RF-Switch: A Novel Wireless Controller in Smart Home

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***Abstract*—This paper presents the design of RF-Switch, a novel method to control the devices in smart home. We replace the traditional switch with passive RFID tags. By analyzing the phase value of the tags, RF-Switch can realize both on-off and volume control which are the most commonly used commands in home environment.**

I. Introduction

In smart home environment, all of the devices are in the charge of unified platform. Through this, smart home can achieve the goal of home automation. The platform and devices are connected through different kinds of wired and wireless technologies, that the platform can easily get the state of the devices and control them at the same time. However, the interface between platform and human is far more complex than it is between platform and devices. Some research have been done in this area. Basically, they try to combine the smart home platform with human mind through audio[1], video[2] and action sensing[3]. Both audio-based and video-based interactions may bring privacy problems to users, especially in home environment. Action sensing methods usually require users to carry some additional equipments around or to act in specific region, which make it hard to implement in the real life. Thus, we turn to look for a feasible way to replace the current widely used controller: switch.

When it comes to traditional switch, it is not difficult to cite some examples of its advantages, such as stable, convenient and easy to carry out. While under the concept of smart home, the traditional switch seems not that appropriate in the future. The position of switch is fixed once it is installed which may cause troubles to elderly and children. Even if the inhabitant are not used to the place of the switch, the switch can hardly be moved. And human may get electric shock when touch the switch with a wet finger, not to mention the influence to the beauty of home decoration. Therefore, a exquisite, flexible and scalable switch is needed in future smart home.

In this paper, we design a novel switch for smart home using passive Radio Frequency IDentification(RFID) tags. Passive RFID tags is completely battery-free, which make it possible to be quite thin and small, and can even be customized into arbitrary shape[4]. Thence, the tags can be attached everywhere without any brackets and can be moved easily. Besides, the tag ID is long enough to be encoded for every device in one's home. Futhermore, the Ultra High Frequency(UHF) RFID technology works on the frequency between 858MHz and 930MHz, that will not effect the other commonly used wireless communication in home environment like Wi-Fi. All the above characteristics make RF-Switch a qualified substitute of current switch and the design of RF-Switch will be introduced in the next section.

II. Architecture and Design

In this section, we present the architecture and design of RF-Switch in detail. The verification experiment is implemented using the ImpinJ R420 reader and Alien ALN-9654 tag.

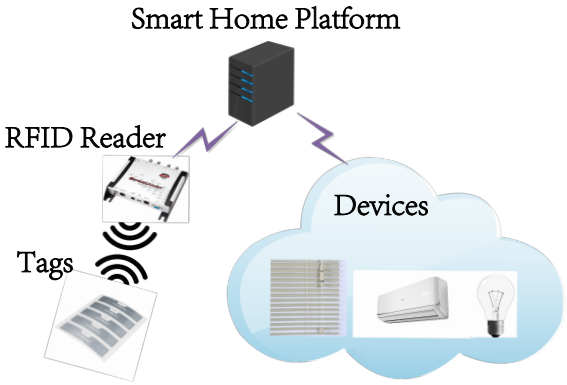


Fig. 1: The architecture of RF-Switch. Note that RF-Switch can be accessed into different kinds of smart home platform.

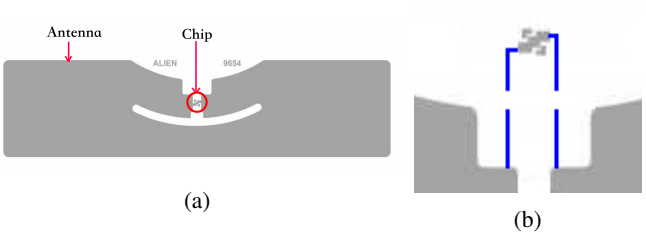
As depicted in Fig.1, RF-Switch works with the help of smart home platform. RF-Switch is in charge of sensing the intention of inhabitant and sending the commands to smart home platform, then the platform is responsible for the control of devices in the smart home.

In this paper, we consider that all of the control commands consist of two basic commands: on-off control and volume control. For example, the ordinary light only has two state, thus it only needs on-off control. While the modern light can change the brightness, then it needs volume control. More complicated commands may need several RF-Switches work in collaborative way and this will be discussed in the future work. Next, we present our design of both on-off control and volume control separately.

A. On-Off Control

In this part, we introduce how RF-Switch can realize on-off control. Actually, it is because of the structure electric circuit that passive RFID tag does not need battery.

As shown in Fig.2a, passive RFID tag is composed of RFID chip and tag antenna. The chip is in the red circle and the other



(a) (b)

Fig. 2: The structure of tag. (a) shows the structure of original passive RFID tag. And (b) shows the redesigned tag structure.

part is antenna. Firstly, tag antenna receives the wireless signal from the antenna of reader, and the chip can get the most power from the tag antenna when the chip impedance and the reader antenna impedance are conjugately matched[5]. It means if the chip can not get power from the tag antenna, the tag will not response the reader's request even if it is covered by the reader's effective range.

Based on this, a simple but effective and easy to carry out idea comes to our mind. We remove the chip a little bit from its original position. Then add two leading wires to both the chip and antenna, as shown by the blue lines in Fig.2b. We can see from the picture that the wires are close to each other but not connected with each other. This means in this state the tag can not be seen by the reader, thus this state can represent "off". When a finger touch the middle of the tag, the skin will connect the four wires together. Since the skin of human can be treated as conductor, the chip will receives energy from the antenna and send the response back to the reader. In this situation, the tag can be seen by the reader, thus this state can represent "on". In this way, RF-Switch can works as a on-off controller.

B. Volume Control

In this part, we introduce how RF-Switch can realize volume control. To control the volume, RF-Switch should have the ability to send continuous mutative commands whose value can cover a range from the minimum to the maximum.

$$\theta = mod(2\pi\frac{2d}{\lambda} + \theta_T + \theta_R + \theta_{TAG}, 2\pi) \quad (1)$$

In a basic RFID system, the reader transmits continuous-wave signals to the tags, and then receive backscattered signals from the tags. The phase value of RF signals calculated by Eq.1 describes the offset between the transmitted and received signals, which depends on the round-trip(2d) and hardware-specific factors[6]. Usually, the switch is fixed while working. Therefore, the round-trip distance is fixed. Phase can be seen as a continuous feature of tag.

We assume the human body can also absorb RF signal as the antenna does. When the finger touches different parts of the tag, θ_{TAG} will change correspondingly. The verification experiment proves our assumption. As shown in Fig.3, we collect phase data while sweeping a finger on the surface of the tag's antenna in 5s-8s. The blue line is the unwrapped phase

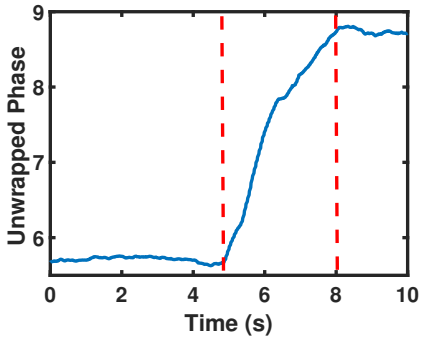


Fig. 3: Sweep a finger from left to right on the surface of a tag.

value. It changes from less than 6 to nearly 9. And if the finger stops moving, the phase value does not change any more. This phenomenon is explained in the latest research [7]. The finger does change the impedance of the tag and futhermore changes the θ_{TAG} and θ finally. Thus, by monitoring the phase value of a tag, RF-Switch can control the volume.

III. Conclusion

This paper presents a novel RF-Switch to replace the currently used switch. RF-Switch utilizes the characteristics of passive RFID tag to realize both on-off control and volume control for smart home platform. In the future, we will implement RF-Switch in our test house and attach it to different smart home platforms.

Acknowledgment

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