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Implementation of Braille-Mobile Device to Help Visually and Speech-Impaired Persons Communicate Based on the Blynk IoT

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ABSTRACT

Visual and speech impairment is a condition in which an individual is unable to communicate with family or society due to the inability to see and speak. The objective of this study is to develop a Braille-Mobile device that assists individuals with visual and speech disabilities in communicating remotely with family members or society using Internet of Things (IoT) technology. In this study, the method used to generate messages from the Braille-Mobile device is based on the combination of six buttons pressed on the device, which are translated into letters using the Braille code concept. The messages are then transmitted via the Blynk IoT platform from the Braille-Mobile device to the mobile devices of family members or society through the Internet network. The results of this study show that the developed Braille-Mobile device can be used to send messages in the form of the words HELP, EAT, DRINK, and DRUG to family smartphones using IoT technology with a success rate of up to 76.25% and a message transmission time ranging from 4 to 8 seconds. Furthermore, the Braille-Mobile device is also capable of receiving confirmation from family smartphones in the form of voice responses.

I. Introduction

Based on data from the World Health Organization (WHO) in 2020, the number of people with disabilities reached more than 1 billion worldwide, including individuals with visual and speech impairments [1]. Visual and speech impairment is a condition in which an individual experiences a disability characterized by the inability to see and speak, either due to biological factors since birth or as a result of an accident. In certain situations, individuals with visual and speech impairments may need to communicate remotely with family members or society through mobile phones to request assistance or convey important information. However, this becomes a significant problem when they are unable to use mobile devices for remote communication due to blindness and muteness. Such limitations may cause individuals with visual and speech disabilities to feel isolated, and can potentially lead to stress, depression, mental disorders, and psychological issues. Based on this background, the objective of this study is to develop a Braille-Mobile device that enables individuals with visual and speech impairments to communicate remotely with family members or society by utilizing Internet of Things (IoT) technology.

In its application, several previous researchers have developed systems or devices to assist individuals with visual and speech impairments in communication. Kusumastuti et al. developed a Braille printer device for individuals with visual disabilities [2]. In that study, the researchers designed a Braille printer based on Arduino Uno and servo motor movements. Furthermore, Handayani et al. created a Mobile Braille Touch (MBT) training model for students at UPT Tunanetra, East Java [3]. The researchers in that study developed a smartphone-based Mobile Braille Touch application with audio and visual outputs to support learning for students with visual impairments. The development of an interactive communication tool (INCOM) for the visually and hearing impaired in the learning process was conducted by Beny [4]. In that research, the author designed a communication device for individuals with visual and hearing impairments based on the ADDIE model using Raspberry Pi for educational purposes. The implementation of training in the use of Braille learning devices for visually impaired students was carried out by Purnama [5]. In that study, the researchers developed a self-learning device for Braille letters using Braille cards capable of producing sound. Furthermore, Mardiyah et al. developed the Braille Button media for visually impaired children [6]. In their research, the device was designed as an assistive Braille Button media capable of producing sound to help visually impaired individuals learn Braille letters.

In addition, Saifullah et al. implemented an electronic system for a refreshable Braille device with voice features integrated with Android [7]. The results of the study demonstrated that the researchers successfully developed a refreshable Braille device capable of converting Braille characters into speech using an Android platform and an Arduino Uno microcontroller. Wahyujati et al. designed a low-cost Braille learning and playing prototype device based on an Arduino microcontroller and RFID sensor [8]. In that study, the researchers developed a Braille learning device for visually impaired individuals using an Arduino microcontroller and an RFID sensor as Braille input. Furthermore, Susanti et al. designed a smart book medium to address the difficulties of visually impaired children in learning Arabic script [9]. In that research, the researchers developed a smart book device for visually impaired Quran learning based on voice recognition, Raspberry Pi, loudspeakers, and Braille boards. The implementation of a Braille character recognition device for visually impaired students with Android control was developed by Maruzi et al. [10]. In that study, the researchers built a Braille learning device for visually impaired students by integrating Arduino-based learning tools with Android. Moreover, Binari et al. developed a Braille character recognition medium for visually impaired children based on a microcontroller [11]. In their study, the researchers designed a Braille recognition device using push buttons, Arduino Atmega, DF Player, and speakers.

Based on the findings from previous studies, several researchers have developed Braille-based devices to assist individuals with visual impairments, such as supporting Braille reading from printed text, Braille learning through smartphone applications and tools, as well as the utilization of microcontroller-based controls and devices to facilitate Braille learning and recognition. However, according to the state-of-the-art review and previous research, no studies have yet developed a device that enables individuals with visual and speech impairments to perform remote communication with family or society through mobile devices using Braille and Internet of Things technology. Therefore, the novelty of this research lies in the development of a Braille-Mobile device as an assistive communication medium for remote interaction of individuals with visual and speech impairments based on the Internet of Things. Furthermore, this study demonstrates that the developed Braille-Mobile device is a prototype ready to be utilized to assist individuals with visual and speech impairments in communicating remotely through the Internet of Things (IoT) technology.

The researchers will present in detail the outcomes of this study in this paper, which is structured into four sections. The first section is the introduction, which discusses the research background. The second section describes the methodology applied to address the problems in this study. The third section presents the results and discussion, while the fourth section provides the conclusions along with recommendations for future research development.

II. METHOD

The problem-solving approach proposed in this study to assist individuals with visual and speech impairments in performing remote communication with family or society through mobile media is the development of an Internet of Things (IoT)-based Braille-Mobile device. The constructed Braille-Mobile device consists of several interconnected components that function as an IoT-based communication system, including a keypad combination that serves as the Braille character generator, a Raspberry Pi as the central processing unit for converting Braille characters into text messages and transforming text messages into speech, a speaker for delivering audio messages and notifications, an LCD for displaying text messages, and the utilization of the Blynk IoT platform for transmitting text message data between the Braille-Mobile device and the mobile devices of family members or society.

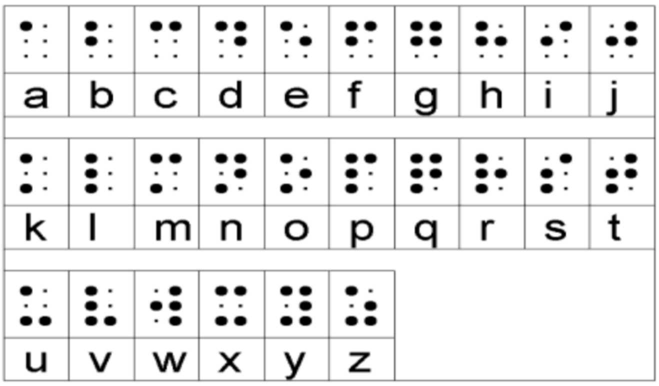

Figure 1. Braille Characters [12]

In this study, we applied a data conversion technique from button inputs to Braille characters to facilitate individuals with visual and speech impairments in determining the letters and sentences to be transmitted to family members or society through IoT-based messages. Figure 1 illustrates the method of converting Braille characters into text. Based on the information in Figure 1, several dot combinations can be observed that are used to convert Braille codes into text applied in this study. Furthermore, Figure 2 presents the architecture and the proposed solution to address the problem in this research.

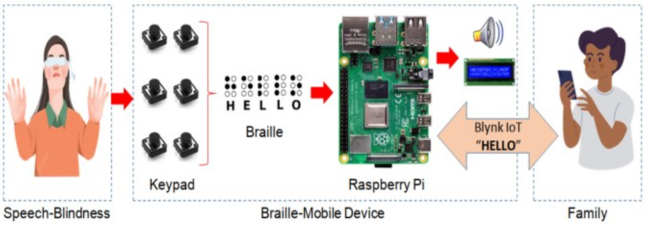

Figure 2. Illustration of Research Problem Solving Approach

Based on the information in Figure 2, it can be observed that the initial step taken by individuals with visual and speech impairments to communicate is by pressing a combination of buttons on the Braille-Mobile device to generate Braille characters. The Raspberry Pi then reads the Braille character input data and converts it into text data. After the Braille characters are converted into text, the Raspberry Pi transmits the text message to the mobile devices of family members or society using the Blynk IoT platform over the Internet. Furthermore, the Raspberry Pi provides message delivery notifications through the speaker and LCD, and it is also capable of converting incoming text messages into speech when family members or relatives send messages to the Braille-Mobile device of individuals with visual and speech impairments.

Furthermore, Figure 3 represents the system architecture design to be developed as a method for addressing the problem in this study.

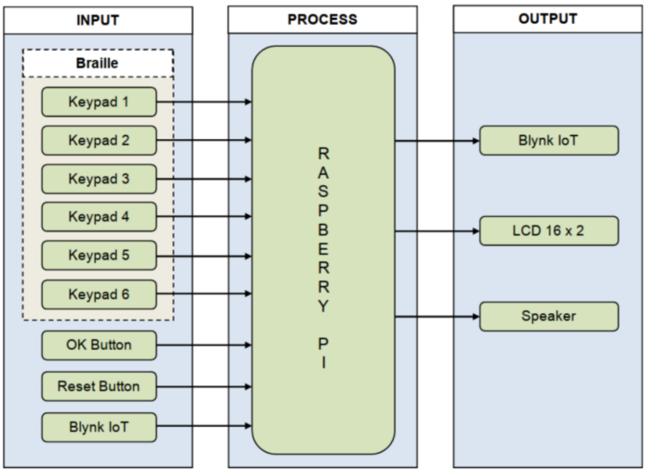

Figure 3. Systems Architecture

Based on the information in Figure 3, it can be observed that the system architecture of the Braille-Mobile device to be developed consists of three core components: input, process, and output. The input section includes six keypads functioning as buttons for entering Braille character data into the Raspberry Pi, an OK button for sending and confirming messages, a reset button for canceling messages, and the Blynk IoT platform for receiving text messages sent from family or community mobile devices through the Blynk platform. The keypads or buttons are passive electronic components that act as triggers to allow electrical current to flow when pressed [13], whereas Blynk IoT is a mobile-based Internet of Things platform that enables the exchange of text messages between IoT control devices and user smartphones via the Internet [14].

Furthermore, in the process section, the Raspberry Pi functions as the central data processing unit of the Braille-Mobile device. In the developed system, all input components from the keypads are connected to the GPIO pins of the Raspberry Pi, which then reads the input data when individuals with visual and speech impairments press the keypad buttons to enter Braille codes or characters. The Raspberry Pi is a mini-sized microcomputer that can be utilized to control IoT-based devices through its available GPIO pins [15]. In the output section, a speaker is used to deliver notification sounds and incoming Blynk messages transmitted from family or community smartphones to the Braille-Mobile device of individuals with visual and speech impairments. A speaker is a device that converts signals from the processing unit into audible sound [16]. In addition, a 16x2 LCD is employed to display incoming message data on the Braille-Mobile device. The 16x2 LCD is an output control device used to present messages in text form [17]. Furthermore, the output section also integrates the Blynk IoT platform, which is utilized to transmit text message data converted from Braille characters to family smartphones using Internet of Things technology. The Internet of Things is a technology applied for monitoring and controlling devices remotely via the Internet [18]. In this study, we employed a Wireless Access Point device that establishes a connection between the Raspberry Pi and Wi-Fi to transmit data information from the Braille-Mobile device to the Internet. The software employed to control all hardware components and the system in this study is Linux Ubuntu 24.04 LTS and the Python programming language.

III. Results and Discussion

This study has developed a Braille-Mobile device designed to assist individuals with visual and speech impairments in communicating remotely with family or community members using Internet of Things. Figure 4 shows the external view of the Braille-Mobile device.

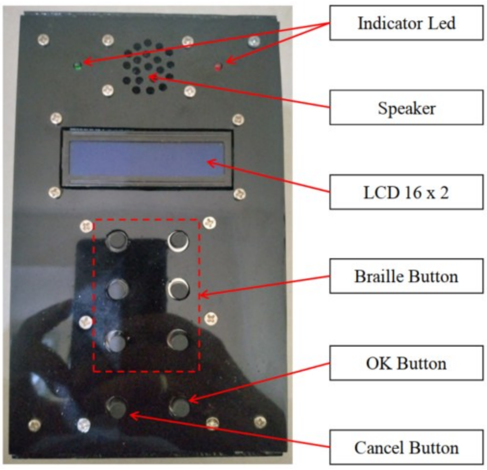

Figure 4. Braille-Mobile result view from the outside

Several interconnected hardware circuits are implemented in this study to enable the developed Braille-Mobile device to assist individuals with visual and speech impairments in mobile communication. Figure 5 presents the research outcome in the form of the internal view of the constructed mobile hardware device.

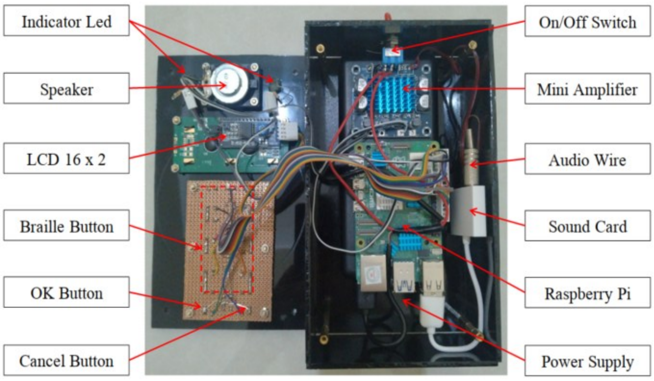

Figure 5. Braille-Mobile result view from the inside

Based on the internal and external results shown in Figures 4 and 5, it can be observed that several hardware components are integrated to construct the Braille-Mobile communication device for individuals with visual and speech impairments. The hardware implementation includes green and red LED indicators used to provide information when the device is powered on and when a message is received. In addition, a speaker is employed to generate sound output when the Braille-Mobile device receives a text message from family members or the community. Furthermore, a 16x2 LCD is utilized to display text messages, Braille buttons serve as input for converting Braille codes into characters when pressed by the user to communicate, and OK and Cancel buttons are provided to confirm or cancel message transmission.

In the internal section of the Braille-Mobile device, it can be observed that an on/off switch is used to power the device, a mini amplifier is employed to amplify audio signals when the Braille-Mobile receives text messages from family members, and an audio cable is utilized to transmit sound data from the sound card to the mini amplifier. Furthermore, the internal components include a sound card that converts digital audio data from the Raspberry Pi into analog sound, connected via the Raspberry Pi USB port; a Raspberry Pi serving as the central processing unit of the Braille-Mobile; and a power supply that provides voltage to all components within the device. Table 1 presents the power consumption required by each component to operate the Braille-Mobile device.

In this study, we utilized Linux Ubuntu 24.04 LTS as the operating system running on the Raspberry Pi, along with the Blynk IoT platform to transmit and receive text message data between the Braille-Mobile device and the family's or community's mobile devices. Figure 6 illustrates the Blynk software interface on a family mobile device, which is used to receive text message data from visually and speech-impaired individuals through the Internet of Things.

TABLE I
POWER REQUIREMENTS OF EACH DEVICE

Devices	Power
Raspberry Pi	5 Volt DC
Mini Amplifier	5 Volt DC
LCD 16x2	5 Volt DC
Braille Button	5 Volt DC
Sound Card	5 Volt DC

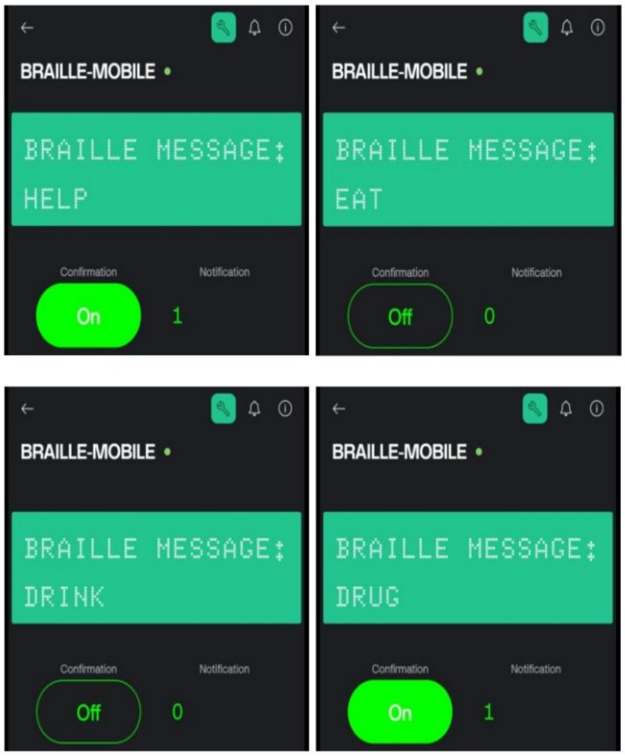

Figure 6. Results of text messages received by family using Blynk IoT

Based on the information in Figure 6, it can be observed that the Braille-Mobile device successfully transmitted messages to the family's mobile device using the Blynk IoT platform technology. In the Blynk IoT software implemented on the smartphone, several front-end components are utilized, including an LCD display to show text messages, an on/off button to confirm message reception, and notifications to verify that the messages sent from the smartphone have been successfully received by the Braille-Mobile device. Table 2 presents the Blynk Datastream used for transmitting and receiving message data along with their data types.

TABLE 2
DATASTREAM AND DATA TYPE OF BLYNK

Information	Datastream	Data Type
LCD	String V1 [V1]	String, id=1
	String V2 [V2]	String, id=2
Confirmation	Switch Control [V3]	Integer, 0/1, id=3
Notification	Switch Value [V3]	Integer, 0/1, id=4

Based on the information in Table 2, it can be observed that several Datastreams are utilized for transmitting message data from the Braille-Mobile device to the family's smartphone via the Blynk platform, using String data types for the LCD and Integer data types for the confirmation button and notifications. In this study, we conducted experiments on message transmission from persons with visual and speech impairments using the Braille-Mobile device to the family's smartphone. Figure 7 illustrates the experimental results of the Braille-Mobile device applied to individuals with visual and speech disabilities.

Figure 7. Braille-Mobile device trial results

Furthermore, in this study, we conducted usability testing to evaluate the comfort of individuals with visual and speech impairments in pressing the Braille buttons on the Braille-Mobile device. Figure 8 provides a detailed illustration of the finger positions of users with visual and speech disabilities while pressing the Braille buttons.

Figure 8. Finger position when pressing Braille keys

Based on the information in Figure 8, it can be observed that individuals with visual and speech impairments can easily press the Braille buttons due to their large size and user-friendly design. Furthermore, Figure 9 illustrates the resulting text message that was successfully entered and transmitted through the Braille-Mobile device.

Figure 9. Text message sender test results

Based on the information shown in Figure 9, it can be observed that the visually and speech-impaired user successfully pressed the Braille button, displaying the message "HELP" on the Braille-Mobile LCD. Furthermore, the researchers conducted an experimental test to evaluate the ability of visually and speech-impaired individuals to press the Braille buttons and generate corresponding text messages. The experiment was carried out indoors, where each word was tested five times by a single respondent. Table 3 presents the results of the Braille button press tests in generating text on the Braille-Mobile device.

TABLE 3
BRAILLE BUTTON TEST RESULTS

Messages	Output	Results
HELP	HELP	Success
	HDLP	Fail
	HELP	Success
	HELP	Success
	HELR	Fail
EAT	EAT	Success
	EAT	Success
	EAT	Success
	EAS	Fail
	EAT	Success
DRINK	DRINK	Success
	DPIQK	Fail
	DRIQK	Fail
	DRINK	Success
	DPINK	Fail
DRUG	DRUG	Success
	DPUG	Fail
	DRUG	Success
	DPUG	Fail
	DRUG	Success

Based on the information in Table 3, it can be observed that several trial results showed failures in generating the intended Braille characters according to the desired text to be sent. This occurred due to the necessity for users to memorize the entire Braille character combinations and the sensitivity of their fingers when feeling and pressing the buttons. Furthermore, Figure 10 illustrates the percentage of success and error rates in Braille button press trials conducted by individuals with visual and speech impairments.

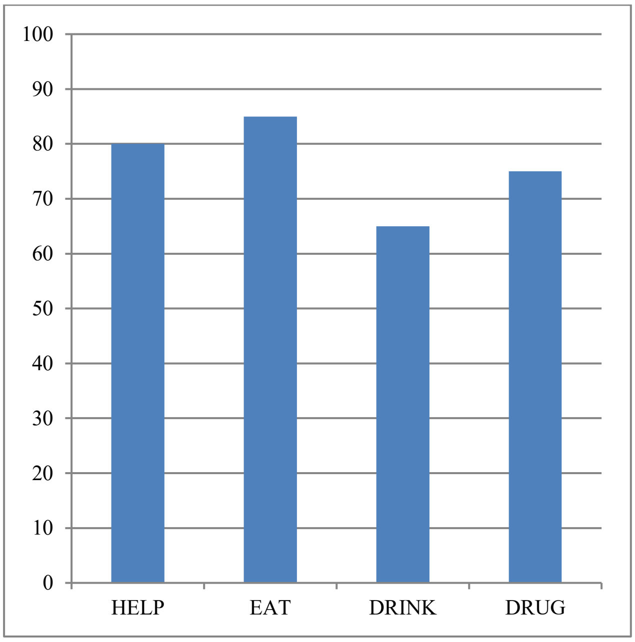

Figure 10. The results of the trial successfully revived Braille letters

TABLE 4
RESULTS OF MESSAGE DATA DELIVERY TIME ANALYSIS

Messages	TIME (Second)
HELP	4.7
	5.3
	4.5
	6.1
	5.6
EAT	7.2
	6.7
	4.8
	8.1
	5.6
DRINK	4.3
	5.6
	7.4
	6.6
	5.8
DRUG	5.8
	6.5
	4.9
	6.9
	7.2

Based on the trial results of generating Braille characters into text as shown in Figure 10, it can be observed that the word *HELP* was successfully generated with a success rate of up to 80%, *EAT* up to 85%, *DRINK* up to 65%, and *DRUG* up to 75%. From these trials, it can be concluded that the users successfully transmitted text messages to the family's smartphone with an overall success rate of 76.25%. This outcome occurred due to the necessity for individuals with visual and speech impairments to memorize Braille character combinations to generate letters, as well as the sensitivity of their fingers when feeling and pressing the Braille buttons. In addition, the user's level of understanding in pressing the buttons while recalling the previously pressed letters becomes an important factor in the success of individuals with disabilities to transmit message data using the correct words.

Furthermore, in this study, we conducted experiments to measure the time required to transmit text messages from the Braille-Mobile device to the family's smartphone. Table 4 presents the results of the message transmission time from the Braille-Mobile device to the family's smartphone. Based on the trial results presented in Table 4, the time required to transmit text messages from the Braille-Mobile device to the family's smartphone ranged between 4 and 8 seconds on average. This variation occurred due to dependencies on the local network and Internet conditions used for message transmission, as well as the server performance of the Blynk IoT platform. The impact resulting from the system delay in message transmission is a significantly slow response time, which greatly affects the ability of individuals with visual and speech impairments to promptly request assistance from their family members or the surrounding community. Therefore, the findings of this study demonstrate that the Braille-Mobile device can be effectively used for IoT-based message transmission.

The recommendation for future research development is to increase the number of words that can be used for communication by individuals with visual and speech impairments to more than four words, allowing them to form complete sentences. In addition, the message data transmission time from the Braille-Mobile device to the family's smartphone becomes a limitation of this study. Therefore, future research should focus on minimizing message transmission delay to achieve a shorter response time that closely approximates a real-time data transmission system. Furthermore, the size of the developed device can be reduced to make it more convenient for individuals with visual and speech impairments to carry it anywhere with ease.

IV. CONCLUSION

This study implemented the utilization of the Braille-Mobile device as an assistive communication medium for individuals with visual and speech impairments to communicate remotely with their families' smartphones using the Internet of Things (IoT). The hardware employed to generate Braille characters on the Braille-Mobile device was based on Braille button inputs pressed by the users, which were then processed by the Raspberry Pi. The output of the Braille-Mobile device consisted of text messages such as HELP, EAT, DRINK, and DRUG, successfully transmitted to family smartphones with an average success rate of 76.25%. This limitation occurred due to the necessity for users to memorize Braille button combinations and the sensitivity of their fingers when pressing the Braille buttons. Furthermore, the transmission time analysis indicated that the Braille-Mobile device was capable of sending text messages to family smartphones via the Blynk IoT platform with an average delay ranging from 4 to 8 seconds. In addition, the output of the Braille-Mobile device included voice feedback to confirm to users that their messages had been successfully received by family members, as well as an LCD to display the generated text messages. Future research is suggested to focus on minimizing the physical size of the Braille-Mobile device and integrating Artificial Intelligence and Machine Learning to enhance dataset processing and message transmission. In addition, the transmission capacity for words and sentences in this study needs to be improved, and the data transmission delay should be minimized to achieve faster data delivery that closely approximates a real-time system.

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