A Health Monitoring System Based on Wearable Sensor and Data Aggregator

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Abstract

IoT (Internet of Things) is now a part of technology development. In utilizing the IoT technology, data aggregation can be applied. Data aggregation itself is a method that can help perform data processing in a system. Sensor technologies are widely used in health systems, in particular to help with health monitoring. A health system utilizing the technology of a smartwatch with sensors that can record body conditions and allow real-time data transmission can be developed with the help of several methods, one of which is data aggregation. To avoid data loss or lack in the midst of sending data packets, it is necessary to use a data aggregator as well as the cloud and an API to attract and send the data packets. The cloud is also a component that is quite important because it enables cloud computing as well as data storage. The data aggregator also helps reduce the transmission delay in sending data packets and compute the data that arrive from the sensors. Meanwhile, the API is widely used to carry out the process of transmitting data on an application or system, so it can be connected to a server or the cloud to manage data requests from a user to the server. It is also important to assess the source or resource used in the system, including the throughput or the amount of load that can be received by the resource.

Keywords
Internet of Things, data aggregation, cloud, sensor and throughput

1. Introduction
Health is an important aspect in life. In the past, to undergo health checks, we were required to come to the nearest health facility or hospital. However, with current technological developments, some companies have started to develop technologies that can be used daily to check the condition of the body with ease. The technological developments now have also seen the use of the Internet in combination with medical devices. Here is used what is referred to as IoT or Internet of Things. With IoT, all objects around us and our daily activities can be connected. It enables the performance of data collection, processing, monitoring, analysis, and control (Guth et al., 2018).
To determine our health status, we can start from our sleep. It is necessary to find our sleep habits and assess the quality of our sleep in order to detect our health status. The better the quality of our sleep the better our health. Many studies assess the quality of sleep of an individual, and some do so using sensors. However, studies on sleep quality using wearable devices are still quite rare. Therefore, a new development is required to enrich research in this field, and this is where this study comes in.

The use of the IoT technology can improve health services, particularly in monitoring health, fitness programs, diseases that are difficult to cure, and care for the elderly (Budida & Mangrulkar, 2018). As a new technological advancement, IoT is evolving into a smart system that can support and develop healthcare as well as biomedical-related processes (Sivagami et al., 2016). The research by (Ara et al., 2017) explains that an aggregator can be in the form of a device such as an LPU or a smart device such as a smartphone. It can also be in the form of BDS. Another research work (Pantelopoulos & Bourbakis, 2010) describes the general architectures of wearable health-monitoring systems (WHMS), following their functionality and system components. However, this should not be considered a standard system design as many systems can adopt a significant variety of architectural approaches.

The present research will develop a health monitoring system for transmitting health data using wearable sensors involving an aggregator for data introduction and data processing for the wearable sensors. The research will explain how the system can receive and process data from the sensors to the server. It will also calculate the throughput and response time of the system. However, it does not rule out a room for improvement or researching in several aspects regarding the system itself as well as the components that support the making of the system. Data transmission will utilize a data aggregator, in which case the data will be transmitted in real-time, following a flow from data recording in the sensors to the display of the data to users.

The following is the organization of this paper. Section 2 will present a literature study related to the present research. Section 3 will explain the model and system design that will be made and used for the research. The results of the research and testing will be explained in Section 4, and finally the conclusions of the study will be presented in Section 5.

2. Related Research

Wireless sensors are now widely used and are starting to evolve along with the developments of many technologies for activity recording. A wireless sensor network can be defined as a small network that is embedded in a device called a sensor, which is connected wirelessly and with an ad hoc configuration. The sensor is embedded in a strategic place to be able to record information and interact with the object to be measured (Rodrigues et al., 2016).

Researchers have provided explanations of health detection utilizing wearable devices. (Cayamcela et al., 2018), for instance, describes a system for health detection using photoplethysmography (PPG). The research uses an Android wearable application that is connected to the application on the watch. We will analyze the body and health using medical indices of relative weight and obesity and the uniformity in the definition of basal rate of metabolism.

According to a research work, the main challenge for the application of IoT using a smart device is how to ensure transmission of large amounts of data using the device. An IoT data center that has collected some data in real time may not be able to efficiently verify the data collected. The researchers have proposed a verifiable and efficient data aggregation scheme that can reduce computing for IoT data centers (Liu et al., 2017).

It is explained by (Zhang et al., 2016) to use aggregation on mobile phones as tools for computing. The researchers provide an example of aggregation to perform some computations on a mobile phone, including arithmetic operations. They intend to let the aggregator know the data contents and delink the data from the sources to protect the privacy of the users.

The present research, meanwhile, explains how to make a sleep quality detection system along with its components using a wearable device and a data aggregator. (Surantha et al., 2017) has previously described a design for the creation of a sleep quality detection system. There are several architectural components that determine sleep quality: data acquisition system, data concentrator/aggregator, cloud storage/ processing, and monitoring application. In a data acquisition system, there are sensors to collect data and make connections. Then, a data concentrator/aggregator collects data from the sensors and send them to a cloud service. Cloud storage/processing, meanwhile, is valuable for data processing as cloud computing is an excellent, powerful tool for processing data. Lastly, after being processed, the data are displayed and reported to patients using a mobile application.

To create a health monitoring system, several supporting components are needed. In (Yue et al., 2020) it is stated that a remote health monitoring system consists of 3 parts. The first is a wearable device that is used to collect and process data, including blood pressure, heart rate, and electrocardiogram data. The second is an Android mobile terminal that receives and displays the data from the wearable device and sends the data to the cloud server, which is the last component. The cloud server is the place where the data will be collected into a database. It also performs an analysis process for medical diagnosis.

A data aggregator has supporting protocols such as sensing nodes, or just nodes, called sensors that are attached to an individual or an object to be studied. The sensors will record the state of the individual in aspects such as blood pressure, heart rate, and body temperature, among others. The data obtained using these sensors will be sent to the data aggregator that will carry out the initial process. The concentrator acts as a communication gateway for the sensors and connects each sensor to the Internet (Page et al., 2015).

There have been a large number of IoT developments related to health monitoring systems. However, research on the use of data aggregators has been scarce, requiring a lot of tests on them. Therefore, the researchers feel it necessary to conduct research and tests on an aggregator. This research will create a system with a data aggregator, in which case the data aggregator will select and send data to the cloud. The research will also conduct related evaluations of the throughput and response time of the aggregator used in the system.

3. System Model

This section describes how to design the system that will be used. Here, three important parts are needed in the design process of the IoT-based health monitoring system, as mentioned by (Yue et al., 2020), who developed a system for remote monitoring of human health. The three said parts are wearable device, Android mobile terminal, and cloud server. This research collects data involving a wearable device and the cloud as data storage, where the data are then examined using decision tree, random forest, k-nearest neighbor method, and Naive Bayes classifier. While, other researchers explain the design of a sleep quality assessment system based on IoT (Internet of Things) that utilizes a web server for data bridging between sensors and smartphones and the cloud, here the system will focus on the retrieval and the presenting process of data in the system. The system will in large part refer to the system design by (Surantha et al., 2017).

At the system design stage, the researchers plan a system that includes how the wearable sensors send data to the data concentrator section, in which case the data will be collected first from the sensors. In the data processing process in the concentrator, the data come from the sensors in the form of a data array, which is a set of data with differential identities. Alike to sending data using a network or Bluetooth, the data aggregator also uses supporting protocols such as sensing nodes, or just nodes, named sensors mounted on the individual or object to be studied.

The data to be used in this research are directly obtained using the data recording by the sensors applied to the wrist in the form of a smartwatch. In the process, the system will perform a withdrawal process via the API where the data will be pulled through the Fitbit server after being recorded by the sensors. The data that go through the first transmission process are rough data in a large amount which will then be stored in a database in the researchers' cloud storage through the processing in the data aggregator to select necessary data such as heart rate data and sleep data, including data on the sleep quality value, sleep time, and record data when someone sleeps. Furthermore, when the data are withdrawn, an evaluation of the data transmission or transmission process will be carried out. The data that have been sorted by the aggregator over the cloud will then be transmitted or sent to the smartphone.

Figure 1 shows the architecture of the system to be built in this study. The system to be built contains three parts: data acquisition which contains the dashboard and the smartwatch that will be used in the research, the data aggregator that will receive data and carry out the transmission of data from data acquisition, and the cloud as a server to store data that have been processed. The researchers used a smartwatch product from Fitbit. API Bridge in this research serves liaison between the system to be developed and the application on the watch. To make the API Bridge, we use PHP programing language with Laravel framework. Javascript language with React native framework is used to make the application dashboard on the smartphone.

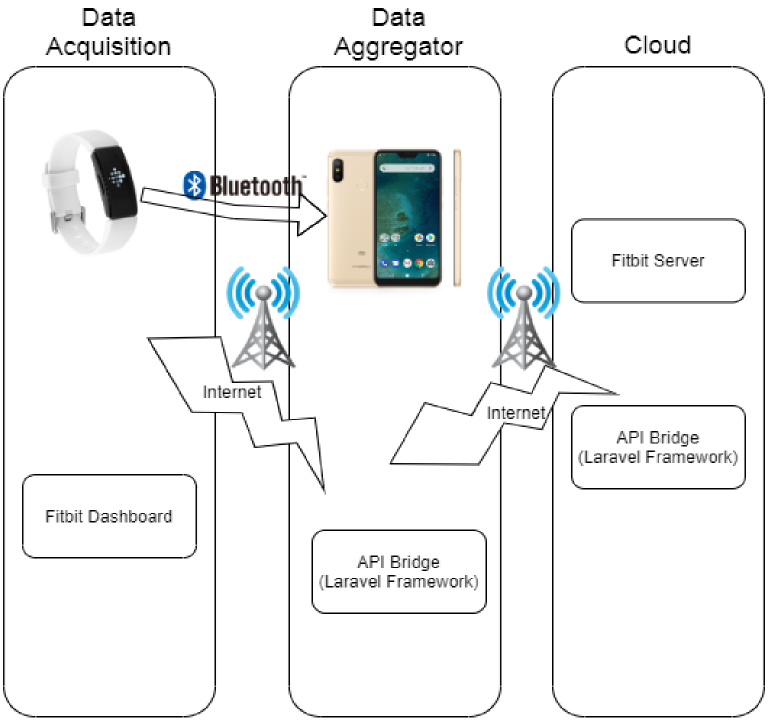

Figure 1. System Architecture

The system to be developed will retrieve data through the Fitbit server, and the data will then be received by the application on the smartphone. The data received will be forwarded to the cloud or server through a process using the data aggregator. An evaluation of the throughput and response time for sending the data will be carried out, both using and not using the data aggregator.

4. Results and Discussion

The finished system is tested to measure the capabilities of the rented server and to find out whether the system can run properly from the beginning when the data were recorded until the data are displayed on the smartphone application. To test the system's run, the smartwatch is applied to the users. The researchers will first get authenticated with Fitbit to access data, as shown in Figure 2.

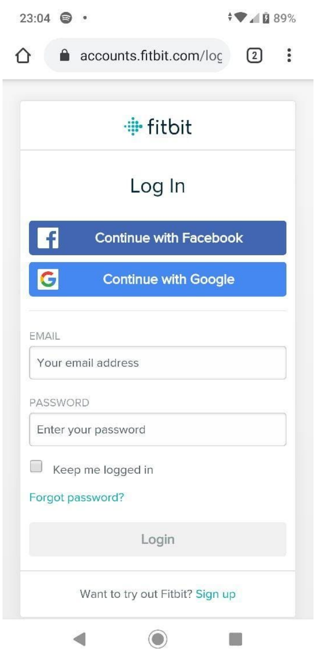

Figure 2. Fitbit Authentication page

To test the data transmission from Fitbit to the researchers' server, we will measure the server's capabilities. For throughput measurement, we use the application Apache Jmeter. The test scheme uses 1,000 virtual users and will be repeated 30 times. The users will request raw data from Fitbit and do data using the aggregator.

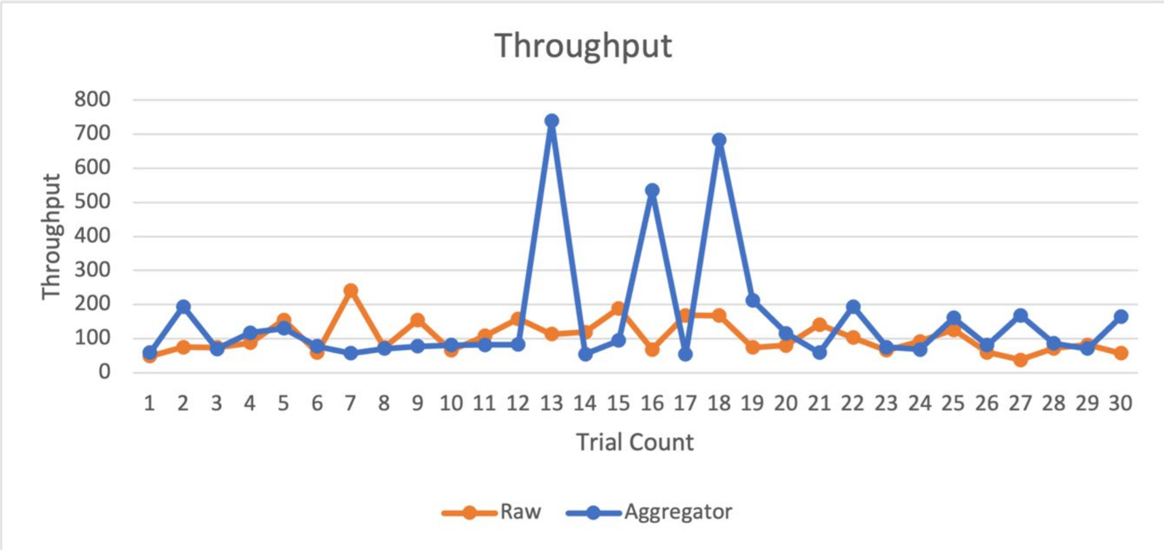

Figure 3. Throughput Testing Graph

Figure 3. shows the comparison of the throughput received by the server when the users make a request or pull and send data. In this study, raw or unprocessed data are collected. Data retrieval is carried out by the aggregator. The data retrieval process itself involves an API that has been installed into the device used, such as smartphone, and the server to transmit data.

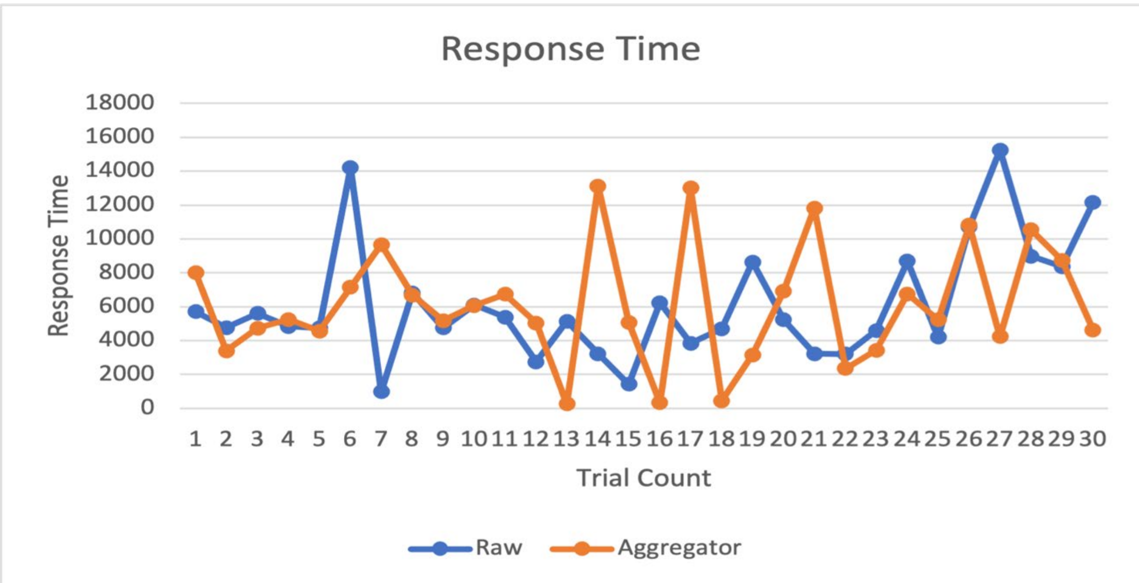

Figure 4. Response Time Testing Graph

Figure 4 shows the test graph of the response time from the users' recording data requests captured by the sensors for the display of the data on the application that has been made. This also involves an API to carry out the process of pulling and sending data to the users as a result of recording.

Table 1. Throughput and Response Time Test Results

	Throughput		Response Time/ms	
	Raw Process	Aggregator	Raw Process	Aggregator
Total Value	3120	4720	184474	183331
Average Value	104	157.33	6149.13	6111.03

Table 1 shows the total and average values from the tests carried out on the system. In the table above, it can be seen that the throughput values for the aggregator are quite high. Throughput is the value of the server's ability to control the amount of load from the server, and the higher the throughput value the better the performance of the server. Meanwhile, the response time value was smaller with the aggregator use. Shorter response time means that the server can process requests from users and provide feedback faster.

The testing of throughput and response time can be influenced by several conditions, such as the Internet network and the specification of the server or device used in the test. Because the test requires a cloud service to accommodate data and a smartphone to serve as a data aggregator and because the sending of data involves an Internet network connection, if one of the research objects does not carry out its role properly, then the results of the research will be affected.

Overall, the results prove whether the system made can run according to the design and show the throughput and response time values of the system. Throughput value is measured to assess the load of the server, and response time is measured to find out the time it takes to deal with a a request to the server.

5. Conclusions and Future Works

From the results of the design and implementation of the sleep quality detection program, some conclusions can be drawn. The application created can display time data by pulling data following a request when the program is run, and the system will process the data. Meanwhile, the aggregator used can pull data from the Fitbit server and process the data for data display. The test on the system shows that the system has high enough throughput to be able to attract more data and accommodate enough user usage so that the application can be utilized by many users. The use of a cloud service makes it easier to withdraw data and lighter to process the data because computing over the cloud is performed per computing request.

In the future, it is hoped that the application or system can be developed further in integration with other health devices. It is also expected that the application or system can measure, calculate, or make a diagnosis of abnormality in the body more quickly and accurately so that the users can find out information on their health on their application earlier.

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