Low-cost central monitor based personal computer with electrocardiogram and heart rate parameters via wireless XBee Pro

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ABSTRACT

Heart rate signals and electrocardiograms are crucial indicators of a person's health, particularly for individuals in intensive care units (ICU). The goal of this study is to wirelessly use a central monitoring system to continually and in real-time monitor the electrocardiogram signal and heart rate. The result of this research is that a wireless system can transmit continuous, distant, and real-time electrocardiogram and heart rate readings. Two transmitters and two receivers were used to send the signal in real-time. Lead II was used to capture the electrocardiogram (ECG) data, which was then processed by a microprocessor to determine the heart rate in beats per minute. The XBee Pro wireless was then used to transmit the data to the monitor in the form of an electrocardiogram and heart rate signal. The results of the XBee wireless performance test with statistics for determining heart rate value revealed that there was no discernible difference in the average value at a distance of 8, 10, 25, and 30 meters (P-value > 0.05). According to the study's findings, wireless transmission is feasible over a limited distance and in real-time. Hospitals can use a central monitor to implement this research.

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1. INTRODUCTION

The advancement of telemedicine technologies, particularly in the Internet of Things (IoT), especially wearable equipment [1], many researchers use information and information technology in the field of health that provides visual communication and transfer of patient data called telemedicine [2]. Because telemedicine technology is seen as a realistic choice and has been demonstrated to be effective in future health services. In this study, a telemedicine system was created to track the vital signs of patients in the intensive care unit (ICU) [3], [4]. Electrocardiograms and heart rate signals are vital signs to determine a person's condition, especially those in the ICU [5]-[7]. Therefore, in essence it is necessary to periodically monitor the patient's condition continuously and in real time. In general, the ICU has several monitors provided by the patient using cables. However, using cables is less efficient, particularly if there is a large distance between the patient's room and the monitor room; therefore, it is expensive and necessary to measure the cable's exact length. From these problems, it is necessary to develop systems that are efficient and accurate and low-cost by changing the cabling system to a wireless system that is used as an alternative for data transmission [8]-[11]. This is done so that paramedics can easily find out how the patient condition is.

Many low-cost systems have been developed in various fields, both industry and health, as is the case with research conducted by Auccahuasi *et al.* [12] a panel system and sensors to detect luminance, voltage, and current are used to create inexpensive systems to distribute power to public lighting poles, and information is then transferred using XBee. This is then displayed using LabView for autonomous control. This system is considered effective in reducing lighting pole operating costs by up to 15%‒18% which operates for 365 days continuously. However, in this study the battery life used was less than optimal. Bond *et al.* [13] have devised a low cost method using telehealth software used in an ICU room for the simulation of two rural edson real estate (Eds). This system is considered quite efficient for a rural monitoring system. However, it is quite difficult to implement because of inadequate adjustment of human resource awareness of technology. The telehealth system is implemented as a low cost system by several other researchers [14]-[16] because by utilizing the internet system it can reduce costs such as cabling or also time efficiency. Daud *et al.* [17] have studied the use of wireless technology (ZigBee) for data transfer in body temperature and heart rate monitoring. The advantage obtained is that ZigBee can provide data transmission stability and transmission distance, but it is not equipped with the appearance of the patient's electrocardiogram signal other than the heart rate value and body temperature. Research on monitoring patient health using ZigBee wireless technology was also carried out by Singh [18] for measuring body temperature, heart rate, and electrocardiogram. Despite the research's positive findings, the wireless technology was only used to connect one patient to one monitor. Furthermore, Fanani *et al.* [8] have developed a system of monitoring tools used to monitor the lead II heart signal based on a wireless receiver performing a personal computer (PC). The advantage of this tool is that the heart signal can be monitored using one receiver with two transmitters. However, in this tool, the HC-11 wireless device is still used, which has limitations in transmission. When experiments were carried out at a distance of 10 meters, there was a change in the shape of the signal sent and the transmission was carried out alternately. A pulse monitoring method has been also developed using ZigBee by Yuan *et al.* [1] to transmit pulses tens of meters away for physical training efficiency [19]. However, this method was only used to monitor the saturation perifer oxygen (SpO2) value. In the research conducted by Jiangtao *et al.* [20] about the management of mental illness patients in hospitals using the ZigBee wireless system, it has the advantage that it can serve mental patients and monitor their activities in real-time, but it was not equipped to support the patient's health condition [20]-[23]. Research conducted by Sumalan *et al.* [24] on the use of low-cost wireless systems to monitor patients using the X-Bee Pro has proven that this wireless system was used as an alternative in performing patient conditions [25]. The system can provide more flexibility to patients as well as lower costs for implementing improved care. However, in this study, the monitoring of blood pressure and body temperature was chosen to facilitate the experiment. In Hadiyoso *et al.* [25] research regarding the effect of the network in sending electrocardiograph data to the error rate of data using XBee, the advantage of this tool is that it can transmit electrocardiogram signal data from four devices connected to the XBee and installed in one network coordinate connected to a PC as a centralized monitoring display. However, this study has a weakness, namely when testing data transmission, the average error for 1000 data for each device is obtained randomly when two or more devices are connected to the XBee system. Therefore, random delivery is not suitable to be used as vital real-time human monitoring. Research on the ZigBee wireless system has been carried out by several researchers but monitoring has not been used to monitor electrocardiograph signals and heart rate [20]-[22]. In Spanò *et al.* [26] research on low-power electrocardiograph monitoring experiments using several wireless protocols in real-time delivery, it can be done in real-time, however, this study did not have any additional parameters other than the electrocardiograph. Bhuvaneswari and Muthumari [27] research was further conducted on communication experiments to unify e-bikes using long range (LoRA) and XBee as data transmitters. In this study, the two transmitters can unify in real-time, but there are deficiencies in XBee delivery that cannot be used to send data packets further than LoRA. The XBee Pro delivery device is one of many types of delivery devices that are used to replace wires as delivery of each parameter stored in the patient monitor. The XBee device uses the ZigBee protocol to communicate. This gadget uses little power and can be used as a trustworthy communication mechanism between gadgets across vast distances. Additionally, this XBee gadget uses the 2.4 GHz industrial, scientific, and medical (ISM) band for operation [28].

Based on the investigations that have been carried out by researchers there are deficiencies carried out by previous researchers, among others including not being equipped with an electrocardiogram signal display, using one monitor for one patient, the sending can only be done 10 meters away and carried out alternately, only for SPO2 parameters, and not equipped with real-time monitoring of patient health conditions and continuously. Accordingly, this study's objective was to create a low-cost central monitor-based PC with electrocardiogram and heart rate parameters via wireless XBee Pro so that monitoring could be carried out through a central system using wireless or without using wired media as data transmission with electrocardiogram and heart rate parameters in real-time and continuously. The electrocardiograph signal was tapped using lead II and the electrodes were paired according to the Einthoven triangle rule [29]. The results of

the acquisition of the electrocardiograph signal have then calculated the value of the heart rate in units of beats per minute (BPM). This system used two transmitters and two XBee Pro device receivers which were then displayed in one monitor. The contributions of this research are:
– Because they use the central monitor with the XBee Pro wireless system, health professionals may more easily monitor the vital status of two patients at once in the ICU room, simultaneously, and in real-time.
– Doctors can monitor and analyze the electrocardiogram (ECG) signal and heart rate of two patients simultaneously in different rooms because the XBee can transmit data up to a distance of 25 meters.
– Can reduce operational costs from the cabling system to be replaced with a wireless system so that monitoring can be reached at a greater distance.

2. RESEARCH METHOD

2.1. Participants

The electrocardiograph device that has been developed can be used for both sexes as well as children and the elderly, but in this study the participants, 6 guys with an average age of 18 years and 2 years, did not have any cardiac issues. Informed consent was given to the actors so they could become familiar with and comprehend the experimental procedure. The experimental protocol has been adjusted to comply with the Republic of Indonesia's Minister of Health's Patient Safety Regulation No. 11 of 2017. The outcomes of the test on the subject were then contrasted with those of the phantom electrocardiograph calibrator, model MPS450 by Fluke. The BPM settings for the phantom electrocardiograph were 30, 60, 120, 180, and 240.

2.2. Experimental protocol

For tapping the electrocardiograph signal, electrodes were attached to the patient's body according to the Einthoven's triangle rule [29]. In this study, the electrocardiograph signal tapped was lead II. Electrodes were positioned on the skin's surface to record the potential difference between the two electrodes, specifically the potential difference between the right arm (RA) and the left foot (LF), which had opposite charges (–) on the right hand and (+) on the left foot. The subject's skin was covered with disposable electrodes (Ag/AgCl, size: 57×48 mm, Onemed, Onedot, Indonesia). Figure 1 shows how the electrocardiograph equipment used in this investigation was created with the XBee Pro wireless technology. To obtain a lead II signal, electrodes were positioned on the skin's surface in the left-hand corner of the Einthoven equilateral triangle. The instrument amplifier's (AD620) input is amplified 100 times before being used as the electrode output. The cardiac electrical frequency signal was used to build the high pass filter (HPF) and low pass filter (LPF) electrocardiogram, which had a bandwidth of 0.05 Hz to 100 Hz. Furthermore, the Arduino Uno microcontroller transformed the filter output into digital data. The data was then transmitted by the transmitter using a wireless device.

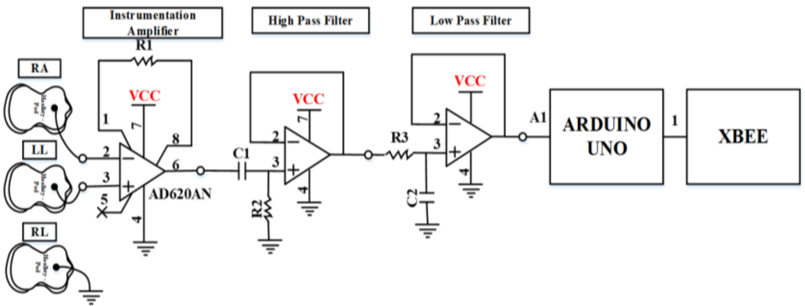


Figure. 1 The complete electronic transmitter system

Figure 2 describes the entire system. In this study, two transmitters and two receivers were used to send and receive monitoring data for electrocardiograph signals and heart rate from several patients with a PC display. Heart signals were detected by a series of instruments attached with the help of electrodes to tap the patient's heart signal. The output of the instrumentation was filtered using high pass filter (HPF) and low pass filter (LPF) filters with a frequency value of 0.05 Hz – 100 Hz. In order for the microcontroller to read the filter output, it is also adjusted to the reference value. Digital data in the form of an electrocardiogram signal is the microcontroller's output. The *R* peak from the electrocardiograph signal will be identified in order to determine the number of heartbeats (BPM) [30]-[32]. The transmitter then used the wireless device to send the data. The receiving block then used a wireless device to receive the data that had been sent. The results were then presented as a graph of the electrocardiograph signal value and heart rate on a computer.

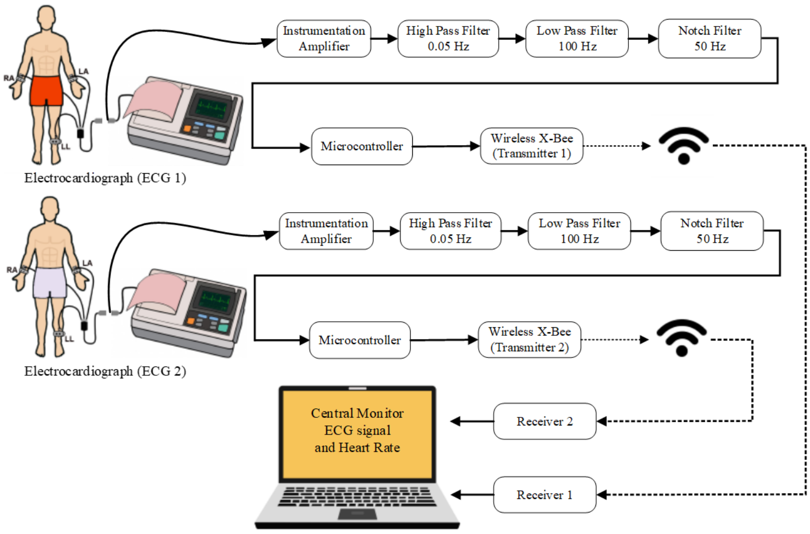


Figure. 2 The design of the electrocardiograph central monitor system

2.3. Data processing

The electrocardiograph signal was recorded using standard data acquisition, which included a bio amplifier with a bandwidth frequency of 0.05 Hz – 100 Hz and a 50 Hz notch filter. The sample frequency employed for electrocardiograph signal acquisition was 250 Hz. Signal preparation, searching for the maximum value, R peak identification, adaptive threshold, and heart rate calculation are all parts of data processing (Figure 3).

According to Figure 3 explanation, the ECG signal is first processed using an infinite-impulse response (IIR) filter to remove noise, after which the maximum amplitude value is found and utilized to identify a R signal. If the R signal is identified, the adaptive threshold is then calculated to get the BPM value. The adaptive threshold method was used to count the number of heartbeats using peak detection R [30]. In detecting the peaks of the $x(n)$ signal, the signal was compared with a value of v that moves along with the $x(n)$ signal. When this signal v finds a peak, the value of the signal v will be constant at the value of $x(n)$ until v detects a rising $x(n)$ or another peak. In addition to the signal peak $x(n)$ which is really a peak, if $x(n)$ drops to exceed $v/2$, it will also be detected as a peak and v will follow the peak value until it finds a new peak (either $x(n)$ rises or down) as described in Figure 4.

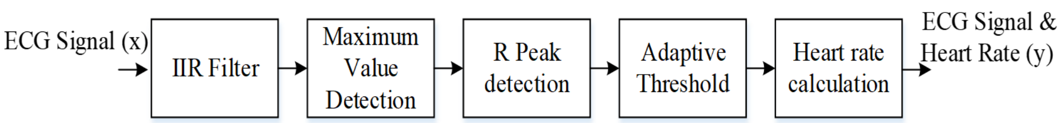


Figure 3. R peak detection process to get the BPM value

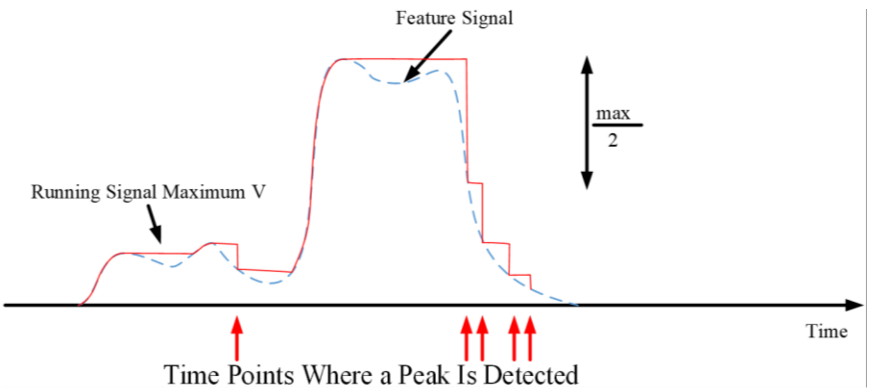
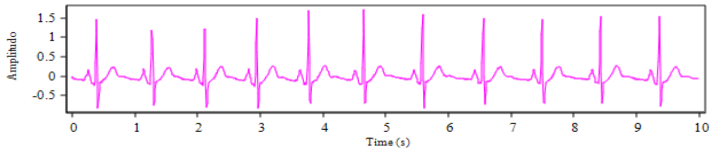
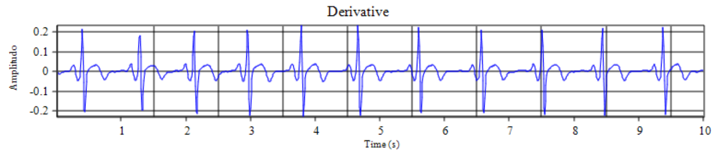


Figure 4. Illustration of R peak detection based on adaptive threshold



(a)



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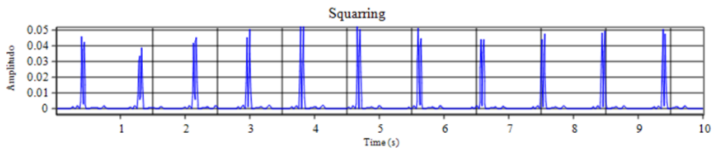
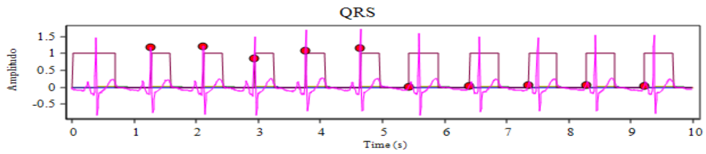


(c)



(d)

Figure 5. The explanation: (a) electrocardiograph input signal; (b) derivative process; (c) the derivative process removed the P, Q, S, T signals so that only R signals were detected; and (d) R detection with threshold adaptive system

Figure 4 reminds us that if the signal $x(n)$ drops more than v from the previous peak, then the signal v will drop and detect a point below $v/2$ as a new peak. In addition, if $x(n)$ falls again more than $v/2$ the previous peak, it will detect that point as a peak. The value of v which is the height value of the peak and other parameters in the form of a fiducial mark which indicates the highest peak of the $x(n)$ feature was entered into a vector and then processed at the decision stage. At the decision stage, the feature $x(n)$ was compared with the threshold described in (1) [30].

$$\Theta = L_N + \tau(L_p - L_N) \quad (1)$$

Where the positive threshold coefficient τ. So that we got a peak whether it is the R peak or the noise peak. An R peak was detected when the $x(n)$ value has exceeded the above threshold. Peak level R or noise level is calculated if peak $x(n)$ is detected as peak R or noise and was determined based on (2) and (3) [30].

$$L_p(n) = \lambda_p . L_p(n-1) + (1-\lambda_p) . A_p \quad (2)$$

$$L_N(n) = \lambda_n . L_N(n-1) + (1-\lambda_N) . A_p \quad (3)$$

Where L_p is the peak level of the respiratory rate, L_N is the noise level, A_p is the peak amplitude (peak value $x(n)$ at that time), while p and N are parameter values of 0.98. After the R peak was detected, the heart rate (BPM) can be calculated without waiting for one minute. The formula for calculating BPM is described in (3).

$$HR = \frac{60}{t_{n+1} - t_n} \quad (4)$$

Where HR is heart rate (BPM), t_{n+1} is the period time the peak of R-peak $(n + 1)$ and t_n is the period time for the peak of R to n. Before doing it online, the program was tried offline for detecting R. The results of detection of R using an adaptive threshold are described in Figure 5. From the explanation in Figure 5(a) is the ECG input signal, then in Figure 5(b) the ECG signal is processed by using an IIR filter to reduce noise. Then in Figure 5(c) a squering process is carried out to remove the P, Q, S, and T signals so that only the R signal is detected with the highest amplitude value. Then if the R signal has been detected, the next process is to calculate the adaptive threshold to calculate the total BPM value which is described in Figure 5(d).

2.4. Data transfer

In this study, the electrocardiograph signal and heart rate data transmission system used a wireless XBee. XBee wireless configuration settings can be done using XBee configuration and test utility (XCTU). The XBee configuration settings aimed to make the transmitter and receiver communicate well. This system used 2 transmitters and 2 receivers. The device 1 which used transmitter 1 was received by receiver 1. Meanwhile, device 2 was sent by transmitter 2 and received by receiver 2. The following is a description of the delivery system (Figure 6).

From the explanation in Figure 6, the data transfer system is carried out using a wireless system using XBee Pro, using 2 devices, data transmission can be carried out simultaneously, not alternately, and carried out simultaneously and in real time. Before using the system, the first step that must be taken is to set the configuration of the wireless transmitter device to be the same as the receiver configuration so that data can be sent and captured by the wireless receiver. Furthermore, the data will be displayed through the central monitor.

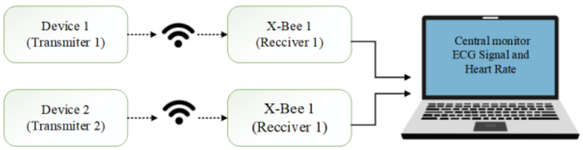


Figure 6. Data transfer process

3. RESULTS AND ANALYSIS

According to the study's goals, which included using a wireless XBee Pro device to transmit electrocardiogram and heart rate data from a central monitor-based PC, data transmission was tested at various distances, including 8 meters, 10 meters, 25 meters, and 30 meters. Data is collected from two devices connected to the wireless XBee Pro and attached to the central monitor. The central monitor was placed in a room that had several barrier walls at this stage three stages of testing are carried out which consist of: shipping signal by distance based on wireless XBee Pro, measurement, performance testing and measuring the performance of the wireless system and statistical analysis.

3.1. Shipping signal by distance based on wireless X-Bee Pro

In this test, data is collected from two devices connected to the wireless XBee Pro and attached to the central monitor. The central monitor was placed in a room that had several barrier walls. Electrocardiograph and heart rate signals were sent at a distance of 8, 10, 25, and 30 meters. Figure 7 describes the results of sending electrocardiograph signals and heart rate values at a distance of 8 meters, we did the same test at a distance of 10, 25, and 30 meters.

Figure 7 describes the real-time and continuous display of device 1 and device 2 with a delivery distance of ± 8 meters. The image data of the electrocardiograph signal and the number of BPM were sent properly without any data loss. The BPM value in device 1 was 109 BPM, while the BPM value in device 2 was 108. We carry out the same test for sending data at a distance of 10 meters, 25 meters, and 30 meters, the results for sending at a distance of 10 meters and 25 meters are the same, there is no difference in data between the device and the central monitor display. However, when we do the test at a distance of 30 meters, the data cannot be received by the central monitor due to the unreachable wifi problem.

3.2. Results of measurement and performance testing and measuring the performance of the wireless system

Test and measurement wireless system performance data is collected from two devices connected to XBee Pro wireless and attached to a central monitor. The central monitor is placed in a room that has several barrier walls with distances of 8 meters, 10 meters, 25 meters, and 30 meters as described in Table 1. Measurements were carried out on two subjects using an electrocardiograph device with electrode tapping placed in lead 2 mode according to the placement of the triangle Einthoven [33].

Figure 7. Display delivery distance 8 meters

Based on these results, the mean value and standard deviation were obtained. The distance of 8 meters obtained 30.16 and 0.3727% for BPM 30. Furthermore, 180.1667 and 0.4082% were obtained for BPM 180, and 239.667 and 1.366% were obtained BPM 240. At a distance of 10 meters, the mean value and standard deviation obtained were 60.142 and 0.3727% for BPM 60, 120.167 and 0.3727% for BPM 120, 180.1667, and 0.4082% for BPM 180. 239.667, and 1.366% for BPM 240. At a distance of 25 meters, the mean value and standard deviation obtained were 180.33 and 1.0327% for BPM 180 as well as 240.333 and 1.032% for BPM 240. At a distance of 30 meters, the mean value and standard deviation was 0 because the server loss the data at this distance.

Table 1. Test and measurement of the wireless system measurement at a distance of 8, 10, 25, and 30 meters

BPM	Distance of 8 (m)		Distance of 10 (m)		Distance of 25 (m)		Distance of 30 (m)	
	Mean (%)	Standard deviation (SD) (%)	Mean (%)	SD (%)	Mean (%)	SD (%)	Mean (%)	SD (%)
30	30.166667	0.3727	30	0	30	0	0	0
60	60	0	60.1429	0.3727	60	0	0	0
120	120	0	120.167	0.3727	120	0	0	0
180	180.1667	0.4082	180.1667	0.4082	180.333	1.0327	0	0
240	239.6667	1.36626	239.6667	1.3662	240.333	1.0327	0	0

3.3. Statistical analysis

The central examiner would display the electrocardiogram signal and heart rate data at distances of 8 measures, 10 measures, 25 measures, and 30 measures after receiving them via XBee wireless transmission. To establish whether there were any significant differences, statistical analysis was used. In statistical testing, this test was carried out using the ECG simulator brand strike type MPS450. The test was carried out at BPM settings of 30, 60, 120, 180 and 240, each BPM was tested at the same distance as described in Table 2 to Table 6. The results of the statistical analysis used as a reference the nascence value of 0.05 was used in this study with the condition that if the results of the analysis of variance (ANOVA) test yield a P- value > 0.05 also there's no significant difference between the data displayed on the ECG device and the data vended by wireless XBee Pro displayed on the central examiner. A P-value less than 0.05, on the other hand, denotes a substantial difference between the two groups. The computation of the ANOVA statistical test findings to ascertain whether there is a difference in readings with a BPM setting of 30 is shown in Table 2.

Based on the results of the ANOVA statistical test at the BPM 30 setting described in Table 2, data collection tests were carried out at a distance of 8, 10, 25, and 30 meters and the results obtained from statistical tests obtained a P-value of 4.84E-37. The results of the ANOVA test yield a P-value > 0.05 also there's no significant difference. Table 3 describes the calculation of the results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 60.

Based on the results of the ANOVA statistical test at the BPM 60 setting described in Table 3, data collection tests were carried out at a distance of 8, 10, 25, and 30 meters and the results obtained from statistical tests obtained a P-value of 4.71E-43. The results of the ANOVA test yield a P-value > 0.05 also there's no significant difference. Table 4 describes the calculation of the results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 120.

Based on the results of the ANOVA statistical test at the BPM 120 setting described in Table 4, data collection tests were carried out at a distance of 8, 10, 25, and 30 meters and the results obtained from statistical tests obtained a P-value of 7.68E-39. The results of the ANOVA test yield a P-value > 0.05 also there's no significant difference. Table 5 describes the calculation of the results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 180.

Based on the results of the ANOVA statistical test at the BPM 180 setting described in Table 5, data collection tests were carried out at a distance of 8, 10, 25, and 30 meters and the results obtained from statistical tests obtained a P-value of 7.69E-38. The results of the ANOVA test yield a P-value > 0.05 also there's no significant difference. Table 6 describes the calculation of the results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 240.

Based on the results of the ANOVA statistical test at the BPM 240 setting described in Table 6, data collection tests were carried out at a distance of 8, 10, 25, and 30 meters and the results obtained from statistical tests obtained a P-value of 5.99E-32. The results of the ANOVA test yield a P-value > 0.05 also there's no significant difference. The results of the calculation of the ANOVA test error rate are still within the appropriate level for medical purposes.

Table 2. The results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 30

ANOVA						Alpha 0.05		
Sources	SS	df	MS	F	P- value	Eta-squared	RMSSE	Omega squared
Between groups	4065.125	3	1355.042	32521	4.84E-37	0.999795	73.6217	0.99975
Within groups	0.833333	20	0.041667					
Total	4065.958	23	176.7808					

Abbreviation: sum of squares (SS), degree of freedom (df), mean squares (MS), simultaneous test (F), probability value (P- value), root mean squared scaled error (RMSSE)

Table 3. The results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 60

ANOVA						Alpha 0.05		
Sources	SS	df	MS	F	P -value	Eta-squared	RMSSE	Omega squared
Between groups	16230.125	3	5410.042	12984	4.71E-43	0.999949	147.106	0.999938
Within groups	0.8333333	20	0.041667					
Total	16230.958	23	705.6938					

Table 4. The results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 120

ANOVA						Alpha 0.05		
Sources	SS	df	MS	F	P-value	Eta-squared	RMSSE	Omega squared
Between groups	54060.15	3	18020.05	360401	7.68E-39	0.999985	268.4776	0.99998
Within groups	0.8	16	0.05					
Total	54060.95	19	2845.313					

Table 5. The results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 180

ANOVA						Alpha 0.05		
Sources	SS	df	MS	F	P-value	Eta-squared	RMSSE	Omega squared
Between groups	121590.55	3	40530.18	270201.2	7.69E-38	0.99998	232.4656	0.999975
Within groups	2.4	16	0.15					
Total	121592.95	19	6399.629					

Table 6. The results of the ANOVA statistical test to determine whether there is a difference in the reading with a BPM setting of 240

ANOVA						Alpha 0.05		
Sources	SS	df	MS	F	P-value	Eta-squared	RMSSE	Omega squared
Between groups	215641.35	3	71880.45	49572.72	5.99E-32	0.999892	99.57181	0.999866
Within groups	23.2	16	1.45					
Total	215664.55	19	11350.77					

4. DISCUSSION

From the results of performance testing and measurement of wireless system performance shown in Table 1, the highest error value is obtained by the BPM 240 with an average value of 239.66 BPM ± 1.36 BPM. It can be concluded that the higher the BPM value, the higher the error value obtained, but the value generated in this assessment is that this tool is suitable for use according to medical standards. The X-Bee wireless system in this study can only reach a maximum distance of 25 meters for data transmission. Error data transmission in this range is still at a level suitable for medical purposes. Data transmission error within this range is still at a level suitable for medical purposes. Furthermore, the results of testing the XBee wireless performance with statistics show that the results of the tests that have been carried out based on Table 2 obtained a P-value of 4.84E-37, Table 3 obtained a P-value of 4.71E-43, Table 4 obtained a P-value of 7.68E-39, Table 5 obtained a P-value of 7.69E-38, and Table 6 obtained a P-value of 5.99E-32. It can be concluded that the mean P-value is greater than 0.05, indicating no significant difference between the two groups. Conversely, if the P-value is less than 0.05, it means that there is a significant difference between the two groups and the error rate was still within the appropriate level for medical purposes. This indicates that XBee's wireless performance is suitable for centralized monitoring with a maximum distance of 25 meters in a room with double barrier walls. Meanwhile, at a distance of 30 meters, there has been a loss of data on the central monitor screen.

In the Sharma study [21], a centralized monitoring system was also carried out to monitor the patient's condition [10]. The wireless system used was based on ZigBee technology. In this case, the ZigBee device can work up to a distance of 100 meters. The presence of noise interference on the electrocardiograph device, which results in the electrocardiograph signal quality still being subpar, is the study's flaw. Additionally, the new monitoring system's working distance is just 30 meters. This component needs to be improved with a stronger filtering system and a longer wifi range being two crucial additions.

5. CONCLUSION

The goal of this study is to wirelessly use a central monitoring system to continually and in real-time monitor the ECG signal and heart rate. After the inquiry, the XBee wireless system in this study could only transmit data a maximum distance of 25 meters, according to the performance of the XBee Pro wireless system. The data displayed on the ECG device and the data delivered by wireless XBee Pro displayed on the central monitor did not differ significantly in the results of the statistical testing of XBee wireless performance, and the error rate was still within acceptable levels for medical applications. This shows that this design is suitable for central medical monitoring. This system can be developed in further research, namely adding parameters according to vital signs and monitoring a longer range.

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