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Heart Rate Monitoring Based On Electrocardiogram (ECG) Module Using IoT

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ABSTRACT

The Message Queue Telementary Transport (MQTT) protocol is able to adjust the sending and receiving of messages to monitor in accordance with the user's preferences because the sending and receiving of messages is topic based on a specified topic, making it necessary to routinely monitor the condition of patients who have been diagnosed with heart problems from a distance. With the aim to perform a Quality of Service (QoS) analysis with throughput, delay, and packet loss parameters using Unshielded Twisted Pair internet transmission media (UTP) and Wireless, the goal of this research is to design and implement (MQTT) a heart rate monitoring device with an EKG module as a sensor and ESP32 as a microcontroller. On the Ubidots website, EKG signals are transmitted over the internet and shown in real time. QoS analysis is performed using the Wireshark application. Data was collected on two scenarios at intervals of 30 minutes, 1 hour, 2 hours, 5 hours, 8 hours, 12 hours, 18 hours, and 23 hours. The throughput, latency, and packet loss metrics used in this study's results cause different value variations; these are influenced by the weather, internet bandwidth, computer, and router specifications. According to testing, the tool is portable and has a 3000mAh battery, but it has the restriction that it can only be used with reliable internet and bandwidth.

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1. PENDAHULUAN

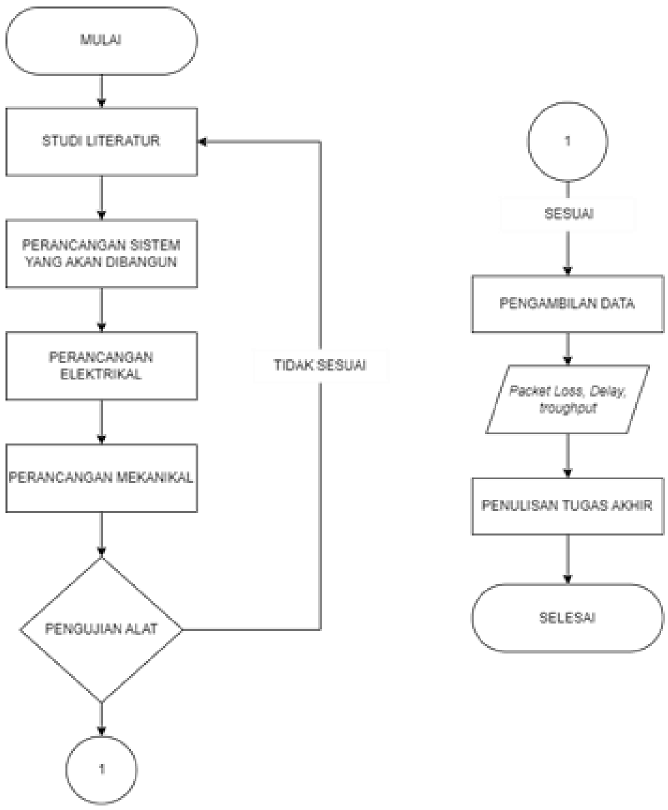
Everyone is affected by the rapid development of technology and information. This has an impact on ongoing, simple to complex developments in the field of electronics. One of these is technological advancement in the field of sensor-based networks. In terms of applications and technology, the medical field has even adopted and developed electronic technology (Wohingati & Subari, 2015). The Arduino microcontroller is frequently used, particularly in monitoring and measuring. An electrocardiogram, a measurement of the electrical activity of the heart, is typically performed during the medical examination stage (ECG). The doctor will learn about the patient's heart condition from the ECG process of heart signals. The ECG test is required to help diagnose the patient's heart condition, regardless of whether the electricity is normal or not (Madona & Fadilla, 2021). A regular ECG is also required to check on patients who have been given a diagnosis of heart disease. Real-time and long-term (24-hour) heart rate monitoring is possible with a wireless electrocardiogram (ECG) (Hasibuan & Mulyadi, 2018).

Sudden cardiac death is defined as an unexpected death that occurs without prior trauma within a short period of time, usually less than an hour from the onset of symptoms. Symptoms appear when the heart's normal rhythm is disrupted and the heart begins to beat erratically, causing the heart to lose its ability to effectively pump blood to the brain (Ponikowski et al., 2014). The brain dies within ten minutes, and the patient can no longer be helped. When a heart patient who is alone at home has a heart attack and cannot be helped (Nadia, 2018).

The research "Heart Rate Monitoring System Using Sensor AD8232 Based on the Internet of Things" by Ria Hariri, Lutfi Hakim, and Riska Fita Lestari (2019), Engineering Electrical Students from the University of PGRI Banyuwangi, is previous research associated with the subject of discussion and used as the basis for conducting research(Ria Hariri et al., 2020a). This research aims to propose a system design for monitoring heart rate activity at a lower cost using the AD8232 sensor using the NodeMCU ESP8266 module that supports the Internet of Things (IoT) system. According to the results of this test, the results of calibrating the device using an ECG simulator from the Blambangan Regional General Hospital (RSUD) show an error percentage of 1.7%. Furthermore, the average percentage error between measurements when using the proposed system with medical devices was 1.21%. This result demonstrates that the proposed system has a very low level of error. The measurement results were successfully monitored using a web application developed on an Android or a browser application on a personal computer. Because it is based on the internet of things, this demonstrates that monitoring heart conditions can be done anywhere and at any time in real time (Ria Hariri et al., 2020b).

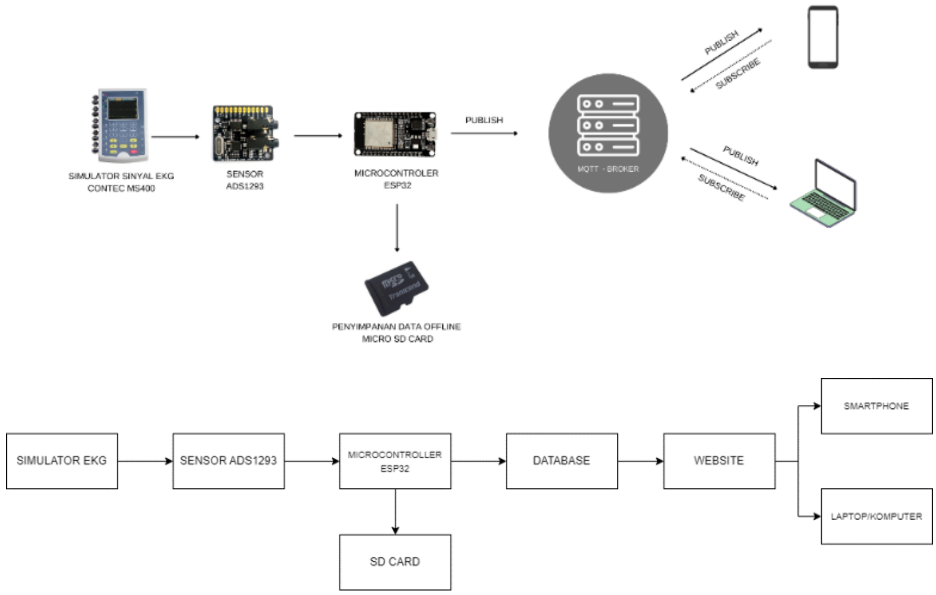
Based on the above problems and previous research, a research on "Human Heart Rate Monitoring Tool by Utilizing IoT-Based Electrocardiogram (ECG) Module" was made.

2. METODE



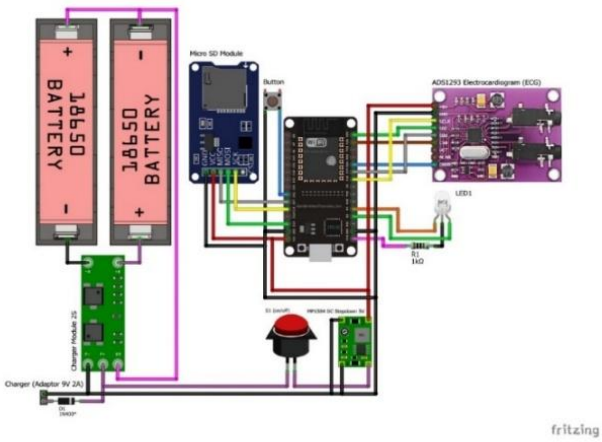
Gamar 2. Flowchart of Research Design

Figure 2 explains the stages of the research. The research stages begin with a literature study to find and study the analysis methods that will be used for this research. After obtaining and studying the methods carried out, then proceed to design the system to be built and proceed with the electrical design and then testing the tool. If the test is successful, then proceed with the data collection stage to be written in the final project report, if it is not successful, troubleshooting is carried out and conducting a literature study again.



Gambar 3. System Design

Figure 3 is the system design in this research. Which consists of CONTECT MS400 as an ECG signal simulator, then the ADS1293 sensor as a heart signal reader sensor that has been sent by the simulator, then an ESP32 microcontroller that is directly connected to the ADS1293 sensor. The microcontroller is connected to the internet and has the task of being a sensor communication tool. Then it is also used as a tool The control and buttons used on the device to be tested and forward the sensor communication to the IoT gateway using the MQTT communication protocol. Furthermore, the data is stored on the SD card offline storage and the communicated data is also stored in the MYSQL database which can be displayed via smartphone or laptop in graphical form.



Gambar 4. Electrical Design

Figure 4 above is the electrical design of the human heart rate monitoring device by utilizing the IoT-based ECG module. The components consist of two series of 18650 batteries, with specifications of

3000 mAh battery capacity and 7.4v voltage which serves to provide power supply support from the components used. Then, the micro SD module functions to write and store offline data read by the sensor, the 2S charger module is used as a battery charging component and disconnects the current when there is a short circuit or short circuit in the battery. Then the adapter jack for charging batteries with 9V 2A adapter specifications. Then the button functions as a start and stop button for the sensor to read, the ESP32 microcontroller is used to control the components used such as sensors, micro SD, start and stop buttons, ADS1293 functions as a sensor to read the output in the form of ECG signals and step down which has a DC 5V specification which functions to reduce the voltage from the battery so that it can be received properly, so as not to damage other components, and the resistor is a component used to inhibit or inhibit the ECG signal reduce the voltage that has been supplied. LED as an indicator of the tool that the tool is ready for use and the on/off switch is used to cut off the supply.

The electrical design of the tool has a workflow, namely when the switch is turned on in the on condition, the component has been supplied with current from the battery whose voltage has been reduced by the step down and then the LED indicator is on. A live LED indicates that the component has been supplied properly. Then, when the battery weakens the LED starts to dim, then the battery can be charged through the adapter jack that has been attached to the component. The current that delivered by the adapter is received by the charger module 2s, slowly charging the battery).

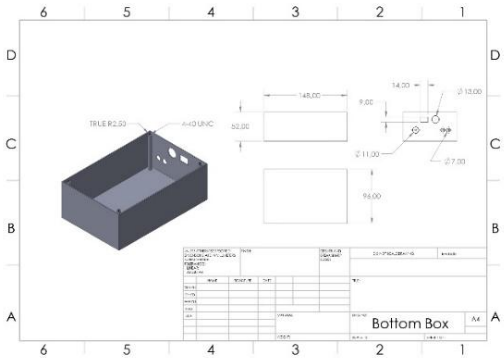


Figure 1 Mechanical Design of Bottom Box

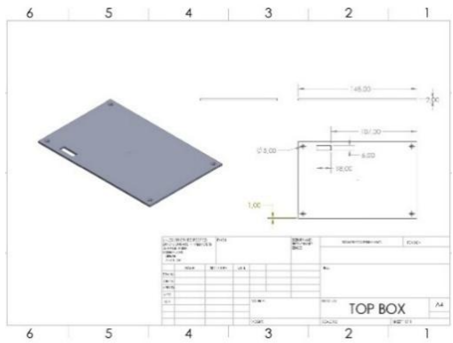


Figure 2 Mechanical Design of Top Box

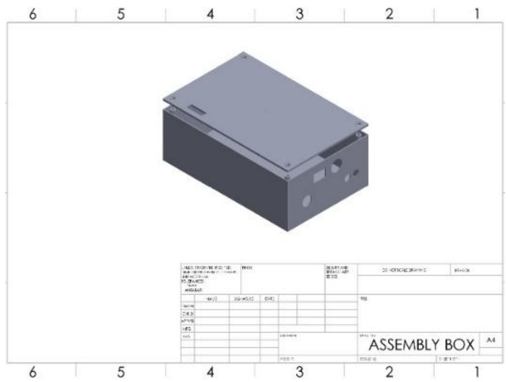


Figure 3 Mechanical Design of Assembly Box

Mechanical design can be seen from Figure 5, Figure 6, and Figure 7 which has a box or case function that serves as a protector and to avoid components from unwanted touches, which can cause damage. The box or case has a length of 148 mm and a width of 96 mm with a height of 52 mm, the box is 2 mm thick, and several holes for the power adapter, turn on/off switch, start/stop switch, micro SD and two holes for channel 1 (one) and channel 2 (two). Each hole has a different size, the adapter hole has a diameter of 11 (eleven) mm, the turn on/off switch has a hole size of 14 (fourteen) mm long and 4 (four) mm wide, the start/stop switch hole has a diameter of 13 (thirteen) mm, the micro SD hole has a size of 18 (eighteen) mm long and 6 (six) mm wide and two holes for channel 1 (one) and channel 2 (two) have a diameter of 7 (seven) mm

Tests were carried out using the bandwidth specifications of UTP and Wireless internet transmission media as follows.

Figure 8 displays the bandwidth specifications of UTP internet transmission media having an upload power of 25.18 mbps and a download power of 27.27 mbps, using the Batam State Polytechnic's

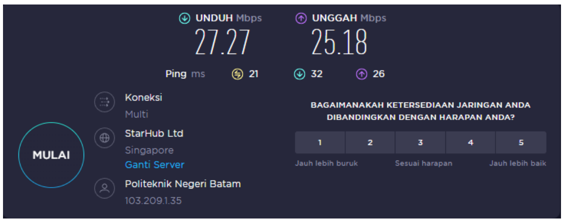


Figure 4 Bandwith of UTP Transmission Media

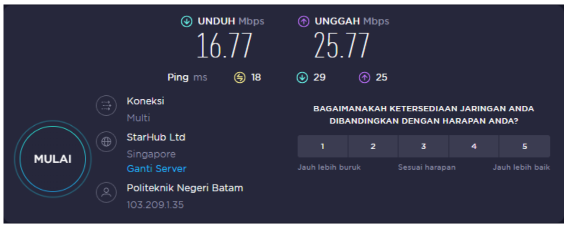


Figure 5 Bandwith of Media Transmission Wireless

router connection. In Figure 9 bandwidth specification of wireless internet transmission media has an upload power of 25.77 mbps and a download power of 16.77 mbps, using the Batam State Polytechnic's router connection.

3. HASIL DAN ANALISIS

Tool Design Realization Results

Figure 6 Realization View of Heart Rate Monitoring Tool Using the ECG Module

Figure 10 is a picture of the realization of the mechanical design of the heart rate monitoring device using the IoT-based ECG module along with all supporting components installed in the black box. The black box is made of plastic material which has an overall size of 14.6 cm x 9.5 cm x 5.2 cm. Each hole has a function for the 9v adapter, power on/off, start/stop, channel 1 (one) and channel 2 (two), led indicator, and micro SD card.

Figure 7 Monitor/Record

Figure 8 Iddle Mode

In Figure 11 is a condition when the device starts recording and sending data to the website and Figure 12 is a condition when the device is not recording or in iddle mode where this condition does not receive or send data.

Figure 13 is the realization of the previously designed electrical design consisting of esp32, micro sd card, charging module, battery supply, 9v adapter, on/off switch, LED, ADS1293 sensor, and step down module.

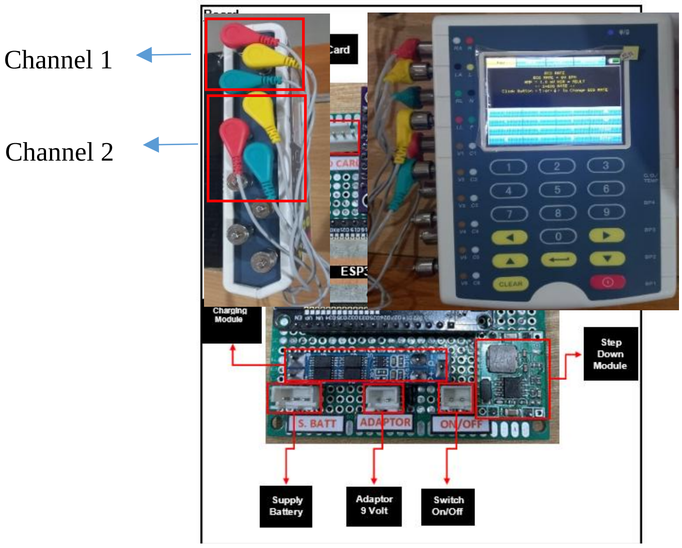


Figure 9 Electrical Board

In Figure 14 is the placement of electrodes on the simulator that will be used for sensor calibration and distributing ECG signals, 6 (six) electrodes and simulators used in this study to simulate ECG signals on the heart, channel 1 (one) is placed on ports RA, LA, and RL. Then channel 2 (two) is placed on ports LL, V1, and V2. The usefulness of the port in the simulator is as an alternative to the point where the body will be monitored.

Research Result Data

In the research work there are 2 (two) stages, the initial stage of the research is to conduct sensor calibration testing which aims to test the sensor so that it can be used and receive signals distributed by the simulator properly. The next stage is to test the communication with the broker that will be used with different transmission media. The following are the testing stages.

Sensor Calibration Testing

Figure 10 Electrode Placement on the Simulator

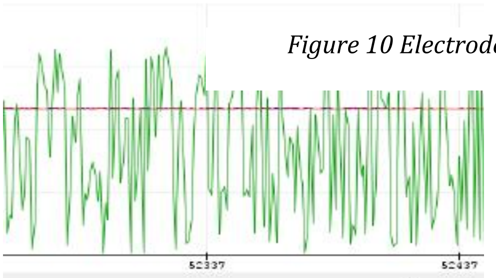


Figure 12 ECG Signal Observation Before Sensor Calibration

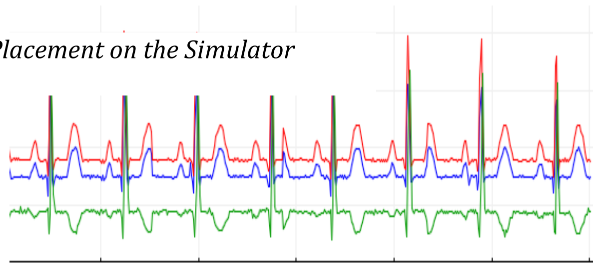


Figure 11 ECG Signal Observation After Sensor Calibration

Figure 15 is an image of the sensor that is still not connected to the simulator, so there is noise generated. Then, Figure 16 is the result of observing the ECG signal generated by the simulator using the arduino serial plotter display. Based on testing before and after calibration, the results obtained are that the sensor can receive signals sent by the simulator and can be displayed offline on the plotter display owned by the arduino IDE feature, after the validation stage, the sensor can be used with the simulator

Communication Testing

Communication testing is carried out periodically with different internet transmission media infrastructure with a laptop as a monitor. Then the observation and analysis of QoS parameters by the data sent from the microcontroller connected to the internet to the broker with the parameters of delay, packet loss, and throughput. The test scenario consists of 2 (two) with different internet network transmission media used. The following is a Table 3 of test scenario:

Table 1 Communication Testing

Scenario	Internet Transmission Media	Website	Parameter
1	*UTP Cable*	*Ubidots*	*Delay, packet loss, throughput*
2	*Wireless*	*Ubidots*	*Delay, packet loss, throughput*

In scenarios 1 (one) and 2 (two), tests were carried out by sending data using different internet transmission media. Observation during testing is done using a wireshark software, from the test results, the results of quality of service delay, packet loss, and throughput are obtained.

Scenario 1 (one)

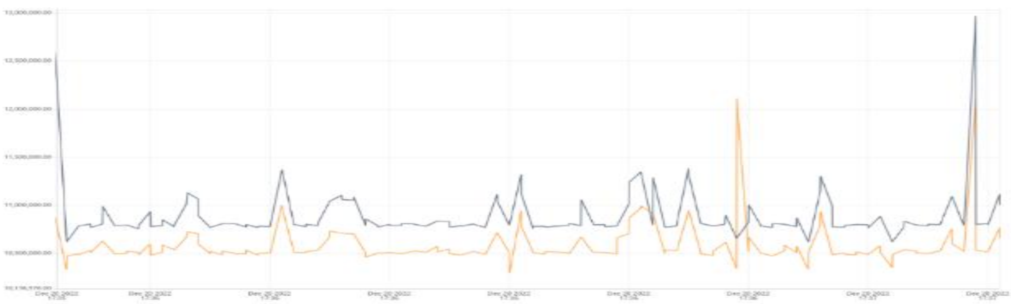


Figure 13 ECG Signal Observation Scenario 1 (one)

In this scenario, tests are carried out with different time durations, using a laptop as a monitor, the transmission medium used is an unshield twisted pair (UTP) internet cable and the ubidots website as a broker to observe and analyze the parameters of delay, packet loss, and throughput. The following is a display of the ECG signal observation with scenario 1 (one) in Figure 17.

Scenario 2 (two)

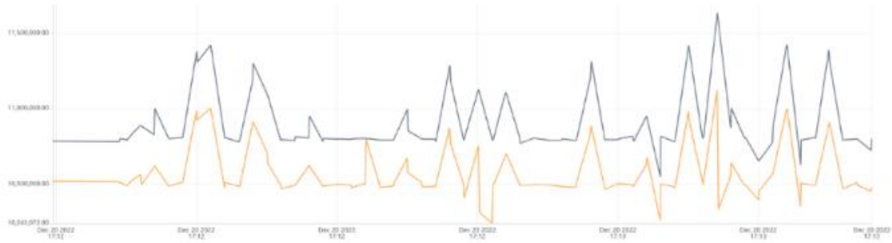


Figure 14 ECG Signal Observatin Scenario 2 (two)

In scenario 2 (two), testing is carried out with a different time duration, using a laptop as a monitor and the transmission media used is wireless internet and the ubidots website as a broker to measure delay, packet loss, and throughput parameters. The following is a display of the ECG signal observation with scenario 1 (one) in Figure 19.

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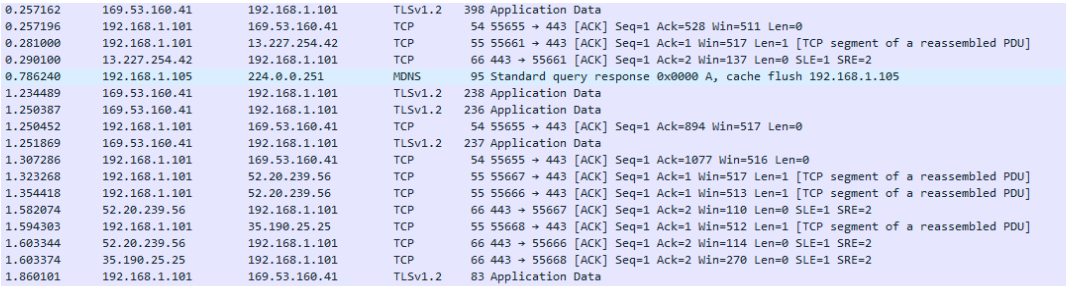
Delay Calculation Analysis



0.257162	169.53.160.41	192.168.1.101	TLSv1.2	398 Application Data
0.257196	192.168.1.101	169.53.160.41	TCP	54 55655 → 443 [ACK] Seq=1 Ack=528 Win=511 Len=0
0.281000	192.168.1.101	13.227.254.42	TCP	55 55661 → 443 [ACK] Seq=1 Ack=1 Win=517 Len=1 [TCP segment of a reassembled PDU]
0.290100	13.227.254.42	192.168.1.101	TCP	66 443 → 55661 [ACK] Seq=1 Ack=2 Win=137 Len=0 SLE=1 SRE=2
0.786240	192.168.1.105	224.0.0.251	MDNS	95 Standard query response 0x0000 A, cache flush 192.168.1.105
1.234489	169.53.160.41	192.168.1.101	TLSv1.2	238 Application Data
1.250387	169.53.160.41	192.168.1.101	TLSv1.2	236 Application Data
1.250452	192.168.1.101	169.53.160.41	TCP	54 55655 → 443 [ACK] Seq=1 Ack=894 Win=517 Len=0
1.251869	169.53.160.41	192.168.1.101	TLSv1.2	237 Application Data
1.307286	192.168.1.101	169.53.160.41	TCP	54 55655 → 443 [ACK] Seq=1 Ack=1077 Win=516 Len=0
1.323268	192.168.1.101	52.20.239.56	TCP	55 55667 → 443 [ACK] Seq=1 Ack=1 Win=517 Len=1 [TCP segment of a reassembled PDU]
1.354418	192.168.1.101	52.20.239.56	TCP	55 55666 → 443 [ACK] Seq=1 Ack=1 Win=513 Len=1 [TCP segment of a reassembled PDU]
1.582074	52.20.239.56	192.168.1.101	TCP	66 443 → 55667 [ACK] Seq=1 Ack=2 Win=110 Len=0 SLE=1 SRE=2
1.594303	192.168.1.101	35.190.25.25	TCP	55 55668 → 443 [ACK] Seq=1 Ack=1 Win=512 Len=1 [TCP segment of a reassembled PDU]
1.603344	52.20.239.56	192.168.1.101	TCP	66 443 → 55666 [ACK] Seq=1 Ack=2 Win=114 Len=0 SLE=1 SRE=2
1.603374	35.190.25.25	192.168.1.101	TCP	66 443 → 55668 [ACK] Seq=1 Ack=2 Win=270 Len=0 SLE=1 SRE=2
1.860101	192.168.1.101	169.53.160.41	TLSv1.2	83 Application Data

Figure 15 Delay Data Capture on Wireshark Software

Delay is the time delay for packets to arrive at the client or host until they are finished being transmitted. From the test result in Figure 19, the packets received from the server to the client are obtained.

Table 2 Delay Categories Index

Media transmission	Time Testing	*Delay* (ms)	Index	Categories *delay*
UTP	30 minutes	1.46	4	Excellent
	1 hours	134.86	4	Excellent
	2 hours	126.51	4	Excellent
	5 hours	23.20	4	Excellent
	8 hours 6 minutes	81.67	4	Excellent
	12 hours	53.97	4	Excellent
	18 hours	214.90	3	Good
	23 hours 34 minutes	260505.05	1	Bad
Wireless	30 minutes	49.33	4	Excellent
	1 hours	122.44	4	Excellent
	2 hours	179.17	3	Good
	5 hours	147.94	4	Excellent
	8 hours 27 minutes	107.647078	4	Excellent
	12 hours 7 minutes	80.754086	4	Excellent
	18 hours	126.10	4	Excellent
	22 hours 6 minutes	120.721149	1	Bad

Delay is highly dependent on the internet connection which is affected by the network hardware, the internet router between the computer and the server. Data packets going through the router will experience a delay of several milliseconds. If the delay increases, this is due to the distance between the monitor device and the access point or switch which is quite far. This applies to the use of monitoring using wireless, due to signal obstruction by walls or other objects. The more obstacles or walls that are passed, the more the wifi delay will increase. Materials such as wood, zinc, or walls can become obstacles to wifi signals. Likewise, using UTP transmission media, delay is influenced by the length of the cable through which the data packet passes. However, the delay is not as great as when using wireless. This is because delay cannot be influenced by walls. It can be seen that the delay of both can be affected by the weather. Delay can cause the heart signal graph to be inaccurate with the simulator.

Packet Loss Calculation Analysis

Figure 16 Capture Data Packet Loss on Wireshark Software

Packet loss can be defined as a failure in transmitting data packets to their destination address. Thus causing some packets in the delivery time to be lost (lost). This is caused by a number of factors such as signal degradation in the network medium, exceeding the network saturation limit, corrupt packets refusing to transit, and network hardware errors can be used as factors. Some network transport protocols such as TCP provide packet delivery, the receiver will request retransmission or delivery automatically (resends) even though the segment has been acknowledged. Therefore, to obtain packet loss, testing is carried out using wireshark software, so that packet loss parameters are obtained in data retrieval. As shown in Figure 20.

Table 3 Packet Loss Category Index

Media Trans-mission	**Testing Time**	**Package sent (*bytes*)**	**Pack-age rece-ived**	***Pac-ket Loss* (%)**	**In-dex**	**Cate-gories**
UTP	30 minutes	12682	12676	0.4	4	Excellent
	1 hours	26857	26846	0.04	4	Excellent
	2 hours	56947	56937	0.01	4	Excellent
	5 hours	780732	778317	0.30	4	Excellent
	8 hours 6 minutes	356207	355298	0.25	4	Excellent
	12 hours	804337	801513	0.35	4	Excellent
	18 hours	304593	301755	0.93	4	Excellent
	23 hours 34 minutes	3233010	3226164	0.21	4	Excellent
Wire-less	30 minutes	37966	37637	0.86	4	Excellent
	1 hours	29675	2964	0.09	4	Excellent
	2 hours	40325	40296	0.07	4	Excellent
	5 hours	122659	122396	0.21	4	Excellent
	8 hours 27 minutes	276711	275933	0.28	4	Excellent
	12 hours 7 minutes	567264	566401	0.15	4	Excellent
	18 hours	514742	513964	0.15	4	Excellent
	22 hours 6 minutes	675905	671385	0.66	4	Excellent

When data transmission takes place, it will produce packet loss with values in each test, namely 0.25%; 0 . 35%; 0.21%; 0.28%; 0 . 15%; and 0.66%. which indicates that when sending and receiving data (transmission) is broken or lost. This can occur due to packet loss, when requesting or receiving data or from the server experiencing network failure, traffic congestion in the network, hardware errors used such as laptops due to application background updates, and limited bandwidth on the internet network when transmitting data to the server or receiving data from the server to the client.

Throughput Calculation Analysis

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Throughput is a measurable network performance. Throughput is also defined as the ability in a

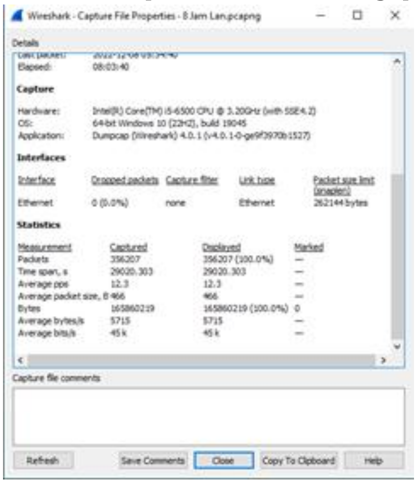

Figure 17 Capture Data Throughput on Wireshark Software

network when sending data per unit time. To get throughput, testing is carried out using wireshark software so that the throughput parameters contained in the data collection are obtained as shown in Figure 21.

Table 4 Throughput Category Index

Media Trans-mission	Testing time	*Throughput* (bit/s)	Index	*Throughput Categories*
UTP	30 minutes	8	1	Bad
	1 hours	11	1	Bad
	2 hours	11	1	Bad
	5 hours	248	4	Excellent
	8 hours 6 minutes	45	2	Average
	12 hours	120	4	Excellent
	18 hours	15	1	Bad
	23 hours 34 minutes	241	4	Excellent
Wireless	30 minutes	115	4	Excellent
	1 hours	20	1	Bad
	2 hours	13	1	Bad
	5 hours	17	1	Bad
	8 hours 27 minutes	47.243	2	Average
	12 hours 7 minutes	66	3	Good
	18 hours	24	1	Bad
	22 hours 6 minutes	66	3	Good

4. KONKLUSI

4.1. Conclusion

After testing the human heart rate monitoring tool by utilizing the IoT-based ECG module, it can be concluded that the tool is portable which has a battery with a capacity of 3000mAh that can be carried anywhere and anytime. However, the tool has limitations, namely if used with the internet, it must have an internet network with a large and stable bandwidth. If it does not have a stable internet network, it is certain that the QoS value is very bad. But there are other alternatives to overcome this, namely if not connected to the internet, you can use offline mode which can take measurements without the internet. Then, the measurement data is stored in the SD card. If you want to display the data, you can use an SD card reader and convert it into a graph in Microsoft Excel.

4.2. Closure

In completing this final project, there are still many shortcomings and weaknesses from the author. So that if there will be further research, the author suggests that the recorded heart rate uses the real heart rate and has a bandwidth capacity of 100 mbp

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