Design and Implementation of IoT-Based Blood Pressure Monitoring Tools

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***Abstract* - Blood pressure is an indicator of various diseases in the body such as high blood pressure, coronary heart disease, kidney disease and others, while currently the public needs help from agencies that have knowledge related to measure blood pressure. So that people can know and measure blood pressure independently without having to go to agencies that can take measurements, we need a tool that can measure blood pressure automatically and provide measurement statistics so that the public or patient can monitor the state of their blood pressure. In this paper, we will try to integrate digital blood pressure measuring devices with IoT (internet of things) using Arduino to process sensor values from MPX5050DP and NodeMCU to connect to the internet so that they can connect to firebase which acts as a database. The results of measurements using a blood pressure monitoring tool that we made using the MPX5050DP are not much different from those produced by a digital blood pressure measurement device from Omron. After the results are compared and processed with the relative error equation it produces 3.83% for systole and 2% for diastole and obtained an average of 13.94 s for the delay of each data transmission.**

Keywords - Blood Pressure, IoT, Firebase, NodeMCU

I. INTRODUCTION

Blood pressure is the most important aspect to indicate disease in the human body. Many symptoms of the disease can be detected through blood pressure such as heart failure, kidney failure, liver damage and stroke. Therefore periodic examinations are very necessary, especially for patients who need medical procedures such as surgery[1][2].

Digitalization will bring new methods of doing periodic medical examinations, particularly blood pressure examination. Digitization also potentially lead to the examination or operating remotely by utilizing the communication from machine to other platforms[3].

To measure blood pressure, medical staff will usually use a sphygmomanometer, but this method has begun to be abandoned because the price is very expensive and the anxiety of environmental pollution. This method was then replaced with the use of aneroid but due to rapid technological development this method was gradually replaced by digital blood pressure measuring devices such as digital blood pressure gauges from Omron[4].

By integrating digital blood pressure measurement devices with IoT, regular blood pressure checks can be done anywhere and anytime. And of course the results of blood pressure measurements can be directly analyzed by the relevant doctor through a platform such as a web application or mobile application[5][6].

II. BASIC THEORY

A.Blood Pressure

Blood pressure is the pressure of blood pumped by the heart against the artery walls. In humans, blood is pumped through two separate circulatory systems in the heart namely pulmonary circulation and systemic circulation[7].

Blood pressure is measured by getting systole and diastole, both of which represent the heart when beating and resting. systole is a sign when the heart beats and is measured by detecting the first beat when measuring blood pressure while diastole is a sign when the heart is stationary and is measured by detecting the last beat when measuring blood pressure[1][8].

TABLE I. BLOOD PRESSURE RANGE

Status	Systole	Diastole
Hypotension	<80	<50
Normal	80<x<115	50<x<60
Elevated	115<x<124	60<x<75
Hypertension	>125	>75

B. MPX5050 Air Pressure Sensor

MPX5050 is an advanced air pressure sensor and transducer designed for various applications. Of course in the implementation of the MPX5050 type must be supported by a microcontroller as the data processor[9].

Figure 1 MPX5050 sensor type

There are many types of MPX5050 sensors that can be used but this project uses MPX5050dp because it is easy to get and of course the price is affordable. Fluctuating pressure values in blood vessels will be read by the sensor as air pressure values in ADC(analog to digital converter) units and then converted to mmHg units so that we can understand the values displayed on the LED as systole and diastole values[10][11].

C. Microcontroller

The microcontroller is a small computer that contains a microprocessor that can perform arithmetic and logic functions. Inside the microcontroller, there is also a memory to store data to be processed[12][13][14].

Arduino is one of the microcontrollers that are easy to use in development, in this paper Arduino is used as a processor for the value of readings by the MPX5050DP sensor and NodeMCU will be used as a network interface to connect to wifi or hotspots[15][16].

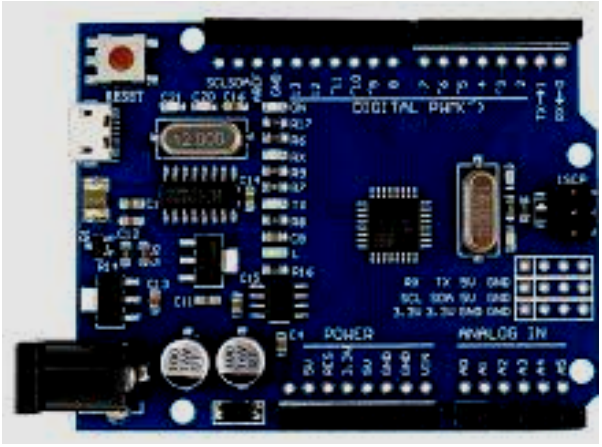


Figure 2. Arduino uno

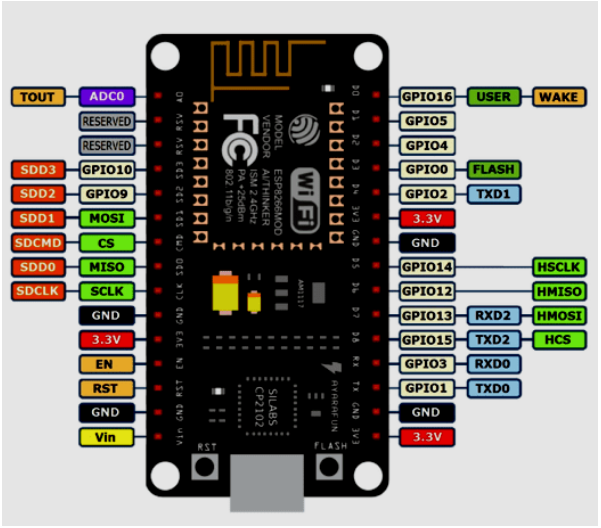


Figure 3. NodeMCU

D. Internet of Things

IoT is a communication network of goods that has sensors and is connected via the internet. In use, IoT can adjust human needs based on the sensors used, in this paper we will try to connect the MPX5050dp sensor with IoT via firebase as the database[17][18].

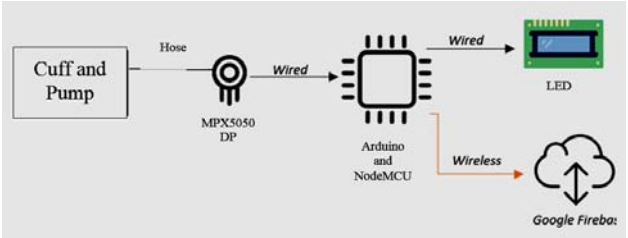


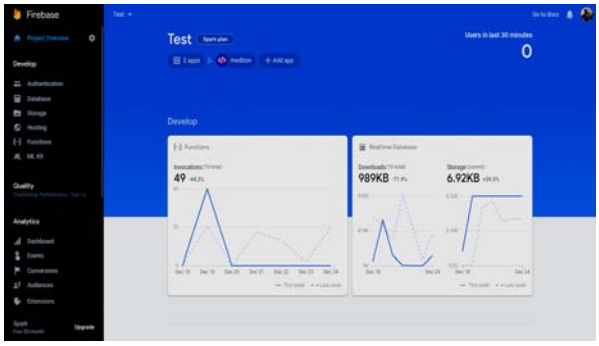
Figure 4 block diagram

The picture above shows a block diagram of the process of measuring blood pressure until the measurement results are sent to Firebase for further display on the web application.

E. Firebase

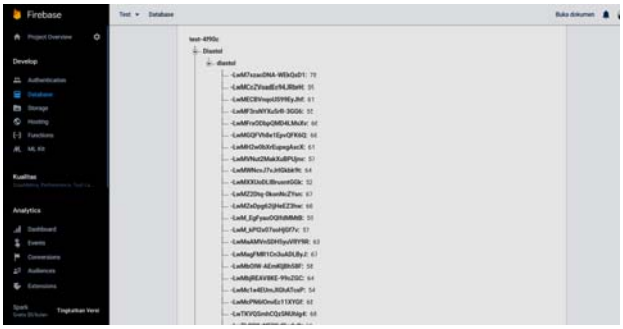
Firebase is a combination of services from Google that are implemented into the cloud. Inside there are services such as real-time database, instant messaging, storage, and hosting. The service most often used by IoT users is a real-time database because it can provide data in real-time depending on the speed of the data the user has and the quality IoT goods themselves[19][20][6].

Firebase will be used as a database to store blood pressure test results and then the cloud function from firebase will provide a timestamp for each blood pressure check data and will then be displayed on the web application as a dashboard (graphical data) and the latest blood pressure examination results[6][21].

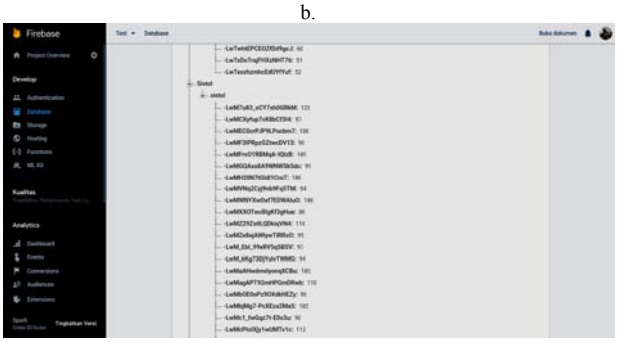


a.

Figure 5 Firebase Console



b.



c.

Figure 6 Firebase Console

F. QoS (Quality of Service)

QoS is a measure to state the good or bad of service, in this case, the service referred to is the network service. QoS itself can be measured by looking Delay, Throughput, Jitter or packet loss[22][23].

In this paper, one of the QoS tested is Delay. The delay itself is the time delay of a packet transmission from a source to the recipient or destination. This is caused by many things such as network queues, propagation, number of buffers, large or small packets and so on[22][24].

III. PROPOSED MODEL

A. Blood Pressure Monitoring Tools

The tools made was calibrated so that the level of accuracy of blood measurements was good. This tool has been compared to blood pressure measuring devices from Omron, using a comparative value between the ADC value of MPX5050dp and the value on an Omron blood pressure measuring tools, this relationship is represented by equation (1).

$$\frac{A}{B} \sim \frac{C}{D} \tag{1}$$

Systole and diastole read by Omron digital blood pressure measuring devices are given the symbols A and B while the systole and diastole read by MPX5050DP sensor are given the symbols C and D. Then to obtain the comparable value requires a multiplier factor then equation (2) and (3) are obtained.

$$\frac{A}{B} = \frac{C}{D} \times R \tag{2}$$

$$R = \frac{C}{D} \times \frac{B}{A} \tag{3}$$

Then we will use the multiplier to find systole and diastole which we can understand, the results of systole and diastole will be given the symbols E and F.

$$\frac{E}{F} = \frac{C}{D} \times R \tag{4}$$

After the above process, we will validate the measurement results with the relative error equation so that we get a comparison between absolute error and the size of something being measured[25]. in this case the absolute error is the result of measuring systole and diastole from MPX5050DP while the measured value is the systole and diastole value of Omron.

$$\delta x = \frac{\Delta x}{x} = \frac{x_0 - x}{x} = \frac{x_0}{x} - 1 \tag{5}$$

where:

x0 = Value read on MPX5050DP sensor
x = Value read on the Omron blood pressure meter
Δx = Absolute error
δx = Relative Error [25]

The MPX5050DP sensor and the microcontroller that is implemented on the device work very well but the serial communication between Arduino with NodeMCU causes delays in sending data to firebase.

a.

Figure 7. Blood Pressure Monitoring Instruments

b.

Figure 8. Blood Pressure Monitoring Instruments

The flowchart below shows how the tool works and serves as a reference so that it's easy to correct if there are any errors.

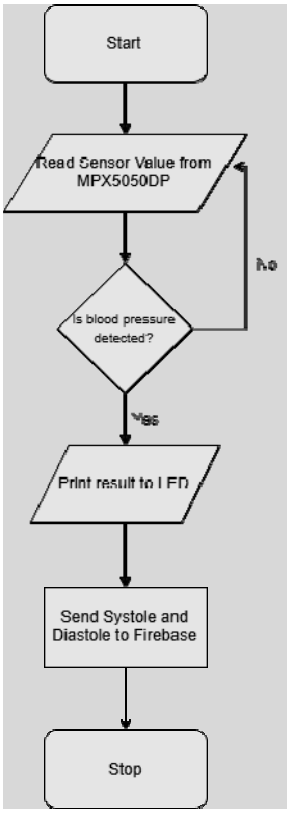


Figure 9. Blood Pressure Monitoring Tools Flowchart

As can be seen in the flow chart above, the sensor will first read the first beat and the last beat and then calculate the blood pressure. After the process is complete the results will be displayed on the LED and then sent to the firebase so that it can then be seen in the web application.

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B. Web Application

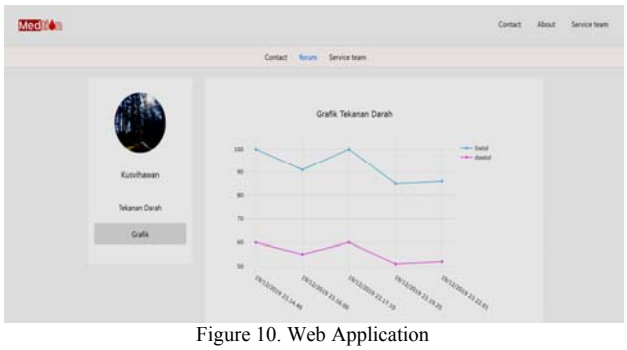

Figure 10. Web Application

This is the alpha test for the web application, the data displayed here is taken from Firebase and of course the same as what is displayed on the LED on a blood pressure meter. At this alpha stage, the web application can only be used by a user who has a blood pressure gauge, in other words, a single user of a blood pressure tools will have a single account to be able to use the web application.

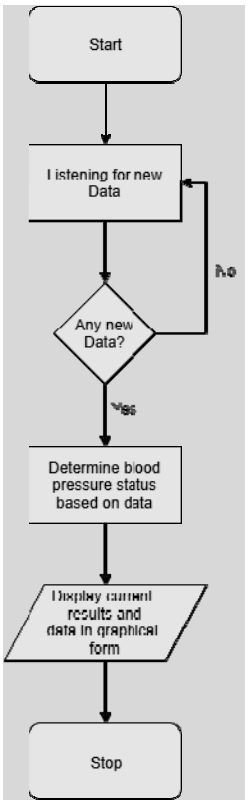

Figure 11. Web Application Flowchart

The alpha test web application will display the latest results from blood measurements to inform the status of the patient

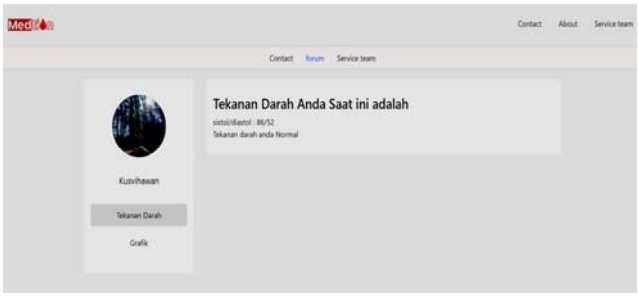

Figure 12. Latest Blood Pressure Measurements Result

The web application also displays some of the results of the last blood measurement in graphical form

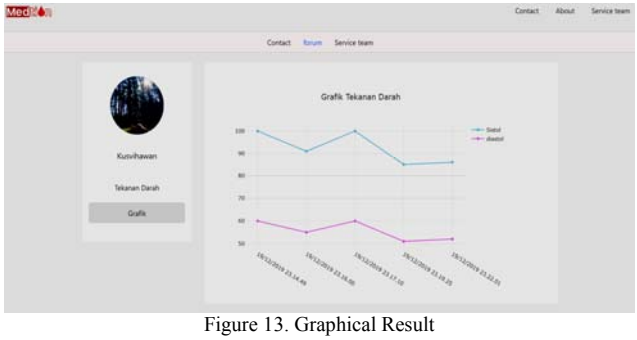

Figure 13. Graphical Result

With a web application like this allows long-distance consultations with doctors and analysis or diagnosis for illnesses that can also be done remotely. Of course, analysis and diagnosis of the disease can be based on the examination history displayed in the web application.

For future research an upgrade will be made on the device, Blood Pressure Monitoring devices with MPX5050DP sensors can be used by many users and of course users will have their respective accounts to access web applications. The multi-user configuration on the device will

be accommodated using NFC sensors so that it can be suitable for existing technology in the future.

IV. RESULTS AND DISCUSSION

The comparisons produced between the results of Blood Pressure Monitoring with MPX5050DP sensors and digital Omron blood pressure measuring devices show results that are not much different, as seen in the graph below.

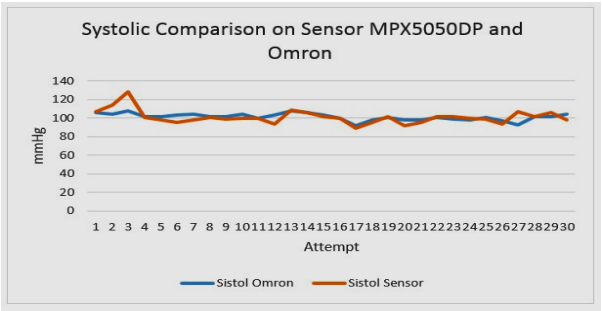

Figure 14. Comprison of Systole Result

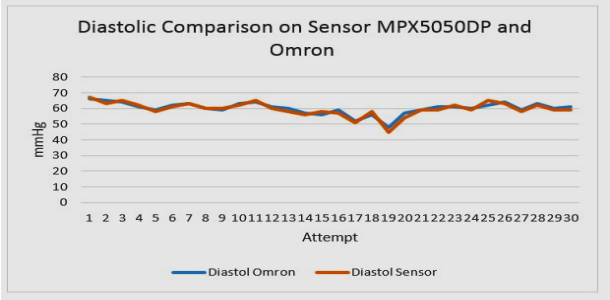

Figure 15. Comparison of Diastole Result

The value read by the MPX5050DP sensor is processed by Equation (3) and Equation (4) to produce R-Factors and then using Equation (5) to find a relative error and the results are in the table below.

TABLE II. R-FACTOR AND RELATIVE ERROR RESULT

R- Factor		Error Relative (%)	
Systolic	Diastolic	Systolic	Diastolic
1.39	1.5	3.83	2

Furthermore, the results of the measurement of the delay in sending data from a Blood Pressure Monitoring tools with the MPX5050DP sensor to the web application are as follows.

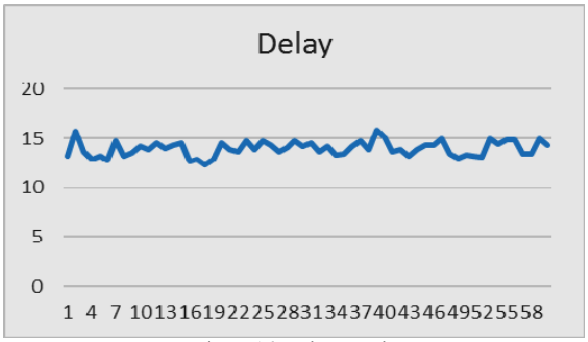

Figure 16. Delay Result

From the graph above we can see that the network performance is not good, The end-to-end delay obtained is 13.94338333 s. The high delay is affected by many factors such as the network interface used or connectivity, but the

main factor is serial communication between Arduino and NodeMCU which takes a lot of time, causing a high delay value.

V. CONCLUSION AND FUTURE WORK

From the above experiments, it can be concluded that the results of Blood Pressure Monitoring using the MPX5050DP sensor have a relatively small error and of course accurate measurement results. But this IoT network still has a fairly high delay due to serial communication from Arduino to Nodemcu, despite that Firebase's performance is fairly good as long as the internet speed owned by the user is also good. The relative error obtained was 3.83% for systole and 2% for diastole and 13.94338333's average for the end-to-end delay.

For future development we can add an introduction module to the device using NFC so that the Blood Pressure Monitoring device with MPX5050DP sensor can be used by many users, this will help periodic health checks for patients.

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