Effectiveness of Bluetooth communication of digital stethoscope using quality of service method

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ABSTRACT

This study aims to design and evaluate a wireless electronic stethoscope that can transmit heart sound using Bluetooth HC-05 and Bluetooth 5.0 transmitter. This novel design contributes to the remote diagnosis and monitoring of heart conditions, especially for patients with infectious diseases. The heart sound signals are captured using a mic condenser mic, amplified, filtered, and converted to digital data by a microcontroller. The data are then transmitted by Bluetooth HC-05 to a module and by Bluetooth 5.0 transmitter to a headset. The quality-of-service parameters such as throughput, delay, and packet loss ratio (PLR) of the data transmission at different distances are measured. The results show that the wireless electronic stethoscope can transmit heart sound data with a small PLR of 0.10% and a throughput of 1002.5 bps. The study concludes that the wireless electronic stethoscope is an effective and useful device for examining heart conditions remotely, without compromising the functionality of the device.

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1. INTRODUCTION

The COVID 19 outbreak was first detected at the end of 2019 in China, and spread throughout the world at the beginning of 2021 [1]. In Indonesia, the COVID 19 outbreak was detected in early 2020 with the first case in West Java. The COVID 19 outbreak caused a lot of deaths, because of this incident many researchers from various fields tried to make tools to help the recovery of patients and support medical personnel in detecting diseases by implementing health protocols. It is aimed at protecting and assisting medical personnel in carrying out their duties. In Indonesia, in addition to the personal protective equipment used by medical personnel, to limit the distance between medical personnel and patients, partitions using acrylic materials are added to the medical personnel. These partitions are found on all desks of medical personnel both in the poly and in the emergency department. So a work system or supporting tools is needed for conditions in health facilities in Indonesia [2]. According to information from the Heart Foundation, heart disease is one of the main causes of mortality in the US, killing 787,000 individuals each year. Similar events occurred in Indonesia, where the Ministry of Health's 2013 annual health report noted that heart disease patients made up more than 1% of the population in most regions [3]. This is made worse by data from the organization of Indonesian cardiologists, the number of people who died from heart disease reached 7.6 million, and 325,000 of those deaths were caused by delays in treatment before getting to the hospital [4]. A stethoscope is the most basic tool for doctors in general. In the case of detecting cardiac and pulmonary sounds, the stethoscope is often used by heart disease doctors, internal medicine doctors, and emergency department doctors in examining or screening tests. Stethoscopes generally use tubing to transmit sound from diaphragm to earpieces. Stethoscopes evolved with the development of technology, so electronic stethoscopes were created using wired headsets. There are also many researchers who work on research on stethoscopes with cable systems [5]–[7]. There are also stethoscopes that have used Bluetooth technology so that they use Bluetooth headsets that eliminate physical connections and diaphragm and earpieces. There are researchers who work on a stethoscope with a wireless system and can record signals so that in-depth analysis can be carried out. However, the built stethoscope sends a signal utilizing Bluetooth to connect to the personal computer [7]–[9]. The process of biased diagnosis for heart illness can be brought on by a number of variables stemming from the challenge of recognizing precise cardiac signals [8]. A crucial step in the Tele-auscultation system's entire operation is signal processing for abnormal heart sounds [10], [11]. In this case, analysis of cardiac problem diagnosis using phonocardiograph [10], [11]. A phonocardiogram (PCG) employs valve technology to capture cardiac sound vibrations from one or more localized auscultation sites in a nonlinear, non-stationary manner. Studies are being done on devices for collecting and analyzing heart sounds for use in home heart condition monitoring [12]. There has already been research on digital stethoscopes that can detect heart sound impulses using a variety of sensors. However, there hasn't yet been any research on employing a condenser mic sensor [10], [11], [13].

In addition, condenser microphones were employed in several experiments to pick up heart sound signals, however wireless devices were not utilised [5]–[7]. Several investigations have also employed adaptive filters and signal extraction techniques. However, because of the pressure field microphone's constrained frequency response, the audio respiratory pulse is muted and appears as a discontinuity [9], [12], [14]–[17]. Furthermore, the creation of a 24 GHz radar stethoscope prototype is being done in order to diagnose heart sounds without having to interact with the patient directly. However, this device continues to not make use of wireless technology [13]. Electric stethoscopes that employ a wireless technology that can record signal are available for in-depth study. However, only one recipient can receive the signal from the built-in stethoscope [10], [11]. A smart digital stethoscope using current electronics and computing technologies was created by Szot *et al*. [18] to aid in the auscultation of the heart and deliver precise information. For the purpose of processing an auscultation signal captured by a microphone, a signal conditioning circuit was created. The processed signal was digitally transformed using an Arduino processor board [18]. Using the HC06 wireless transmission module, Frank and Meng [19] developed a cost-efficient electronic stethoscope that is useful for medical monitoring. The equipment can provide remote real-time visualized signal monitoring as a result of research [19]. A digital stethoscope with wireless transmission was created by Malek *et al*. [20] using a Zigbee module. Signals can be transmitted up to 100 meters away using the Zigbee module. The research's findings showed that the tool could convey data [20]. In this case, digital signal processing has been studied and used to produce medical devices for evaluating, recording, and filtering bio signals. The heart sound signal from a stethoscope can be recorded as a waveform file for use in sound players and patient database systems. The database for this investigation is required for clinical practice or medical education [21], [22]. To build a stethoscope that can be used in the classroom and allow multiple pupils to listen to it, research was done on how to include Bluetooth into it. Multisim was also used for testing in this study. The research's findings showed that the gadget can hear heartbeats and can disregard delays that don't really have much of an impact [23], [24]. Some studies have developed an electronic stethoscope with a Bluetooth system. Mills [25] conducted research on electronic stethoscopes with 2 transmissions, namely earpieces and chest pieces connected to Bluetooth with the low-power microcontroller MSP430. This research is proven if the stethoscope device can function properly and consistently [25]. Shi *et al*. [16] conducted research on digital stethoscope wearables with wireless communication capabilities which will later be compared with stethoscopes with wired communication. This study used nRF24L01 as a transceiver and dongle for connection on a PC.

This study found that the recording results using a digital wearable stethoscope with a cable system have similarities with the cable system [16]. Dao [26] conducted research on PCG monitoring with wireless sensors with MATLAB to record and analyze PCG signals through transmitters and receivers. However, in this study there was no analysis of the results obtained regarding the effectiveness of this wireless PCG as a medical device [26]. Mondal *et al*. [27] conducted research on the development of wireless PCG with Bluetooth using limited sources. This study used a Bluetooth headset that was modified so that it could record heart sound signals recorded by smartphones and sent via Bluetooth. The result of this study is that it is proven that such devices can detect sound signals well seen through Audacity [27]. Patil [28] conducted research on electronic stethoscopes using embedded processors that use wireless delivery with Zigbee modules. This study obtained results heart signals could be read well [28]. Based on the above problems, the author aims to design a wireless electronic stethoscope using a Bluetooth transmitter to a headset with a Bluetooth 5.0 type, and Bluetooth HC-05 as sending data to display signals to the thin film transistor liquid crystal display (TFT LCD) module. The Bluetooth 5.0 headset was used in this study where the headset connected to the Bluetooth transmitter version 5.0 is similar to the headset version used. The purpose of this study was to find out how effective the design was to support the problems, without compromising the functionality of the device where doctors can see pathogenic signals from patients remotely. Researchers analyze data loss at the time of delivery with the design that has been made. The implication of this research is to assist medical personnel in carrying out tasks, in addition to that in the world of academia it is very supportive of the learning process, especially for students in the department of electro-medical engineering technology in diagnostic equipment lessons. It is hoped that this research can help medical personnel and deficiencies can be immediately reinstated so as not to cause misdiagnosis by doctors.

2. MATERIALS AND METHOD

Theoretical background. Level of service a network's quality can be measured using quality of service (QoS), which also attempts to define the features and characteristics of a single service. A set of performance attributes that have been specified and connected to a service are measured using QoS. The term QoS describes a network's capacity to use various technologies to better serve a particular type of network traffic. The ability to specify the characteristics of the network service being offered is provided by QoS.

In a study, it explained the quality of service and provided throughput modelling on multihop wireless networks. The researcher considers the personal view of a station, four different channel states can be identified: i) successful transmission; ii) idle transmission; iii) transmission is busy due to the activity of other stations; and iv) collisions; these states are denoted by: i.=T-s., ii.=T-σ., iii.=T-b., and iv.=T-c., respectively. P is the likelihood that the broadcast packet will be lost, and b is the likelihood that another station's action will cause the channel to become active after an idle period. Station throughput is given by, where (in seconds) is the average duration of all states on the channel and throughput is given in $T_p = \frac{\Pi_s}{\Delta}\Delta$ using (1):

$$T_P = \frac{\tau(1-p)}{\tau(1-p)\bar{T}_s+\tau p\bar{T}_c+(1-\tau)(1-b)\sigma+(1-\tau)b\bar{T}_b} \tag{1}$$

Calculating the expression for which is actually a function of p, it is also shown that the expression is similar to that of being movable for common multihop wireless networks that use arbitrary window distributions and exponential backoff multipliers. The full expression for carrier sense multiple access (CSMA) multi-hop networks taking into account the maximum window size and maximum resend limit is found in the (2):

$$\tau = \frac{2q(1-p^{m+1})}{q(1-p^{m+1})+W_0[1-p-p(2p)^{m'}(1+p^{m-m"}q)]} \tag{2}$$

Where represents the minimum window size, m is the upper limit for retry, $W_0\ q = 1-2p$ and m' is the backoff stage value. And is the average duration of a successful collision and transmission and these two values work together for a single-hop and multi-hop arbitrary topology. There is only $(\mathrm{m}' \leq \mathrm{m})\bar{\mathrm{T}}_\mathrm{c}\bar{\mathrm{T}}_\mathrm{s}$ one unknown quantity in the throughput formula in (1). The probability of loss of conditional packets from the scenario is given by $1-(1-\tau)^{n-1}$ here n indicates the number of stations in the network. But there is an inherent problem when used in multi-hop network scenarios cannot synchronize all stations in the network (3).

$$p(i) = 1-[1-p_{ss}(i,i')][1-p_{ais}(i,i')] \\ [1-p_{sis}(i,i')][1-p_{dc}(i,i')] \tag{3}$$

With the aim of clearly distinguishing between interference from the transmission and transmitter range, identified and modeled four possible types of packet loss that could occur due to CSMA-based MAC behavior in a multi-hop wireless network: loss due to: i) sender sensing with probability; ii) the incomplete state is asymmetrical to probability; iii) the incomplete state is symmetrical to probability; and iv) the objective is linked to probability. To determine the overall chance of packet loss, the probabilities of each recognized category are individually combined. Transmissions that do not suffer from this loss are successful.

In this study, researchers did not consider the phenomenon described above. In this study, it used a standard formula. Where, throughput is the rate (speed) of effective data transfer and is expressed in bits per second (bps) (bits per second). Throughput is calculated by dividing the total number of successfully delivered packets at the destination over a specified period of time by the period's length. Throughput calculation (4):

$$Throughput = \frac{\beta}{\Delta t} \tag{4}$$

where, β=data packet received, Δt=long time observing. The term packet loss refers to a condition that represents the total number of packets that may be lost as a result of network congestion and collisions. Packet loss calculation (5):

$$Packet\ loss = \frac{(\alpha-\beta)}{\alpha}\ x100\% \quad (5)$$

Where, α=packet sent data from the sender section/ master, β=packet received data on the receiving/slave part. The delay (latency) is the time it takes for data to travel the distance from origin to destination. Delay can be affected by distance, physical media, congestions or also long processing time. Delay calculation (6):

$$Average\ delay = \frac{\partial}{p} \quad (6)$$

where, ∂=total delay obtained in the experiment, p=total packets received on the receiver.

Participant. In this study, the subjects who participated were 10 male respondent aged 20 years who did not have a heart defect. Participants agreed to participate in the study after studying and understanding the experimental protocol. Data retrieval locations are conditioned by minimizing noise in the room. Noise conditioning at the data collection site aims to reduce the presence of disruptive signals recorded.

Data acquisition. The design of this research is divided into two parts, namely transmitter (TX) and receiver (RX) where the TX part consists of sensors, preamplifiers, microcontrollers, Bluetooth HC-05 as TX and Bluetooth transmitter version 5.0. for part RX consists of Bluetooth HC-05 which is used as a receiver, microcontroller and 4.5-inch TFT LCD product from Nextion. Initially the sensor was corroborated with a preamplifier circuit and filtered with a band pass filter (BPF) filter with a low frequency of 30 Hz and a high frequency of 1000 Hz. Output from the filter circuit is connected to the adder circuit. The output of the adder circuit is connected to the analog digital converter (ADC) pin of the microcontroller. The microcontroller is connected to Bluetooth with a TX-RX pin. Data sent from Bluetooth TX is received by Bluetooth RX, data is processed in the microcontroller and displayed to the TFT LCD. The sample rate used in this study was 1000 Hz, using a baud rate of 38400 bit-per-second (bps) because communication between Bluetooth to Bluetooth can only be or is recommended at 38400 bps. The proposed stethoscope design illustration is depicted in Figure 1.

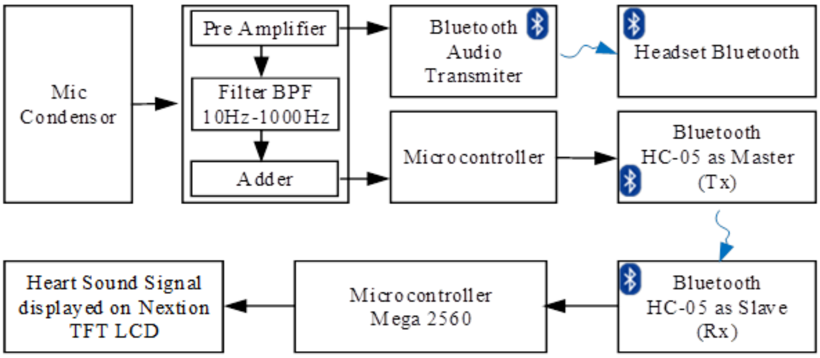
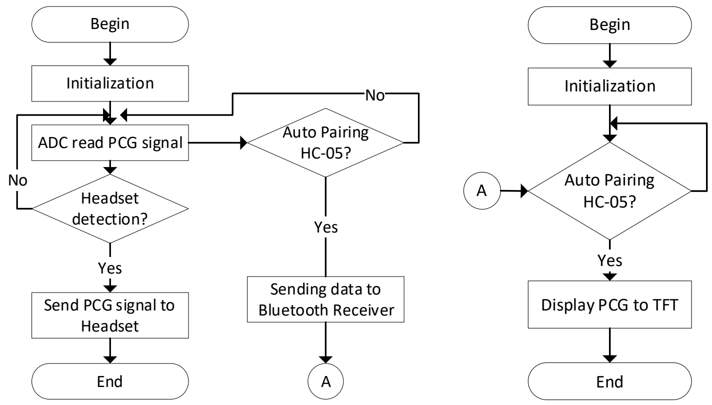


Figure 1. Illustration of the proposed design with health facility conditions, the stethoscope module sends via Bluetooth TX to Bluetooth RX in the LCD TFT module and the stethoscope module sends to the headset version 5.0 via Bluetooth transmitter version 5.0

Flowchart. The Figure 2 shows the flow diagram of the transmitter and receiver process for phonocardiography data acquisition. The transmitter consists of a wireless stethoscope, a microphone, an amplifier, a filter, and a Bluetooth module. The wireless stethoscope is attached to the chest of the patient to capture the heart and lung sounds. The microphone converts the acoustic signals into electrical signals, which are then amplified and filtered to remove noise and interference. The Bluetooth module transmits the signals wirelessly to the receiver. The receiver consists of a Bluetooth module, a filter, an amplifier, a sound card, and a computer. Figure 2(a) illustrates the data acquisition process through an ADC, detection of headset connection, and data transmission to the headset. Further, the microcontroller instructs the Bluetooth HC-05 module to pair with the receiver. Additionally, Figure 2(b) illustrates the process of scanning on the Bluetooth receiver to detect the Bluetooth transmitter. The recorded PCG signal data is received by the transmitter and processed for display on the TFT screen. This process ensures seamless detection and data transfer, enabling real-time monitoring of phonocardiography data. The use of Bluetooth technology facilitates wireless communication, making the system portable and user-friendly. The scanning process is crucial for establishing a secure connection between the devices, ensuring the integrity and reliability of the transmitted data.



(a) (b)

Figure 2. Flowchart of; (a) electronic stethoscope module with Bluetooth HC-05 as transmitter and Bluetooth audio transmitter and (b) receiver module with Bluetooth HC-05 as receiver and LCD TFT

Data collection. The responder was conditioned while sitting down for the duration of data collection. The tricuspids, a single point of measurement, was used to gauge the respondents' responses. By capturing cardiac sound signals for 10 seconds, the procedure for collecting patient data is documented. The data was collected 5 times. The transmission distance tested from this study was 1 meter. The distance is adjusted to the conditions according to the illustration above. The recorded data includes data before being sent using Bluetooth and data after being sent using the concept of sending Bluetooth TX to Bluetooth RX. The Bluetooth transmitter acts as the slave and the Bluetooth receiver acts as the master. The signal is displayed on a personal computer where there is a button for data storage. Data storage can be both image and text data. The data obtained is analyzed by calculating data loss errors.

Data processing. After the amplifier output, the study incorporated a BPF filter with a bandwidth of 30–1000 Hz. Filters used the low pass filter (LPF) and high pass filter (HPF) circuits. The cut-off frequencies for the LPF and HPF were both designed at 1000 Hz and 30 Hz, respectively. Signals between the lower and upper limit frequencies are sent via the BPF to the higher limit frequency. This BPF will, in other words, reject or weaken frequency signals that fall beyond the predetermined range. BPF was employed in this study to pass cardiac sound impulses that range from 30 to 1000 Hz while filtering out undesirable sound signals. Before being employed in this study, filters have undergone testing. Using a function generator with an amplitude setting of 3 Vpp and a changing frequency from 1 Hz to 2000 Hz, a signal was fired at the input filter to test the filter. The purpose of this filter circuit is to lessen background noise or signal interference that isn't caused by heartbeats. A BPF filter with a cut-off frequency of 30–1000 Hz was employed in this filter. Where the filter design calculations are presented in the (7):

$$fc = \frac{1}{2\pi . R . C} \tag{7}$$

where f_c indicates the cutoff frequency, R is the selected resistance, and C is the capacitance.

Statistical analysis. In this study, system performance is calculated based on Bluetooth-based data transmission capabilities. Performance measurements are carried out on two Bluetooth where the first Bluetooth acts as a transmitter/master and the second as a receiver/salve. Experiments were also conducted with Bluetooth as a receiver and using the built-in Bluetooth of the laptop. The distance used is 1, 3, and 5 meter according to the conditions depicted in Figure 1. Based on these measurements, the amount of data before sending with Bluetooth and the amount of data lost in the process of sending using Bluetooth. Respondent was taken 5 times. Furthermore, data is searched for parameter throughput values, packet loss, delays in using quality of service. After obtaining data on 3 parameters in the quality of services, a quantitative difference test was carried out with the T-test.

3. RESULTS AND DISCUSSION

3.1. Result

Measurement results on respondents. The measurement is carried out by placing the chest part on the left side of the patient's chest and then displaying it on a personal computer through a wired system and a Bluetooth system at the same time, in order to obtain the same data between his input data and output data. Microsoft Excel will be used to conduct additional analysis on the computer data from the transmitter and reception portions. The many cardiac sound signals types that have been measured at various transmission distances are listed below. In this ratio, the transmission distance begins at a distance of 1, 3, and 5 meters. Figure 3 shows a heart sound signal with HC-05 delivery and received by HC-05 as well. The blue signal is the form of the signal sent, while the gray signal is the signal received by the laptop/PC Bluetooth and HC-05.

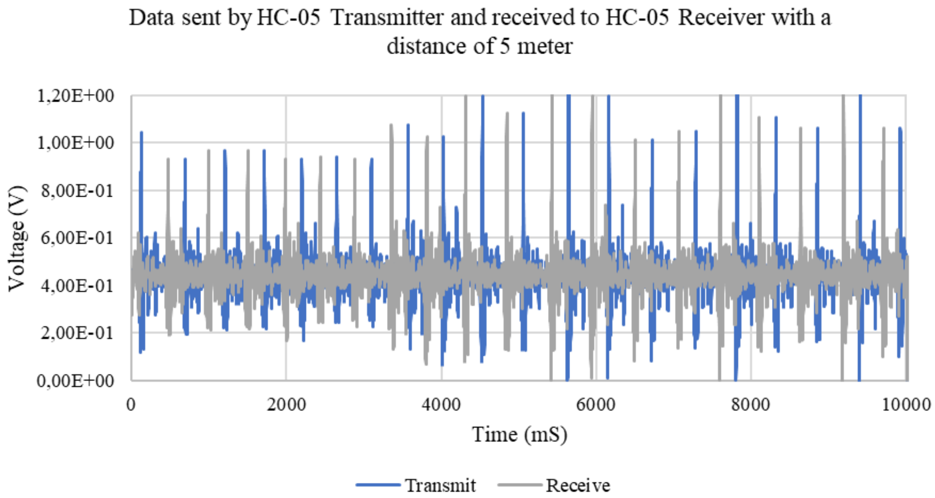


Figure 3. Heart voice data sent HC05 transmitter and HC05 receiver PC with a distance of 5 meters

Calculating the amount of data transmitted to the study subjects with various quantities of data retrieval per unit time and by distance was done in order to test the effectiveness of the cardiac sound signal transmission system. The amount of data delayed is calculated based on the amount of data sent with the data received by the device. Table 1 shows the delay data sent via HC-05 and PC with a baud rate of 38400 and at a distance of 1, 3, and 5 meters. During data collection using Bluetooth HC-05 with a baud rate of 38400, it can be seen that the amount of data delay received has a gradual data delay from the closest to the farthest distance. The throughput data sent with the HC-05 and PC at distances of 1, 3, and 5 meters are shown in Table 2. During data collection using Bluetooth HC-05 with a baud rate of 38400, it can be seen that the amount of data that has been received has the same throughput value of 1002.5 bps.

Table 1. Transmission system delay testing, transmitting heart sound signals from HC-05 to PCs with distances of 1, 3, and 5 meters

A lot of data taken	Delay (S)		
	1 Meter	3 Meters	5 Meters
1	0.346	1.895	0.400
2	2.733	1.405	1.150
3	1.991	1.940	0.804
4	1.099	2.258	1.344
5	1.321	1.138	1.231
6	1.099	1.405	0.920
7	0.346	1.138	1.150
8	1.991	1.895	0.961
9	2.733	2.258	1.150
10	1.321	1.940	0.992
Mean second (S)	1.498	1.727	0.986
Standard deviation	0.811	0.417	0.256

The data sent using the HC-05 and PC at a 38400 baud rate and at distances of 1, 3, and 5 meters are displayed in Table 3. During data collection using Bluetooth HC-05 with a baud rate of 38400, it can be seen that the amount of data that has been received has the same packet loss ratio (PLR) value of 0.10%. The delay data sent using the HC-05 transmitter and HC-05 receiver at distances of 1, 3, and 5 meters are displayed in Table 4. During data collection using Bluetooth HC-05 with a baud rate of 38400, it was seen that the number of data delays received had random data delays of 1.498 seconds, 1.7272 seconds, and 0.9858 seconds. The throughput data transferred at distances of 1, 3, and 5 meters using a baud rate of 38400 is shown in Table 5.

During data collection using Bluetooth HC-05 with a baud rate of 38400, it can be seen that the amount of data that has been received has the same throughput value of 1002.5 bps. The data sent using the HC-05 and PC at a 38400 baud rate and at distances of 1, 3, and 5 meters are displayed in Table 6. During data collection using Bluetooth HC-05 with a baud rate of 38400, it can be seen that the amount of data that has been received has the same PLR value of 0.10%.

Table 2. Throughput testing transmission system, transmitting heart sound signals from HC-05 to PC with distances of 1, 3, and 5 meters

A lot of data taken	Throughput (bps)		
	1 Meter	3 Meters	5 Meters
1	1002.5	1002.5	1002.5
2	1002.5	1002.5	1002.5
3	1002.5	1002.5	1002.5
4	1002.5	1002.5	1002.5
5	1002.5	1002.5	1002.5
6	1002.5	1002.5	1002.5
7	1002.5	1002.5	1002.5
8	1002.5	1002.5	1002.5
9	1002.5	1002.5	1002.5
10	1002.5	1002.5	1002.5
Mean (bps)	1002.5	1002.5	1002.5
Standard deviation	0	0	0

Table 3. Transmission system loss ratio packet testing, transmitting heart sound signals from HC-05 to PCs with distances of 1, 3, and 5 meters

A lot of data taken	PLR		
	1 Meter (%)	3 Meters (%)	5 Meters (%)
1	0.10	0.10	0.10
2	0.10	0.10	0.10
3	0.10	0.10	0.10
4	0.10	0.10	0.10
5	0.10	0.10	0.10
6	0.10	0.10	0.10
7	0.10	0.10	0.10
8	0.10	0.10	0.10
9	0.10	0.10	0.10
10	0.10	0.10	0.10
Mean loss data (%)	0.10	0.10	0.10

Table 4. Transmission system delay testing, transmitting cardiac sound signals from HC-05 transmitter to HC-05 receiver with distances of 1, 3, and 5 meters

A lot of data taken	Delay		
	1 Meter	3 Meters	5 Meters
1	0.000	0.262	0.393
2	0.092	0.000	0.002
3	0.103	0.135	0.275
4	0.023	0.090	0.100
5	0.188	0.216	0.182
6	0.103	0.135	0.275
7	0.092	0.000	0.002
8	0.188	0.216	0.182
9	0.000	0.262	0.393
10	0.023	0.090	0.100
Mean second (S)	0.081	0.141	0.190
Standard deviation	0.0663	0.0925	0.1356

In Figure 4 displays a plot box to find out the distribution of delay time graphically presented on the transmission experiment of data transmission from the HC-05 transmitter to the HC-05 receiver with a baud rate of 34800 at a distance of 1, 3, and 5 meters. In Figure 4, it can be seen that the longer the distance will increase the delay time on the shipment. It is proven that at a distance of 1 meter, the average delay time is 0.0812 seconds, the distance of 3 meters is the delay time is 0.1406 seconds, and the distance of 5 meters is 0.1904 seconds. In Figure 5, it can be seen that the longer the distance will increase the delay time on the shipment. It is proven that at a distance of 1 meter, the average delay time is 1.498 seconds, the distance of 3 meters is the delay time is 1.727 seconds, and the distance of 5 meters is 0.985 seconds.

Table 5. Testing throughput transmission system, transmitting heart sound signals from HC-05 transmitter to HC-05 receiver with distances of 1, 3, and 5 meters

A lot of data taken	Throughput		
	1 Meter	3 Meters	5 Meters
1	1002.5	1002.5	1002.5
2	1002.5	1002.5	1002.5
3	1002.5	1002.5	1002.5
4	1002.5	1002.5	1002.5
5	1002.5	1002.5	1002.5
6	1002.5	1002.5	1002.5
7	1002.5	1002.5	1002.5
8	1002.5	1002.5	1002.5
9	1002.5	1002.5	1002.5
10	1002.5	1002.5	1002.5
Mean (bps)	1002.5	1002.5	1002.5
Standard deviation	0	0	0

Table 6. Transmitting cardiac sound signals from HC-05 transmitters to HC-05 receivers with distances of 1, 3, and 5 meters

A lot of data taken	PLR		
	1 Meter (%)	3 Meters (%)	5 Meters (%)
1	0.10	0.10	0.10
2	0.10	0.10	0.10
3	0.10	0.10	0.10
4	0.10	0.10	0.10
5	0.10	0.10	0.10
6	0.10	0.10	0.10
7	0.10	0.10	0.10
8	0.10	0.10	0.10
9	0.10	0.10	0.10
10	0.10	0.10	0.10
Mean loss data (%)	0.10	0.10	0.10

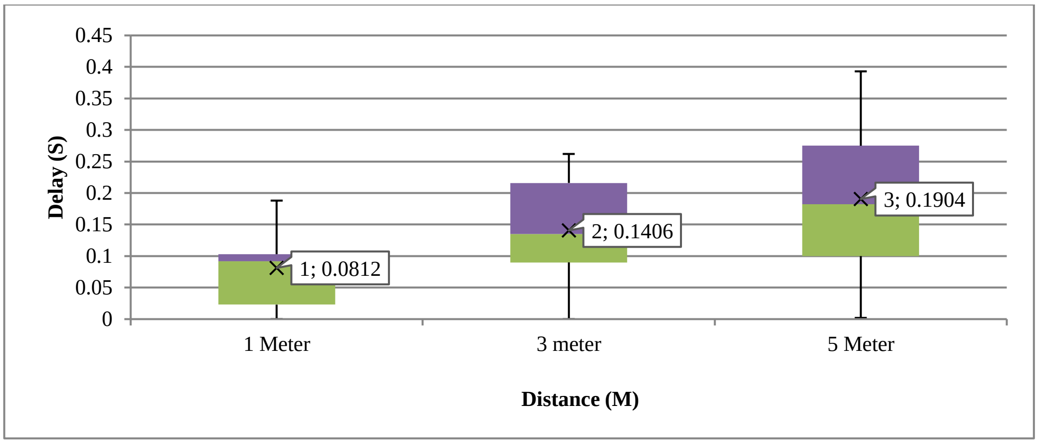


Figure 4. Box plot of data transmission from HC-05 transmitter to HC-05 receiver with baud rate 34800 at distances of 1, 3, and 5 meters

The distribution of data delay in 2 concepts of data delivery is clearly seen visually differently in the box plot Figures 4 and 5 displays. The author continues the analysis quantitatively by conducting data analysis using T-test. Where, the results of data collection from 3 parameters sought in the quality of service, namely throughput, delay, and data loss. After the T test, throughput has a P value of 0.3389 > from an alpha value of 0.05 so that the throughput of both data delivery concepts is the same. The results of the T test on the delay parameter obtained a p value of 0.002313 < from an alpha value of 0.05 so that the delay of the two concepts of data transmission was not the same, and the p value in the data loss parameter obtained a p value of 0.224928 > of the alpha value of 0.05 which means that the data loss in the two concepts carried out in this study was the same.

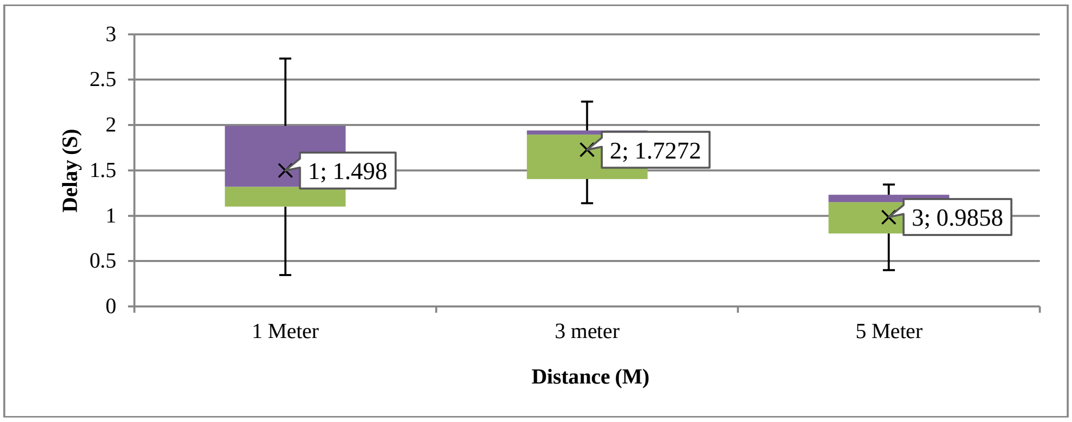


Figure 5. Box plot of data delivery from HC-05 to PC with a baud rate of 34800 at a distance of 1, 3, and 5 meters

3.2. Discussion

In this paper, the designer of the wireless stethoscope for examination of infectious disease patients on this occasion still discusses transmission via Bluetooth first. The work this time is to compare the first 2 ways of sending data Bluetooth HC-05 as a transmitter and received by Bluetooth from a personal computer as a receiver. The second way is to use Bluetooth HC-05 as a transmitter and as a receiver. Both experiments have been created and tested and presented in this work, the work is aimed at using transmitting cardiac voice data in the examination of patients with infectious diseases. The test results can be seen in the signal plotting in Figure 3, where the delivery of the two ways of sending data is tested with different distances, namely 1, 3, and 5 meters. where the longer the distance, the longer the delay time is produced. However, the delivery of Bluetooth HC-05 to Bluetooth personal computers has a greater delay than delivery between Bluetooth HC-05s. For more details, it can be seen in Table 1, where in this table it calculates the average delay time of 5 attempts at each distance used. At a distance of 1 meter, the Bluetooth HC-05 delivery to the Bluetooth personal computer has an average delay of 1.498 seconds, while in sending data with the second concept, namely between Bluetooth HC-05, there is an average delay of 0.0812 seconds. The difference in time delay between 2 types of transmission at a distance of 1-meter averages 1.416 seconds. Then at a distance of 3 meters, the Bluetooth HC-05 delivery to the personal Bluetooth computer has an average delay of 1.7272 seconds, while in Bluetooth to Bluetooth HC-05 delivery there is an average delay of 0.1406 seconds. The difference in time delay caused at a distance of 3 meters is 1.586 seconds. At a distance of 5 meters, the Bluetooth HC-05 delivery to the personal Bluetooth computer has an average delay of 0.9858 seconds, while in the delivery between Bluetooth HC-05 there is an average delay of 0.1904 seconds, and the result of the delay difference obtained from 2 types of shipments at a distance of 5 meters is 0.7954 seconds. From the test results, the average delay time for the second way of sending data is faster than the first way of sending data. In addition to delay testing, the authors also tested the effective data transfer rate or commonly called throughput as seen in Table 2. The results of throughput testing using baud rate 38400 at the time of sending Bluetooth HC-05 to the personal Bluetooth computer and sending between Bluetooth HC-05 both obtained an average result of 1000.25. Writer also tested the loss data ratio which can be seen in Table 3. The average loss data ratio test resulted in the same value, which is 0.10% in all ways of sending data and all distances tested. Figure 5 displays the box plot and it can be seen that the longer the transmission distance will increase the delay time on the delivery. It is proven that at a distance of 1 meter, the average delay time is 0.0812 seconds, the distance of 3 meters is the delay time is 0.1406 seconds, and the distance of 5 meters is 0.1904 seconds.

Patil [28] conducted research on electronic stethoscopes using embedded processors that use wireless transmission of signals with a Zigbee module. However, the Zigbee module is used to send sound signals and is output in the form of sound. Visually this study obtained well-readable heart signal results. However, it was not analyzed statistically [16]. Shi *et al*. [16] conducted research on a digital stethoscope wearable device with wireless communication capabilities that will later be compared with a stethoscope with wired communication. However, in this study using nRF24L01 as a transceiver and dongle for connection on a PC. The study found that the recording results using a digital wearable stethoscope with a cable system have similarities with the cable system [21], [22]. Dao [26] conducted research on PCG monitoring with wireless sensors with MATLAB to record and analyze PCG signals through transmitters and receivers. However, in this study no analysis of the results obtained regarding the effectiveness of this wireless PCG as a medical device [23].

The limitation of this study is not to analyze signals in the time or frequency domain to find out whether the signals are the same before they were sent and after they were sent. It is supportive to diagnose the disease. The implication of this research is as a basis for research to proceed to the next research. where, in the next study researchers wanted to present an extraction feature to analyze some cardiac sound signals. Where later it will be able to be classified as a confirmation of the initial diagnosis of a disease.

4. CONCLUSION

In this study, the author used 2 ways of Bluetooth delivery. That is, the first data transmission of the Bluetooth HC-05 as a transmitter and received by Bluetooth from a personal computer as a receiver. The second way is to use Bluetooth HC-05 as a transmitter and as a receiver. Cardiac signal data collection in each method was carried out at a baud rate of 38400 for 10 seconds 5 times with a distance of 1 meter, 3 meters, and 5 meters. At a trial distance of 1 meter the Bluetooth HC-05 delivery to the personal Bluetooth computer averaged a delay of 1.498 seconds, the delivery between Bluetooth HC-05 averaged a delay of 0.0812 seconds. At a distance of 3 meters Bluetooth HC-05 transmission to a personal Bluetooth computer averages a delay of 1.7272 seconds, on delivery between Bluetooth HC-05s an average delay of 0.1406 seconds. At a distance of 5 meters the Bluetooth HC-05 delivery to the personal Bluetooth computer averages a delay of 0.9858 seconds, on delivery between Bluetooth HC-05s the average delay is 0.1904 seconds. The throughput value on all delivery methods and all distances is 100.25 with a data loss ratio of 0.10%. For voice delivery using Bluetooth audio transmitter with Bluetooth version 5, the sound can be heard clearly. However, researchers were unable to retrieve the data sent to the Bluetooth headset. Based on the results that have been obtained, the author can conclude that the transmission used in this study has a small data loss ratio of 0.10%. However, the longer the distance between the Bluetooth transmitter and the Bluetooth receiver will increase the delay time received by the Bluetooth receiver, be it the personal Bluetooth computer or the Bluetooth HC-05. Delivery between Bluetooth HC-05 is still better than sending Bluetooth to a personal computer because sending between Bluetooth HC-05 has a short delay value of 0.190 seconds at the farthest distance on a 5-meter delivery, in the second way, namely the Bluetooth personal computer as the receiver gets a delay time of 0.989 at the same distance. With a comparison of delays at a distance of 5 meters, it can be seen that using the second method is better than the first way. In future studies, the author wants to analyze the sound of the pocket using the frequency domain before classifying the heart sound. The benefit for the community in this study is that it can create a device that is safe and makes it easier to validate the patient's condition, when used in the condition of the patient suffering from an infectious disease.

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REFERENCES

[1] Z. Wu and J. M. McGoogan, "Characteristics of and Important Lessons from the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72314 Cases from the Chinese Center for Disease Control and Prevention," *JAMA - Journal of the American Medical Association*, vol. 323, no. 13, pp. 1239–1242, 2020, doi: 10.1001/jama.2020.2648.

[2] M. Tejasari, Y. Triyani, T. Respati, W. Purbaningsih, and L. Yuniarti, "KOPIDShield: Safety Partitions as a Novel Approach for Health-Worker's Protection during the Covid-19 Pandemic," *KnE Life Sciences*, vol. 2022, pp. 119–128, 2022, doi: 10.18502/kls.v7i5.12518.

[3] K. R. M. Nur, "Illness perception and cardiovascular health behaviour among persons with ischemic heart disease in Indonesia," *International Journal of Nursing Sciences*, vol. 5, no. 2, pp. 174–180, 2018, doi: 10.1016/j.ijnss.2018.04.007.

[4] A. S. Iskandar, A. S. Prihatmanto, and Y. Priyana, "Design and implementation electronic stethoscope on smart chair for monitoring heart rate and stress levels driver," in *Proceedings of the 2015 4th International Conference on Interactive Digital Media, ICIDM 2015*, IEEE, 2016, pp. 1–6, doi: 10.1109/IDM.2015.7516338.

[5] M. A. Pertiwi, I. D. G. H. Wisana, T. Triwiyanto, and S. Sukaphat, "Measurement of Heart Rate, and Body Temperature Based on Android Platform," *Indonesian Journal of electronics, electromedical engineering, and medical informatics*, vol. 2, no. 1, pp. 26–33, Feb. 2020, doi: 10.35882/ijeeemi.v2i1.6.

[6] Sumarna, J. Astono, A. Purwanto, and D. K. Agustika, "The improvement of phonocardiograph signal (PCG) representation through the electronic stethoscope," in *International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, IEEE, 2017, pp. 1–5, doi: 10.1109/EECSI.2017.8239099.

[7] M. Waqar *et al.*, "Arduino based cost-effective design and development of a digital stethoscope," in *15th International Conference on Emerging Technologies, ICET 2019*, IEEE, 2019, pp. 1–6, doi: 10.1109/ICET48972.2019.8994674.

[8] Y. Tang, G. Cao, H. Li, and K. Zhu, "The design of electronic heart sound stethoscope based on Bluetooth," *2010 4th International Conference on Bioinformatics and Biomedical Engineering, iCBBE 2010*, pp. 8–11, 2010, doi: 10.1109/ICBBE.2010.5516342.
[9] S. Aslan and S. Arica, "Categorization of normal and abnormal heart rhythms from phonocardiogram signals," in *TIPTEKNO 2019 - Tip Teknolojileri Kongresi*, IEEE, 2019, pp. 1–3, doi: 10.1109/TIPTEKNO.2019.8894952.
[10] G. Attarodi, A. Tareh, N. J. Dabanloo, and A. Adeliansedehi, "Classification of congenital heart disease by SVM-MFCC using phonocardiograph," in *Computing in Cardiology*, IEEE, 2017, pp. 1–4, doi: 10.22489/CinC.2017.083-290.
[11] P. Gopika, V. Sowmya, E. A. Gopalakrishnan, and K. P. Soman, "Performance improvement of deep learning architectures for phonocardiogram signal classification using fast fourier transform," in *Proceedings of the 2019 9th International Conference on Advances in Computing and Communication, ICACC 2019*, IEEE, 2019, pp. 290–294, doi: 10.1109/ICACC48162.2019.8986216.
[12] Zo-Afshan, A. Abid, and F. Hussain, "Localization of Phonocardiogram Signals Using Multi-level Threshold and Support Vector Machine," in *2019 IEEE 19th International Symposium on Signal Processing and Information Technology, ISSPIT 2019*, IEEE, 2019, pp. 1–5, doi: 10.1109/ISSPIT47144.2019.9001745.
[13] D. L. Hall, M. I. McTaggart, and W. K. Jenkins, "Use of adaptive filtering for improved performance in digital stethoscopes," in *Conference Record of 51st Asilomar Conference on Signals, Systems and Computers, ACSSC 2017*, IEEE, 2017, pp. 108–112, doi: 10.1109/ACSSC.2017.8335147.
[14] P. C. Adithya, R. Sankar, W. A. Moreno, and S. Hart, "A novel acoustic catheter stethoscope based acquisition and signal processing framework to extract multiple bio signals," in *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, IEEE, 2017, pp. 1336–1339, doi: 10.1109/EMBC.2017.8037079.
[15] H. M. Aumann and N. W. Emanetoglu, "A Radiating Near-Field 24 GHz Radar Stethoscope," in *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, IEEE, 2018, pp. 5121–5124, doi: 10.1109/EMBC.2018.8513478.
[16] W. Y. Shi, J. Mays, and J. C. Chiao, "A wireless stethoscope," *2015 IEEE MTT-S International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications, IMWS-BIO 2015 - Proceedings*, pp. 197–198, 2015, doi: 10.1109/IMWS-BIO.2015.7303845.
[17] W. Y. Shi, J. Mays, and J. C. Chiao, "Wireless stethoscope for recording heart and lung sound," in *BioWireleSS 2016 - Proceedings, 2016 IEEE Topical Conference on Biomedical Wireless Technologies, Networks, and Sensing Systems*, IEEE, 2016, pp. 1–4, doi: 10.1109/BIOWIRELESS.2016.7445545.
[18] S. Szot, A. Levin, A. Ragazzi, and T. Ning, "A Wireless Digital Stethoscope Design," *International Conference on Signal Processing Proceedings, ICSP*, vol. 2018-August, pp. 74–78, 2019, doi: 10.1109/ICSP.2018.8652475.
[19] L. P. W. Frank and M. Q. H. Meng, "A low cost bluetooth powered wearable digital stethoscope for cardiac murmur," *2016 IEEE International Conference on Information and Automation, IEEE ICIA 2016*, no. August, pp. 1179–1182, 2017, doi: 10.1109/ICInfA.2016.7831998.
[20] S. N. H. Malek, W. S. W. Zaki, A. Joret, and M. M. A. Jamil, "Design and development of wireless stethoscope with data logging function," *Proceedings - 2013 IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2013*, pp. 132–135, 2013, doi: 10.1109/ICCSCE.2013.6719946.
[21] S. Sutdipong and K. Tunlasakun, "Heart sound monitor for biomedical instrumentation," *Applied Mechanics and Materials*, vol. 303–306, pp. 650–653, 2013, doi: 10.4028/www.scientific.net/AMM.303-306.650.
[22] K. Tunlasakun, "Heart sound monitor for bio-signal learning," *Advanced Materials Research*, vol. 680, pp. 644–648, 2013, doi: 10.4028/www.scientific.net/AMR.680.644.
[23] J. Malwade, S. Sayyed, J. Nasir, Y. Parab, G. Narayanan, and S. Gupta, "Wireless Stethoscope with Bluetooth Technology," *2020 International Conference on Computational Performance Evaluation, ComPE 2020*, pp. 168–172, 2020, doi: 10.1109/ComPE49325.2020.9200163.
[24] A. P. Mukti, L. Lusiana, D. Titisari, and S. Palanisamy, "Performance Analysis of Twelve Lead ECG Based on Delivery Distance Using Bluetooth Communication," *Journal of Electronics, Electromedical Engineering, and Medical Informatics*, vol. 5, no. 1, pp. 46–52, Jan. 2023, doi: 10.35882/jeeemi.v5i1.275.
[25] G. A. Mills, "Wireless digital stethoscope using bluetooth technolgy," *International Journal of Engineering Science and Technology*, vol. 4, no. 08, pp. 3961–3969, 2012.
[26] A. T. Dao, "Wireless laptop-based phonocardiograph and diagnosis," *PeerJ*, vol. 2015, no. 8, 2015, doi: 10.7717/peerj.1178.
[27] H. Mondal, S. Mondal, and K. Saha, "Development of a Low-Cost Wireless Phonocardiograph With a Bluetooth Headset under Resource-Limited Conditions," *Medical sciences (Basel, Switzerland)*, vol. 6, no. 4, p. 117, 2018, doi: 10.3390/medsci6040117.
[28] K. Patil, "Design of Wireless Electronic Stethoscope Based on Zigbee," *International Journal of Distributed and Parallel systems*, vol. 3, no. 1, pp. 351–359, 2012, doi: 10.5121/ijdps.2012.3130.

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