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Development of a Notification System Using a Wearable Concept that Allows Hearing-impaired Person to Detect that their Doorbell has been Pressed using the nRF24L01 Wireless Module

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Abstract

This research proposes the development of a portable and user-friendly doorbell notification system specifically for the hearing impaired based on the concept of wearable technology. The design is based on two parts which are the doorbell which acts as the transmitter and the wearable which acts as the receiver. Network performance testing was done on both doorbell and wearable in a house. The test was done to observe and record the state of functionality of wearable in a house using different data transmission rate on nRF24L01s. This research has proposed the development of a mobile and user-friendly doorbell notification system specifically for the hearing impaired based on the concept of wearable technology. Network performance tests were performed on both wearables and doorbells to test the effectiveness of the developed system based on its indoor use. The tests performed were observed and recorded based on indoor wearable functional conditions using different data transmission rates on nRF24L01s. Based on the analysis of the data collected, the interpretation that can be given is that the higher the data transmission rate, then it is found that the higher the total number that needs to be pressed on the doorbell to ensure that the signal can be reached by wearables. Additionally, it also assumes that no matter how far the distance range between the doorbell and the wearable is, the response time remains the same which was 0.8ms for 250Kbps data transmission rate in the all the tested rooms. For 1Mbps and 2Mbps, the wearable can only receive signal until the living room which is 5 meters from the front door and stop receiving signal and cannot function even after the doorbell was pressed after passing the living room. While the results also showed that the distance did not influence the response time of the wearable after the doorbell was pressed when using 250Kbps.

Keywords: Hearing-Impaired, Wearable Doorbell, Doorbell Notification System, Data Transmission Rate, nRF24L01.

Introduction

People with disabilities should be treated the same as normal people, meaning they should not be restricted from doing what they want, including socializing with others. There are many types of disabilities that affect the population, one of which includes hearing impairment. A person with hearing loss may have a mild hearing loss or it may reach such an extreme level that they cannot hear anything at all (deafness).

A person with hearing loss can experience many problems. The simple task of answering the doorbell can be a big problem for those with hearing problems. The doorbell that is used needs to have an element other than sound to inform about the presence of guests. For this purpose, a portable and user-friendly doorbell notification system for the hearing impaired needs to be developed. Therefore, this research proposes the development of a portable and user-friendly doorbell notification system specifically for the hearing impaired based on the concept of wearable technology.

Previous Work

Saba et al (2011) developed a system application named "Hey yaa: Wearable Haptic Alert" to support Deaf Communication. This system was developed to allow users to get each other's attention without using voice or sight through haptic sensations. It consists of two waist belts and when a button is pressed on one, the other waist belt vibrates, attracting the user's attention to alert them that another user needs their attention. If one of them can't hear, they can't call each other. The purpose of this project is to solve a problem where a user can contact a deaf person in another room without any physical contact. However, after the focus group test, three of the participants said they did not feel comfortable and reported that it was more difficult to press the button. They also say using it as a belt can get very hot and the vibration is too low that they won't feel it in daily use.

Bragg et al (2016) reported on the construction of A Personalize Mobile Sound Detector App Design for Deaf People. The project is a mobile phone application designed to alert deaf and hard of hearing people to sounds they are interested in. The application uses sounds personally recorded by the user to learn the sound model. Then, it filters the incoming audio stream for that sound using the phone's microphone. When sound is detected, it alerts the user using vibrations and pop-up notifications. The researchers did not use their sound detection algorithm in the application because they did not achieve the expected accuracy for various sounds in noisy environments with the method they used, so they decided to use the Wizard-of-Oz sound detection for their user study to allow them to evaluate application design without precision errors that impact the user experience. However, the algorithm they implemented is preliminary and they hope to find a suitable algorithm in the future that can detect various sounds without any accuracy errors.

Ikova & Mako (2017) tells about the Design of a smart wireless doorbell. In this project, a wireless doorbell is developed to have features such as visitor photo gallery on website and home owner email notification by using Arduino Nano, Raspberry and PHP technology. The Raspberry module is used to communicate directly with the server that serves to store visitors' photos. The server also serves as an email sender of email notifications for home owners. Radio wave communication technology is used to provide wireless communication between the Arduino and Raspberry modules while Wi-Fi technology is used to provide communication between the server and the Raspberry module. This doorbell was developed to increase the safety and comfort of the owner.

Sathe et al (2017) have explained about Arduino Based Smart Watches. The smart watch developed in this project provides new features such as health monitoring notifications at a low cost. It is programmed using the Arduino IDE and embedded with a variety of sensors to detect, track and translate user actions into information. It can also interact with the user's Android smartphone using Bluetooth.

Methodology
Hardware Development
In order to successfully develop this system, all hardware components must be installed on a breadboard. In this project, there are two main parts which are the doorbell which acts as the transmitter and the wearable which acts as the receiver. For the doorbell (transmitter), the hardware components involved are a push button, a 220-ohm transistor, an nRF24L01 wireless module and an Arduino Nano. It starts when the push button is read by the Arduino Nano to allow it to instruct the nRF24L01 wireless module to send messages related to the state of the push button to the wearable. The wearable will then select an action to perform as programmed based on the received push button state. On the wearable side (receiver), the hardware components involved are Nokia 5110 which acts as LCD, 1k ohm transistor, yellow LED, vibrating motor, nRF24L01 wireless module and Arduino Nano. The action of the receiver is triggered when the NRF24L01 receives a message about the state of the push button from the doorbell that will be read by the Arduino Nano. The two possible states of a push button are HIGH or LOW. If the push button's state is HIGH or its value is 1, it will instruct the LCD to display "DOOR OPEN!" notification, the LED flashes and the motor vibrates to notify the user that the push button on the doorbell is pressed by someone which means there is a visitor at the door. If the state of the push button is LOW or the value is 0, the LCD will display the main interface showing "DOORBELL NOTIFICATION FOR DEAF PEOPLE", the LED will not flash and the motor will not vibrate because the push button is not pressed.
All processes will be programmed into the Arduino Nano for both transmitter and receiver according to the flowchart using the source code built with the help of the Arduino IDE.

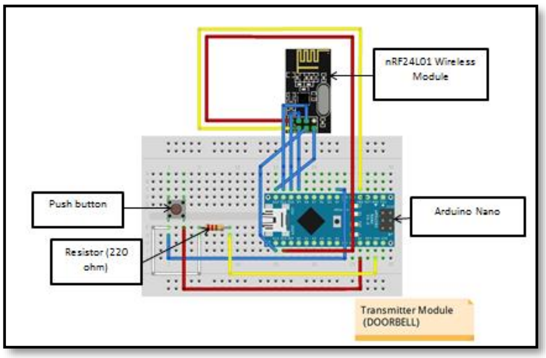

Figure 1 - Sketch Diagram for a Doorbell

Figure 1 shows a sketched diagram for a doorbell. In this diagram, the Arduino Nano, resistors and push buttons are mounted on a breadboard and connected using jumper wires. The Arduino Nano is connected to the nRF24L01 based on pin connections between them using male to female jumper wires. The Arduino Nano is also connected to a push button that acts as a doorbell button based on the pin connections between them using male-to-male jumper wires with resistors between their connections. Every time a push button is pressed, the Arduino Nano will read the state of the push button and send a message telling the state of the push button to the nRF24L01 which will also be received by the wearable.

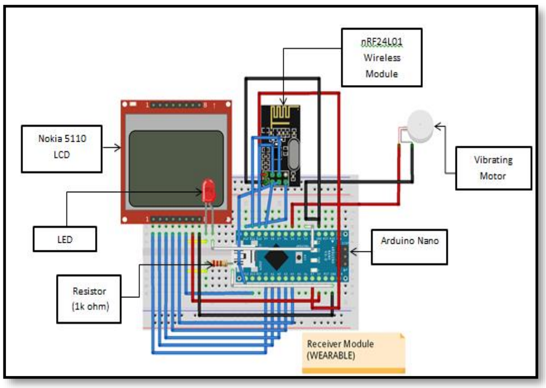

Figure 2 - Sketch Diagram of Wearables

Figure 2 shows the sketched diagram for the wearable. In this diagram, the Arduino Nano, Nokia 5110 LCD, yellow LED, vibrating motor and resistor (1k ohm) are attached to the breadboard using jumper wires. The Arduino Nano is connected to the nRF24L01 based on pin connections between them using male to female jumper wires. The Nokia 5110 LCD is connected to the Arduino Nano based on pin connections between them using male to male jumper wires. The yellow LED is connected to the Arduino Nano with the help of a resistor (1k ohm) based on the start of the pin between them using a male-to-male jumper wire. The vibrating motor is connected to the Arduino Nano using female-to-male jumper wires based on the pin connections between them. Whenever the Arduino Nano reads a message that is the push button state from the nRF24L01 sent by the doorbell nRF24L01, it will instruct the LCD, yellow LED and vibrating motor to work based on the received push button state. If the received push button state is HIGH or the value is 1, the LCD will display its notification, the yellow LED will flash and the vibration motor will vibrate for about two seconds after the push button is pressed. If the received state of the push button is LOW or the value is 0, the LCD will show its main interface instead of issuing a notification, the yellow LED will not flash and the vibration motor will not vibrate because the push button is not pressed.
Figure 3 shows the prototype for the doorbell and Figure 4 shows the prototype for the wearable. The prototype was developed using hardware components and programmed source code to function.

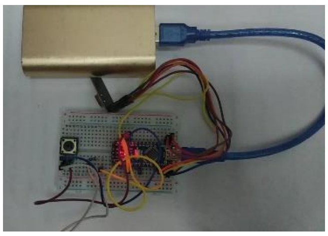

Figure 3 - Prototype for Doorbell (Transmitter)

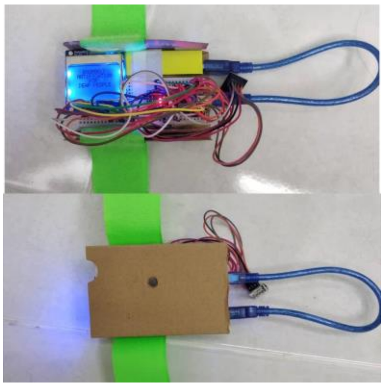

Figure 4 - Prototype for Wearables (Receiver)

Network Performance Testing

Network performance testing was done on both doorbell and wearable in a house. The test was done to observe and record the state of functionality of wearable in a house using different data transmission rate on nRF24L01s. In this testing, the project was tested inside a house which builds up with 120.3 m^2 in area and 55.076 m in perimeter. The doorbell is placed at the front door and the wearer of the wearable moves to five different areas in the house including the living room, kitchen, bedroom, bathroom and store room to test the network performance of the project using different RF power amplifier level.

The house layout that was used to test the network performance of the project is shown in Figure 5 which includes all the furniture and house appliance positions in the house such as television, sofa sets and dining table.

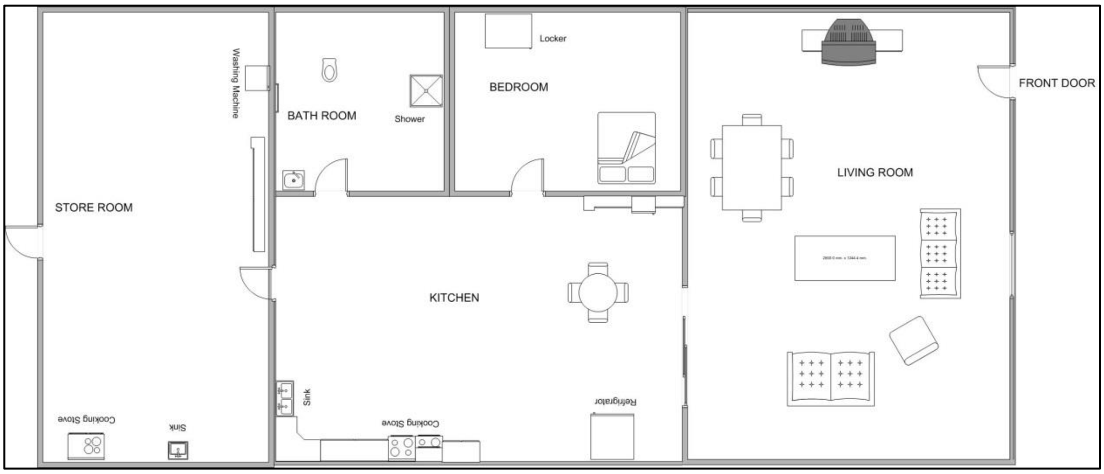

Figure 5 - The layout of the house that was used for this testing

There are several steps in this testing's procedure. First, the doorbell's location is fixed on the front door. The wearer was wearing the wearable and both doorbell and wearable are powered up by connecting them to the power banks. It was needed to wait until the TX led on both Arduino Nano belonging to the doorbell and wearable are blinking rapidly. If one of them did not blink rapidly, they have to be unconnected and reconnected to power banks again.

Then, the wearer was moving to certain rooms such as living room, kitchen, bedroom, bathroom and store room from the front door as the other person is pressed the doorbell on the front door. Then, the state of functionality of the wearable was observed and recorded

as the wearer moved from one room and another to test the network performance of the project by using different data transmission rate of nRF24L01.
Table 1 shows list of data transmission rate of nRF24L01.

Table 1
List of data transmission rate of nRF24L01 and its description

Data Transmission Rate of nRF24L01	Description	Sensitivity	Power consumption
250Kbps	250 Kilobytes per second	-94dBm	12.6mA
1Mbps	1 Megabyte per second	-85dBm	13.1mA
2Mbps	2 Megabyte per second	-82dBm	13.5mA

Source : Nordic Semiconductor ASA, 2008

Data transmission rate of nRF24L01 means how fast data moves through the air. There are three data transmission rates which are 250Kbps, 1Mbps and 2Mbps. There are several steps in this testing procedure that are similar to previous one. First, the doorbell's location is fixed on the front door. The wearer was wearing the wearable and both doorbell and wearable are powered up by connecting them to the power banks.
It was needed to wait until the TX led on both Arduino Nano belonging to the doorbell and wearable are blinking rapidly. If one of them did not blink rapidly, they have to be unconnected and reconnected to power banks again. Then, the wearer was moving to certain rooms such as living room from the front door as the other person is pressed the doorbell on the front door.
Then, the state of functionality of the wearable was observed and its response time was recorded as the wearer moved from one room and another. The remark was recorded for the strange behavior of the signal during this testing. The steps were repeated using different data transmission rate on both nRF24L01s. The results of this testing for each tested rooms were shown in Table 2, Table 3, Table 4, Table 5, and Table 6.

Table 2

Result of functionality of the wearable in living room, its response time and its remark using different data transmission rate

LIVING ROOM (5m from the front door)			
FUNCTIONALITY	DATA TRANSMISSION RATE		
	250kbps	1Mbps	2Mbps
NOKIA 5110 LCD displayed notification	0.8ms	0.8ms	0.8ms
Yellow LED flashed	0.8ms	0.8ms	0.8ms
Vibrating motor vibrated	0.8ms	0.8ms	0.8ms
RESPONSE PATTERN	Only need one press for each signal to be received by wearable	Need two doorbell presses for each signal to be received by wearable	Need five doorbell presses for each signal to be received by wearable

Table 3

Result of functionality of the wearable in bedroom, its response time and its remark using different data transmission rate

BEDROOM (12m from the front door)			
FUNCTIONALITY	DATA TRANSMISSION RATE		
	250kbps	1Mbps	2Mbps
NOKIA 5110 LCD displayed notification	0.8ms	x	x
Yellow LED flashed	0.8ms	x	x
Vibrating motor vibrated	0.8ms	x	x
RESPONSE PATTERN	Only need one press for each signal to be received by wearable	x	x

Table 4
Result of functionality of wearable in kitchen, its response time and its remark using different data transmission rate

KITCHEN (15m from the front door)			
FUNCTIONALITY	DATA TRANSMISSION RATE		
	250kbps	1Mbps	2Mbps
NOKIA 5110 LCD displayed notification	0.8ms	x	x
Yellow LED flashed	0.8ms	x	x
Vibrating motor vibrated	0.8ms	x	x
RESPONSE PATTERN	Only need one press for each signal to be received by wearable	x	x

Table 5
Result of functionality of wearable in bathroom, its response time and its remark using different data transmission rate

BATHROOM (17m from the front door)			
FUNCTIONALITY	DATA TRANSMISSION RATE		
	250kbps	1Mbps	2Mbps
NOKIA 5110 LCD displayed notification	0.8ms	x	x
Yellow LED flashed	0.8ms	x	x
Vibrating motor vibrated	0.8ms	x	x
RESPONSE PATTERN	Only need one press for each signal to be received by wearable	x	x

Table 6
Result of functionality of wearable in store room, its response time and its remark using different data transmission rate

STORE ROOM (22m from the front door)			
FUNCTIONALITY	DATA TRANSMISSION RATE		
	250kbps	1Mbps	2Mbps
NOKIA 5110 LCD displayed notification	0.8ms	x	x
Yellow LED flashed	0.8ms	x	x
Vibrating motor vibrated	0.8ms	x	x
RESPONSE PATTERN	Only need one press for each signal to be received by wearable	x	x

Results and Analysis
Analysis of Network Performance Testing
Analysis of network performance testing is to analyze the results from using different data transmission rate of nRF24L01. This analysis is to summarize the results or data and then interpret them to determine the range that can be achieved in a house and the response time and response pattern of each data transmission rate.
Figure 6 shows the line graph of distance in meter and response time of the wearable after the doorbell was pressed by using different data transmission rate. This graph summarized the response time results of the wearable for network performance testing inside a house using different data transmission rate that were shown in Table 2, Table 3, Table 4, Table 5, and Table 6.

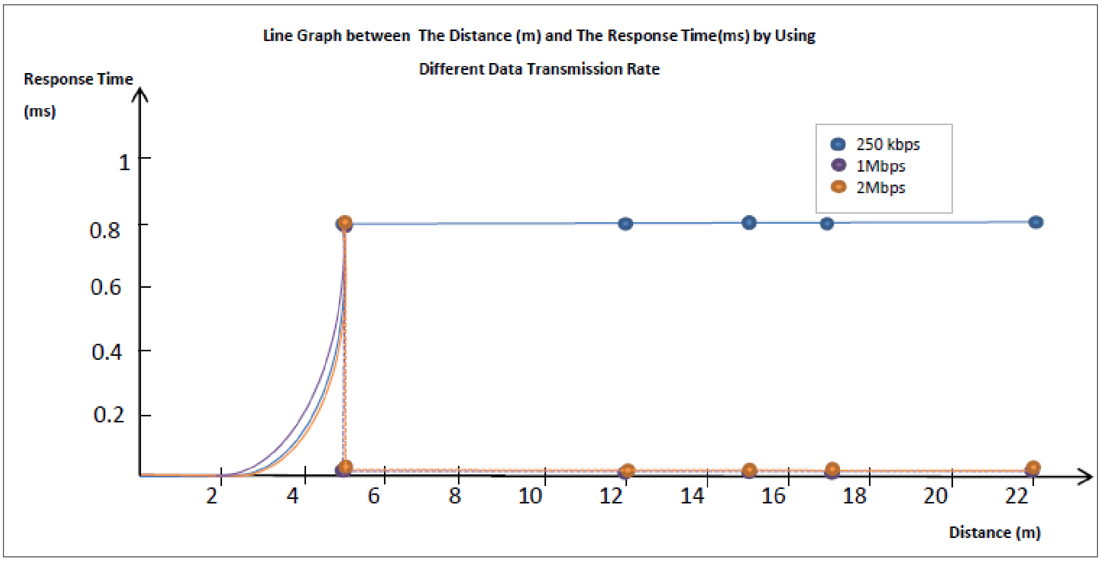

Figure 6 - Line Graph between the Distance (m) and the Response Time (ms) using Different Data Transmission Rate

Based on the graph, it could be interpreted as not matter how long the distance range between the doorbell and wearable, the response time maintained the same which was 0.8ms for 250Kbps data transmission rate in the all the tested rooms. For 1Mbps and 2Mbps, the wearable can only receive signal until the living room which is 5 meters from the front door and stop receiving signal and cannot function even after the doorbell was pressed after passing the living room. These results showed that the distance did not influence the response time of the wearable after the doorbell was pressed when using 250Kbps.
Figure 7 shows the line graph between the distance in meter and the number of doorbells press for the signal to reach the wearable by using different data transmission rate. This graph summarized the results of response pattern of the wearable after the doorbell is pressed that were shown in Table 2, Table 3, Table 4, Table 5, and Table 6.

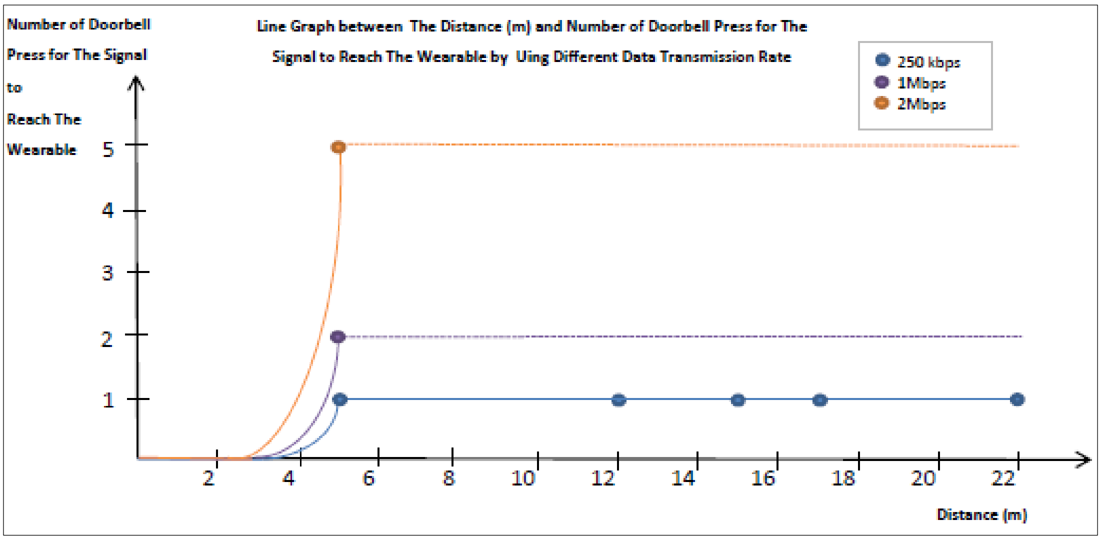

Figure 7 - Line graph between the Distance (m) and Number of Doorbell Press for the Signal to Reach the Wearable by Using Different Data Transmission Rate

Based on the graph, it could be interpreted as the higher the data transmission rate, the higher the number of doorbells press for the signal to reach the wearable. However, after passing the living room which is a distance of 5 meter from the living room, the wearable cannot receive the signal from the doorbell so the functionality of wearable after the doorbell is pressed were not working even after the doorbell was pressed many times for 1Mbps and 2Mbps data transmission rate. For 250Kbps data transmission rate, the number of doorbells press for the signal to reach the wearable maintained as one for every tested room and distance range.
Based on the analysis of the graph, 250Kbps data transmission rate is the best data transmission rate to deliver the signal from the doorbell to the wearable since it only needs one press of doorbell for the wearable to function its functionality after the doorbell was pressed in every room.

Conclusion

This research has proposed the development of a mobile and user-friendly doorbell notification system specifically for the hearing impaired based on the concept of wearable technology. Network performance tests were performed on both wearables and doorbells to test the effectiveness of the developed system based on its indoor use. The tests performed were observed and recorded based on indoor wearable functional conditions using different data transmission rates on nRF24L01s. Based on the analysis of the data collected, the interpretation that can be given is that the higher the data transmission rate, then it is found that the higher the total number that needs to be pressed on the doorbell to ensure that the signal can be reached by wearables. Additionally, it also assumes that no matter how far the distance range between the doorbell and the wearable is, the response time remains the same. The conclusion that can be obtained based on the results and analysis is that the wearable system developed using the nRF24L01 wireless module to inform a hearing-impaired person about the presence of a guest at the door of the house who is pressing the doorbell is successful.

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