in no operational problems for the home appliances.

In the future, we will utilize the latest sensors or modules that provide various functions and expand the functionality of the mobile application in S-mote. Furthermore, we will develop readily available APIs for the controller in various SMART home environments.

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