Passive RFID-Based Phone Call System Integrated into Clothing and Furniture

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***Abstract*—This paper presents design, development, and an early prototype system of a passive ultra-high frequency (UHF) radiofrequency identification (RFID) technology-based phone call system. These tags are used as clothing- and furniture-integrated phone call triggers by utilizing two gestures; tap and double tap. Both gestures work on the principle that a specific tag is made non-detectable for the RFID reader. In preliminary testing, the prototype system was tested in an office environment in two different test setups: one with an RFID tag attached to a table and the other with an RFID tag attached to a shirtsleeve. One user successfully made a phone call 5 times in both test setups by using tap and double tap gestures. The advantage of the prototype system is that it can be integrated into clothing or furniture to make a quick call without a mobile phone. As the used technology is cost-effective and maintenance-free, there can be several RFID tags in the surroundings and in different clothes.**

Keywords—Internet of Things, passive UHF RFID, phone call, serial communication, RFID software, Voice over Internet Protocol

I. Introduction

The telephone, which revolutionized communication, had a major role in the development of the urban lifestyle [1]. Since the first phone call, the technologies used for making phone calls have evolved dramatically, from analog telephone lines to wireless and mobile communication [2] [3]. In addition, the human-telephone interaction methods have changed. For example, pressing the keypad of a telephone or mobile phone, touching the screen of a smart phone or watch, or using a voice command to make a phone call.

Even today, individuals with significant speech, mobility, or cognitive impairments, as well as the elderly, may have limited access to communication technology [4]. Especially in case of an emergency, having access for making phone calls is vital. To overcome the barriers, created solutions include, for example, wireless nurse calling system for people with muscular dystrophy, where the user can press a button to call a caregiver in case of a need [5], an emergency calling device for patients with voice disorders [6], and a nurse calling system via voice command [7].

In this study, a new type of solution is suggested based on passive ultra-high frequency (UHF) radiofrequency identification (RFID) technology, in which simple gestures, i.e., tap and double tap, act as a trigger for a phone call.

Since its transformation from a basic technology in the field of identification tracking to a versatile wireless technology that has applications around the whole society, the passive RFID technology has been integrated into clothing and furniture as an interface for human-technology interaction [8]–[10]. Due to its battery-free and cost-effective nature, the technology has been found useful as a versatile smart environment controller [11]–[13] and capable of capturing human motion and analyzing the kinematics of the body [14]. Recently, we have used the technology as a music player, where the user can play music by touching a specific part of a textile with finger [15].

After this introduction, the second chapter describes how passive UHF RFID tags can be used as triggers for phone calls by using tap and double tap gestures. The third chapter explains how the technical part of the prototype system is developed. The fourth chapter demonstrates a preliminary test for the developed prototype system, while the advantages of the system are discussed in the fifth chapter. The final chapter draws the conclusions of this study.

II. Phone Call System Integrated into Clothing and Furniture

The prototype phone call system was created using SMARTRAC's basic passive UHF RFID tags, which have self-adhesive glue on the backside that allows them to be easily attached to any surface, such as clothing and furniture. As illustrated in Fig. 1, the tags can be attached to a wooden table, on arms of an armchair, on a cotton shirt and on jeans, just to name a few possibilities.

In this study, these tags are used as phone call triggers by two gestures; tap and double tap. Initially all the tags are detectable for an RFID reader. Both gestures work on the principle that a specific tag is made non-detectable for the RFID reader. For tap gesture, the user blocks the tag with hand, and thus it is no longer detectable. If a specific amount of time (in this study 1000 ms) passes as tag blocked, it triggers a phone call. In case of double tap gesture, the user blocks the tag two times within a certain period of time (in this study 3000 ms), which triggers the phone call.

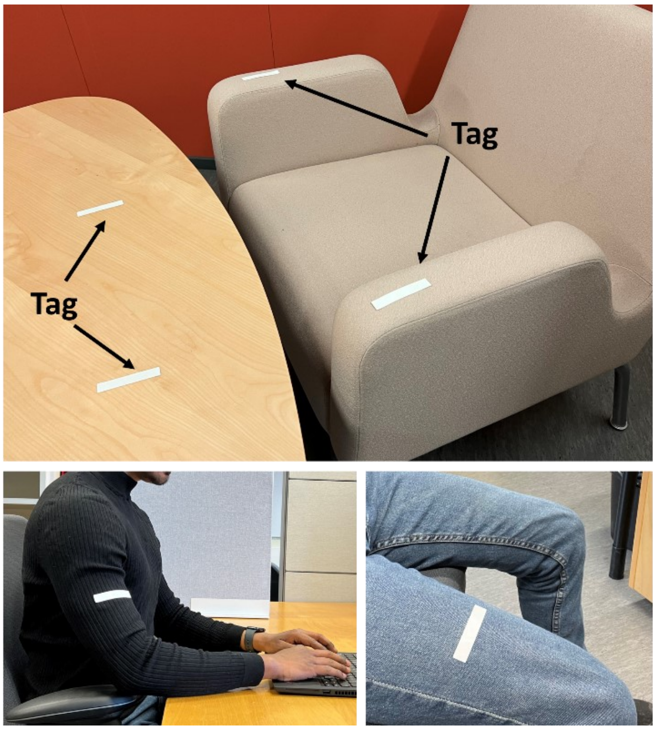

Fig. 1. Basic commercial passive UHF RFID tags attached to furniture (top), and to clothing (bottom).

III. System Developement

For reading the RFID tags, ThingMagic Mercury 6 UHF RFID reader was used at the European standard frequency range (865.6–867.6 MHz). A circularly polarized RFID reader antenna was connected via a connecting cable to the reader. The ESP8266 was connected to the computer via a USB cable.

To make phone calls over the Internet, we used ESP8266, which is a low-cost Wi-Fi microchip that has TCP/IP networking software along with microcontroller capabilities [16]. There is no need for the user to have a mobile phone or a SIM card. The only requirement is a steady Wi-Fi connection.

The prototype was developed with Voice over Internet Protocol (VoIP), which enables the user to make and receive phone calls over the Internet. The user can also use interconnected VoIP services to make and receive phone calls to and from traditional landline numbers by paying a service charge.

If This Then That (IFTTT) is a private commercial company that offers services that enable users to program responses to events [17]. The IFTTT service was used to make VoIP calls. There are several options on IFTTT to make phone calls, by using services such as Amazon Alexa, Arlo, Google Assistant, Telegram, and traditional calls. We decided to make a phone call through Telegram.

A basic software was created that uses the serial communication protocol to transfer the data to the microcontroller. This software is developed in C# as a Windows Forms application and built on the .NET Framework. This software uses ThingMagic Mercury API, which provides continuous reading from the used M6 Reader. The data is stored in a software database and is linked to RFID tag IDs. When a specific tag ID is detected, the data is sent to the microcontroller. When the microcontroller receives the same data from the software that is also present in the microcontroller program, the call is triggered. It is possible to add many tag IDs with different data in the database. This software supports baud rates ranging from 9600 to 115200. This study used a baud rate of 115200 for serial data transmission.

The RFID reader is constantly reading the tag, but the software is programmed to send a character to the ESP8266 only when the tag is not activated for a specific period of time. This time can be changed, and it can range between 100 ms and any positive number of milliseconds.

When the user blocks the RFID tag with a gesture, which in this study is tapping, the tag becomes non-detectable for the RFID reader and the software checks to see if the tag is in the software's database. If it is, the software sends a character to the ESP8266. As soon as it receives the character from the software, it connects to the IFTTT cloud and makes a VoIP phone call via Telegram. A mobile number and a message are defined in the IFTTT applet, the message will be read by the bot when someone receives the phone call.

As we are using free version of IFTTT it can call to a maximum of 5 phone numbers at the same time. Different gestures can trigger different types of calls to different numbers. Fig. 2 shows the working principle of the developed prototype system.

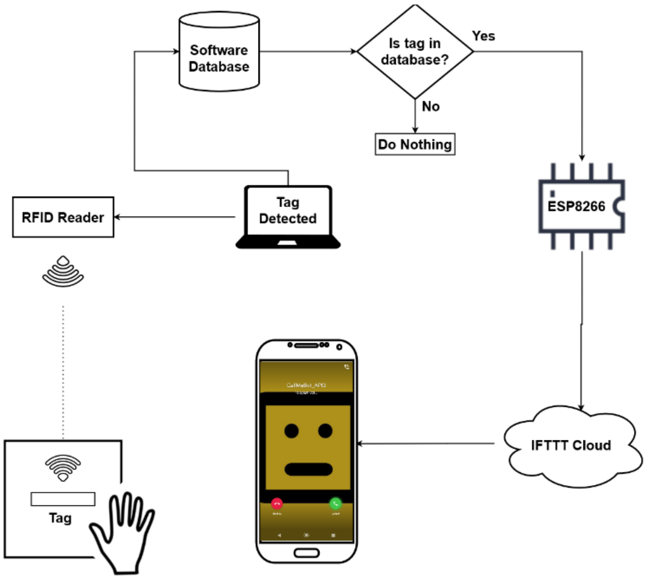

Fig. 2. Working principle of the prototype system that can be used for calling via Internet by using passive UHF RFID tags as phone call triggers.

The IP address must be configured in the computer because this RFID reader is connected via an ethernet cable. Since this microcontroller is connected via USB connection, the serial port can be selected first, as illustrated in Fig. 3. From the drop-down button, the baud rate can be selected, and the same baud rate is programmed in the ESP8266 (in this case 115200). By clicking the open connection button, it establishes a connection between the computer and the ESP8266. The connection between the computer and the ESP8266 can be tested by clicking the test connection button. As soon as the user presses the “Start Reading” button, the software make connection between the computer and the RFID reader via the set IP address and uses the set power, which is in this study 20 dBm. The blocking time (how long the RFID tag should be blocked to trigger the phone call) can be entered, and in this study, it is 1000 ms. Fig. 4 shows how the software's algorithm establishes the connection between the RFID reader, ESP8266, and the computer.

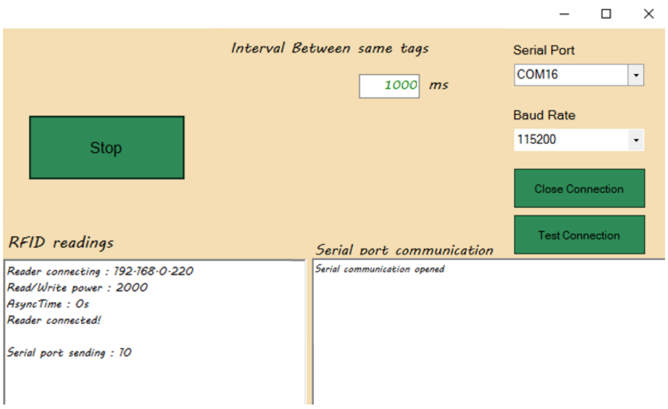

Fig. 3. Screenshot of the software when connected to ESP8266.

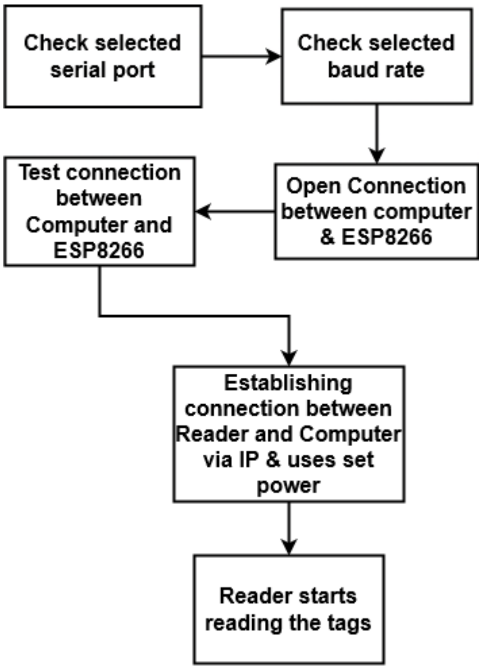

Fig. 4. Flowchart illustrating the software's algorithm for connecting the reader, computer, and ESP8266.

The algorithm of code inside the ESP8266 to recognize which gesture is being used is shown in Fig.5. If nothing is detected after 3 seconds, the microcontroller will make a tap call; if a tag is detected within that time, the microcontroller will make a double tap call.

In this preliminary testing, the prototype system was tested in an office environment. An RFID reader antenna was placed in front of the user or furniture and the distance was 150 cm. The RFID reader power was set to 20 dBm, which is well below the European regulation. The test included two setups: one with an RFID tag attached to a table and the other with an RFID tag attached to a shirtsleeve, as illustrated in Fig. 7. The complete hardware system used in this study is shown in Fig. 8. One user successfully made phone calls 5 times in both test setups by using tap and double tap gestures. As shown in Fig. 6, the user needs to block the tag for 1 second for each gesture.

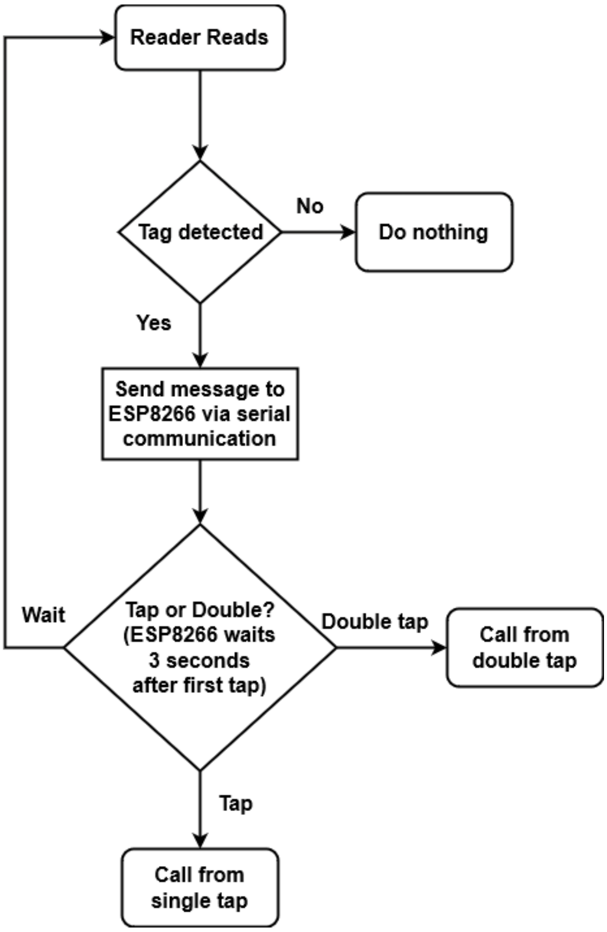

Fig. 5. Flowchart of how gesture detection works inside the ESP8266.

IV. Practical Testing

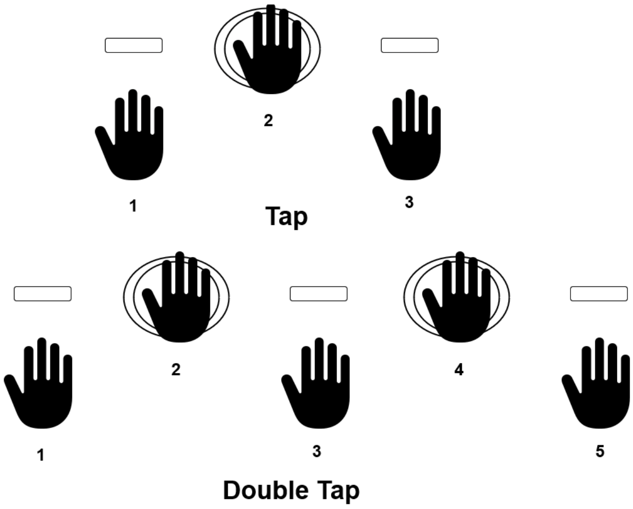

Fig. 6. Two different gestures were used to trigger a phone call: tap, where the user blocks the RFID tag from the reader once for a certain period of time (top) and double tap, where the user blocks the tag two times within a certain period of time (bottom).

In this study, both gestures called the same phone number with different messages; the tap call had a message that was received by the user's friend after picking up the phone that said, "This call is from the tap gesture." Similarly, for the double tap gesture, the message was "This call is from the double tap gesture".

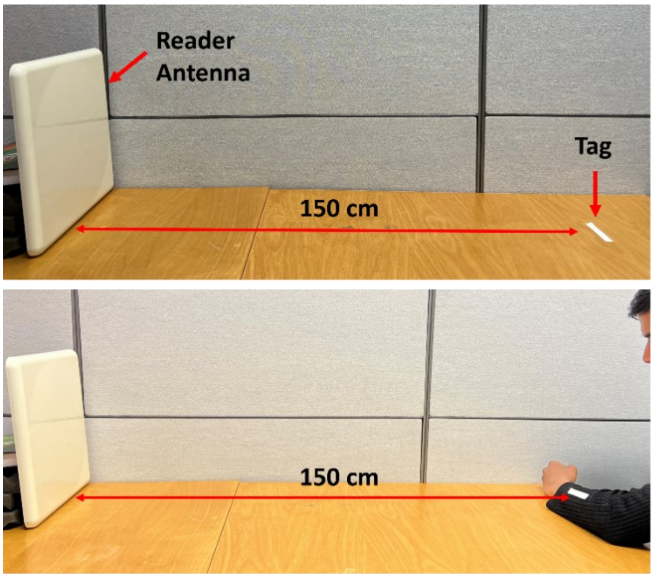

Fig. 7. Test setups in an office environment: passive UHF RFID tag on a table (top) and on a sleeve of a shirt (bottom)

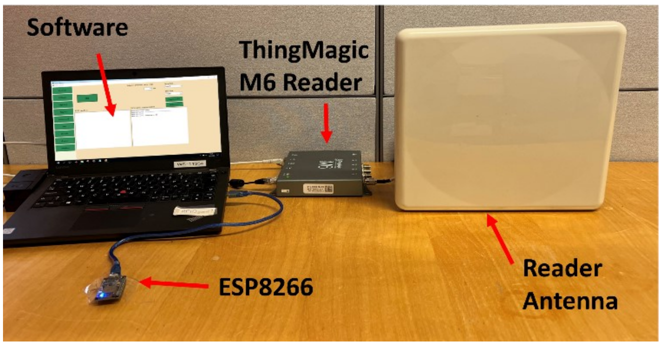

Fig. 8. The complete hardware system.

V. Advantages and Disadvantages of the Developed System

The advantage of the prototype system is that it can be integrated into clothing or furniture to make a quick call without a mobile phone. As the used technology is cost-effective (the cost of an RFID tag is only a few cents) and maintenance-free, there can be several RFID tags in the surroundings and in different clothes. The created wireless calling system is very easy to install anywhere. The system can hold several different mobile phone numbers with different messages. Different gestures can be used to call different numbers.

In this study, the phone call was triggered when the user tapped or double tapped the RFID tag. However, in practical use, this can also happen by accident. Thus, the next step is to test other gestures, which can be incorporated to the system so that it only calls when needed.

To be useful in everyday life, the system needs to be maintenance-free, which supports the use of passive UHF RFID technology, although it has certain limitations, such as relatively short read ranges (up to 10 meters in optimal conditions). Also, it is a challenge, that the human body effectively blocks the RFID tags from the RFID reader, as this may cause problems in practical use. Functionality must be unobtrusively integrated into everyday clothing and furniture around us, which means the technology needs to act invisible.

VI. Conclusions

We described design, development, and an early prototype system of a passive UHF RFID-based phone call system. The prototype system was tested in an office environment in two different test setups and the user successfully made phone calls by using tap and double tap gestures. The advantage of the prototype system is that it can be integrated into clothing or furniture to make a quick call without a mobile phone.

The next step is to test use of other gestures, which can be incorporated into the system, to improve the functionality of the system in practical use. There are also other parts of the system that need further development. For example, the presence of the human body in the surroundings is a challenge that needs to be considered.

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