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A Framework Study on a Real-Time Operated System for Emergency Medical Services (EMS) using NODEMCU Processor

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ABSTRACT

Emergency Medical Services (EMS) has always been a great help in treating patients before they arrive at the hospital. On the route to the hospital, where they will receive proper and additional treatment, pre-hospital care is an emergency aid to help stabilise the patient's condition. However, there is a lack of effective maintenance in the data interchange between the emergency department doctors and the paramedics in the ambulance. To give the patient the highest level of treatment, the patient's handoffs from paramedics or pre-hospital to in-hospital staff are not of sufficient quality. Hence came the idea of incorporating the Internet of Things into the emergency healthcare system. This paper discusses a proposed idea to design a reliable healthcare monitoring system that enables data exchange between doctors and paramedics efficiently. This system utilises the IoT platform, Blynk App, to display the data in both places (ambulance and emergency department) by using NodeMCU as the core processor and wearable sensors to measure the main parameters and vital sign data (as is current practise in ambulances). This system may also confirm that data from the sensors is transmitted in real-time to the host computer. The findings indicate that the vital sign readings are roughly accurate when compared to actual devices or marketable measurement tools. At the same time, the system will help the paramedics and doctors communicate efficiently in two ways and enable them to exchange patient details in real-time, so appropriate action can be discussed and the patient can be treated swiftly. The provided information allows hospital professionals in the emergency department to suggest what tools or medications should be ready to treat the patient further.

1. Introduction

The IoT Technology has been implemented in almost every aspect in our daily life to an extent that it plays an important role in today's world. Technology is the dynamic application of techniques, methods, skills, and processes utilized for practical purposes in the creation of goods and services or in accomplishing outcomes that benefits consumers [1]. This also applies to healthcare industries

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where patients need for the absolute care is a precedence. One of the many opportunities exist to improve the quality of a service or industries is to increase the use of information technology in the said field. Although the combination of Internet of Things (IoT) and medical is not uncommon, it has a lot of potential to improve and incorporate better technology to assist both the emergency healthcare and the healthcare department.

Incorporating technology in emergency healthcare would tremendously help to further enhance the quality of patient's care. This focuses more on the patients that are being rushed to hospitals from incident site in an ambulance as the urgency to treat their wounds falls into the paramedic's priority when it comes to keeping them alive. The condition of the patient may deteriorate along the way to the hospital if they are not assessed and treated in time. Application of technology into this field could reduce the number of fatalities occurred. Countless amount of research has been done to search for advanced, accurate and systematic technology for a better healthcare industry.

The world has been shaken with a new deadly virus that causes a public health emergency to be declared by WHO on 30th January [2]. The virus namely Coronavirus disease 19 or better known as COVID-19 has spread all over the world raising public panic and chaos. The outbreak was denoted as a pandemic seeing it has already spread across the entire world in months and it continues to haunt us to this day. The hospitals and the hospital staffs had it worse as many people were being admitted to hospitals daily requiring emergency care. The rising cases of covid-19 which had caused quite a traumatic impact to the world especially the hospital staffs as they need to treat the patient coming in and out of the hospital daily without rest. With the inpatient that have been in the hospital even before covid-19, the number of patients has increased immensely to the point that the hospital started to run out of hospital beds. The hospital staffs were pushed to make decision quickly to save more patients.

The application of Internet of Things (IoT) into emergency healthcare could be the better digital solutions to saving lives in the time of rush. The patient's vital signs, TRIAGE tags [3] and conditions could be updated to the doctors in the emergency department without lag. Both parties can also communicate with one another to discuss the patient's treatment. This welcomes more possibilities in telemedicine and disaster management. The main purpose of this research is to find the optimum way to improve patient's care once arrived in emergency department. The rest of this paper is organized as follows: Section II describes the work done related to using different processor to collect vital signs data in efficient way. It also gives a comparison using different processor versus data transfer for public health monitoring. Section III describes the methodology of proposed framework implementation of wearable health monitoring system mimics from the current devices are use in ambulance. The replacement wearable sensors are limited to measure the vital sign data connected to the NodeMCU processor and built-in with Wi-Fi module inside to establish the communication between processor and IoT platform to display the data. Section IV describe all the findings from the circuit connections and test phase of this system and discussion was made when comparing the actual data taken with the approved equipment used to determine the hardware accuracy. Section V discusses the objectives of this system based on the performance evaluation results and some points of future recommendations to improve the credibility of health system monitoring.

2. Literature Review on Related Work

Several research on past papers related to health monitoring have been conducted through explorative method of review that led to the discovery of technology in emergency healthcare by reviewing various related articles. Some of which provided a whole new perspective and insights on the topic itself. The review aims to distinguish the various viewpoint that exist on the implementation

of mobility solutions in emergency healthcare. Rahaman *et al*., [4] have gathered a few papers as reviews that discusses on the IoT based health monitoring system. The systems gathered ranges in the microprocessor that they employed, the uses, cost, and the feedback device of the system. It can be concluded that although IoT is considered to be hard to implement in a system, it was undoubted that IoT in the medical world would bring great benefit to both the patient and doctors as they helped in informing real time data. IoT also allows the monitoring process to be done remotely. Early detection of health problems allows the doctors to take immediate action to potentially help save the patient's life.

According to Jayakumar *et al*., [5], the concept of IoT helps in monitoring the patient's health efficiently. He suggested a system that uses Arduino UNO as its microprocessor, heart rate sensor, ECG monitor sensor, and LM35 temperature sensor to be used as the sensors that will monitor the patient's health. Their project was designed to be minimalistic and effective by sensing and transferring data to the webpage provided for every 20 seconds. Once the patient's parameters recorded a value that exceeds the threshold value, doctors will be alerted via a message. The system uses a NodeMCU to help transfer the data acquired to a website that can be displayed from either a PC or a mobile. It employs the software Thing speak to receive and display the data for monitoring purposes. Tastan *et al*., [6], discusses of a wearable smart health monitoring system incorporating an android based application. The system incorporates Arduino Pro mini as its microcontroller with a few sensors such as pulse sensor, and a temperature sensor to gather the patient's heartbeat and temperature to monitor. The system uses a Bluetooth module to transfer the data to blynk that will display the heartbeat and temperature. When an emergency occurred typically whenever the parameters recorded went over the threshold value, a notification will be sent to the doctor and family members. This helps to rescue the patient in time since the data is being displayed in real time.

Kumar *et al*., [7] has proposed a system of an IoT based health monitoring system using android app. The system incorporates a BSN which refers to a body sensor network and other smart products to achieve its aim which was to improve the efficiency and quality of healthcare. The sensors used was pulse sensor and DHT11 that will measure the patient's heartbeat and temperature together with humidity respectively. The system installed a raspberry pi as its microcontroller that will cater to the commands and run the system as desired. The system has an application that will receive the data transferred to be then displayed of the values of the patient's temperature and heartbeat. The system was set so that whenever the values for the temperature sensor went above 38 degrees Celsius or below than 37 degrees Celsius. The family members and the doctors will be informed depending on the seriousness of the situation.

Vaibhav *et al*., [8] suggested an IoT based patient health monitoring system that allows for continuous monitoring of the patient's vital sign. The proposed system has a LPC2148 as its microcontroller, temperature sensor and heart rate sensor as the input that will measure the patient's measurement. In addition, it uses a liquid crystal display with a measurement of (16x2) to display the measurements taken of the patient. It employs a GPRS which stands for General Packet Radio Service, Protocol that enables users to access the data at any time of the day. The system proposed also uses MAX232 which is a dual driver that converts TTL level to RS232 level. A buzzer was installed to help alert the people nearby of any dangerous condition. Another study by Rathy *et al*., [9], who proposed an idea of an efficient IoT based biomedical health monitoring and diagnosing system using myRIO to add twist to the idea of emerging IoT with medical world. The proposed system employs heart rate sensor, pulse sensor, BP sensor wearable ultrasound patch, MAX30205 temperature sensor as the sensors that will measure the patient's measurement, ESP 8266 as a Wi-Fi transceiver development kit, and NI-myRIO as a hardware to process real-time data. The system uses LabVIEW to display the readings taken and monitor the patient's health. Once the sensors

measure the readings from the patient, it will transfer the data through Wi-Fi module and display them on the LabVIEW. It also equips an alert system that will alert the caretaker and patient to either take their medicine or to check on the patient.

Emergency medical services which is pivotal to the healthcare system is an aid given to inpatient and outpatient of hospitals which is necessary to prevent death or serious impairment of the health of the patient. During emergency treatment, the paramedics will first assess the patient's condition before proceeding with appropriate treatment. Emergency assessment is a process that is used to classify and treat life-threatening problems. It assessed the level of consciousness, cervical spinal stabilization, airway, breathing, and circulation [10]. The paramedics are always on the ready to give medical services or emergency medical procedure for the patient that they are attending to in the ambulance. Furthermore, it is necessary to keep the patient alive during the transportation of the patient from incident scene to the hospital [11].

2.1 Development of Framework Study for Emergency Medical Services

Emergency medical services also is an extensive system which supplies the disposition of personnel, facilities, and equipment to ensure efficient, systematic, and prompt delivery of health and safety services to patients of sudden injury, illness, and trauma thus, the incorporation of emergency medical services is fervently endorsed by the World Health Organization (WHO) as one of the crucial components of the healthcare system [12]. It can also help in reducing the rates of suicide [13]. Emergency assessment is an essential step in taking care of the patient hence improving the assessment of the emergency healthcare would reduce fatalities when transporting the patient in an ambulance.

Ambulance is considered as part of the emergency medical services in a form of transportation which is provided for the reason of taking care of sick and injured people to and from hospital usually in the case of emergency and paramedics will tend to the patient in the ambulance. Paramedics, emergency medical technician, emergency medical personnel, emergency dispatch personnel and call-takers are a part of the emergency response team, and their role is to coordinate the response communication for pre-hospital and out of hospital medical emergency care [14]. Not only do the paramedics in the ambulance need to have the medical knowledge on emergency care, but the ambulance also requires a reliable communication system with a back-up system to enable a smooth communication [15]. The paramedics must know how to calm the patient and talk them through the treatment all the way to the hospital to keep the patient relaxed while they treat them therefore, by allowing the paramedics to communicate with the doctors will ensure the paramedics of the treatment executed on the patient [16]. It was shown that communication is crucial in be it between the paramedics and the hospital staffs or with the patient to guarantee that the patient is alive, and their health and safety are taken care of. Enhancing the quality of communication system between the paramedics and the hospital staffs would greatly help in reducing casualties caused by delayed communication. Health information exchange is a patient's summary which consists of previous history, physical examination, diagnosis, treatments, and laboratory investigation [17].

2.2 Parameters Taken During Emergency Medical Service

Vital signs consist of systolic blood pressure, pulse pressure, heart rate, respiratory rate, and Glasgow coma scale [18]. Vital signs are the key to help treat the patient in early identification of distress, wounds or diseases that poses threat to the patient's health causing it to deteriorate along the way that could later be fatal [19]. Vital signs are closely related to TRIAGE and helps in

determining the TRIAGE tags for each patient. Important vital signs are blood pressure, SpO2, heart rate, respiration rate and temperature of the patient. Blood pressure is divided into two categories which are systolic and diastolic. Systolic blood pressure shows the pressure exerted on the artery walls when the heart beats and diastolic blood pressure defines the pressure deployed to the artery walls when the heart is in resting condition which is between the heart beats. Normal values for blood pressure should be less than 120/80 mm/Hg. The former value holds for the systolic blood pressure value meanwhile the latter value denoted as the diastolic blood pressure value. If the blood pressure is higher than the normal value, it indicates hypertension.

Next, SpO2 is oxygen saturation which is the measurement of the amount of oxygen carrying hemoglobin in the blood in relative to the amount of hemoglobin that is not oxygen carrying. The oxygen in the blood needs to be at certain level for the body to function properly. The normal SpO2 level should be in the range of 95% to 99%. Furthermore, heart rate is also known as pulse. It is the number of heart beats per minute. The heart rate may vary each person though the heart rate tends to be lower when one is resting, and it can increase when the person is moving or exercising. The normal range for the heart rate is quite different between an adult and a child. The normal range for a child range from 70 beats to 100 beats per minute while adult's heart rate ranges from 60 beats to 100 beats per minute.

There is a way to count the heart rate which is to patiently take the pulse on the wrist or neck for about 10 seconds then multiple it by 6. Maximum heart rate can also be calculated via simple mathematical solution. The predicted maximum heart rate can be calculated by deducting 220 from your age. Moreover, respiration rate defines as the number of breaths that the person takes per minute. Respiration rate is taken when the patient is in resting condition. It may increase due to illness, fever, and other medical conditions. The normal respiration rate for an adult is within the range of 12 breaths to 16 breaths per minute. Lastly, temperature is one of the most pivotal signs of the things happening inside the person. Body temperature may vary from person to person and types of activities done throughout the day affects the body temperature. Body temperature could be taken by the mouth, armpit, forehead, ear, and rectum. Normal body temperature for a human is 37 degrees Celsius. All the possibilities readings for vital signs [16-19].

2.3 Process Flow of the Vital Sign Monitoring System

The communication in emergency medical services is utterly important because of the high-risk nature of patient handling and patient handoffs to medical error. In cases where the patients were being brought to the emergency department by an ambulance, the only person with the most medical information on the patient in that time is the paramedics. Paramedic's records critical information while tending to the patient in the ambulance to elevate their chance of survival. This information is vital to the hospital staffs that is going to handle the patient afterwards and this could greatly affect the healthcare and triage options. When an accident occurs, the emergency medical service response starts by receiving a report of the incident which will be relayed with the use of an in-station alerting system, pagers, or other means of communication to notify the emergency medical service teams of a need for their service.

Then, the team will acknowledge the receipt of the call by repeating the information received back to the dispatcher to ensure the responding team have the correct information. The responding team should always notify the dispatcher when in route to the location of the incident and all the events happening whilst on the road to enable the dispatcher to dispatch another team if the existing team runs into a problem that may delay the journey. In the ambulance is where the first aid treatment of the patient and health information exchange occurs. Health information exchange is a

patient's summary which consists of previous history, physical examination, diagnosis, treatments, and laboratory investigation.

Emergency medical services utilizes the radio to exchange health information, patient's details, and the condition of the patient with the hospital staffs in the emergency department. Sometimes the information is not available or is received at such little data or even incorrect and this causes the diagnosis and treatment of the patient to be prolonged when arrived at the emergency department. The radio communication system used may experience interference with other electrical devices and surrounding environment. Internet of Medical Things gave access to a continuous, remote, and real-time monitoring of patients. Although there are plenty of obstacles to overcome relating to communication protocols, flexibility, bandwidth, reliability, big data and data volume, data management, energy efficiency as well as data security and, privacy [20].

The block diagram of patient's vital sign monitor used in Emergency Medical Services specifically ambulance shown in Figure 1. The block diagram consists of two inputs, one microcontroller and two outputs. Since the microcontroller chosen to be used in the project is NodeMCU using Wi-Fi as communication protocol to transfer the data in real-time operating system. MAX30102 and GY 906 is considered as input of the system which will be controlled by NodeMCU that acts as the system's microcontroller. NodeMCU will then transfer the data to the output of the system which are Serial Monitor, OLED, and Blynk. This system will operate whenever the sensors are attached to a patient since it will start to measure the readings. The data read will then be displayed on a screen in the ambulance for the paramedics to monitor the patient and simultaneously display the same data in real-time on a screen in the emergency department of a hospital for the doctors and nurses to monitor. The vital signs gathered from the systems are heart rate, SPO2 level indicating the oxygen level in the blood and the body temperature of the patient. The overall flowchart of this project is shown by Figure 2. The aim of this project is to transfer the data from ambulance monitor to the monitor in the emergency department.

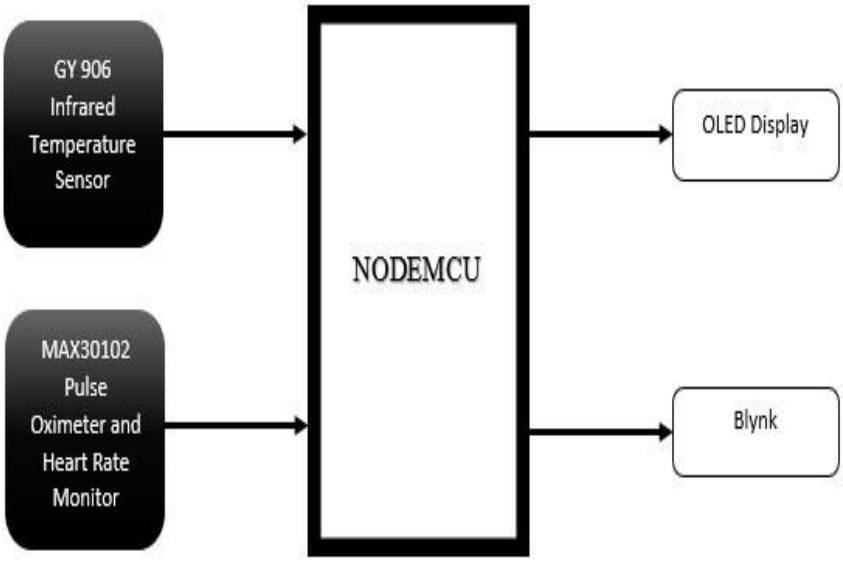

Fig. 1. Block diagram of the main process from data collection using GY906 Sensor and MAX30102 Sensor to NODEMCU as processor before display to IoT Platform

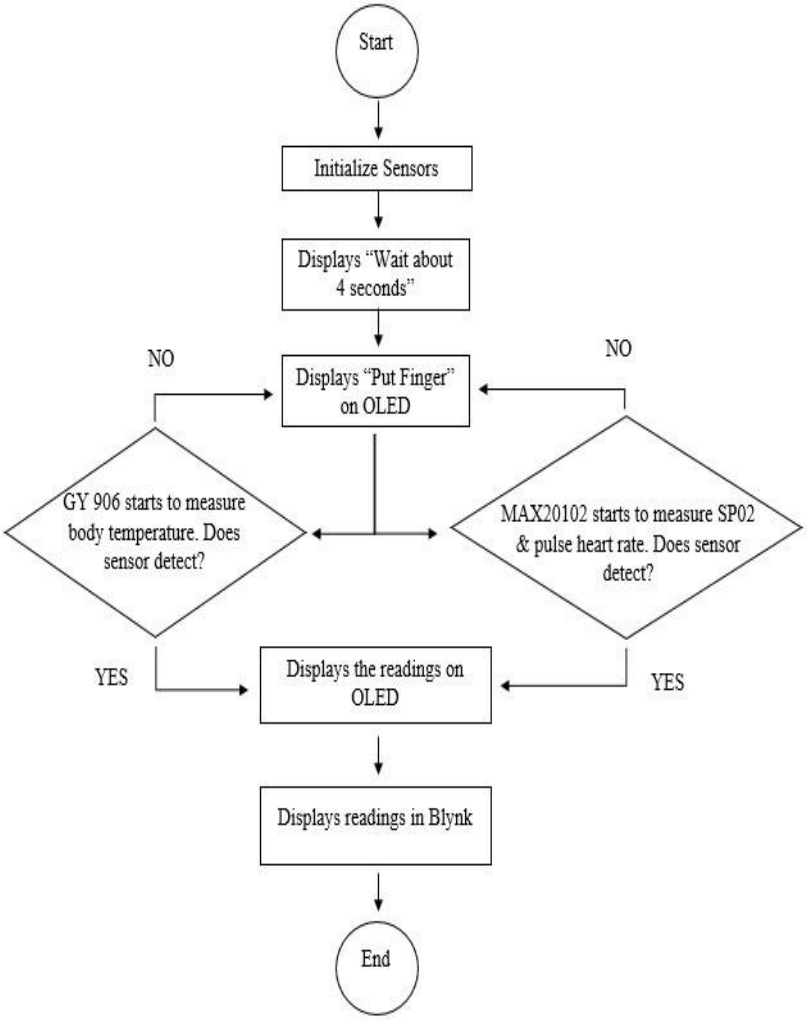

Fig. 2. Flowchart of the main project to transfer all the data collection from ambulance side to Emergency Department (ED)

3. Results and Discussion

The process starts when the system is turned on. The sensors will then be initialized and ready to take measurements from a patient. Once there is a presence on the sensors, it will start to measure the readings. In an ambulance, once the paramedics attach the sensors to the patient, it will start to measure the patient's body temperature, SPO2 level, and pulse heart rate as shown in Figure 3. The readings will then be displayed on OLED or a screen in the ambulance for the purpose of monitoring the patient on behalf of the paramedics. Simultaneously, the same real-time readings will be displayed on Blynk or a screen in the emergency department. The doctors and nurses in the emergency department will be able to monitor the patient's vital signs from afar allowing them to prepare for equipment's needed, rooms, apparatus needed to welcome the patient during handoffs. Once the ambulance arrives at the emergency department, the doctors and nurses will have to continue to monitor the patient but all the hassle of preparing the room will be reduced as it had been done before the patient arrive saving time and helps in increasing the patient's chance in surviving and improving the patient's care in the hospital. Figure 4 shows the parameters shown on OLED when the system was started.

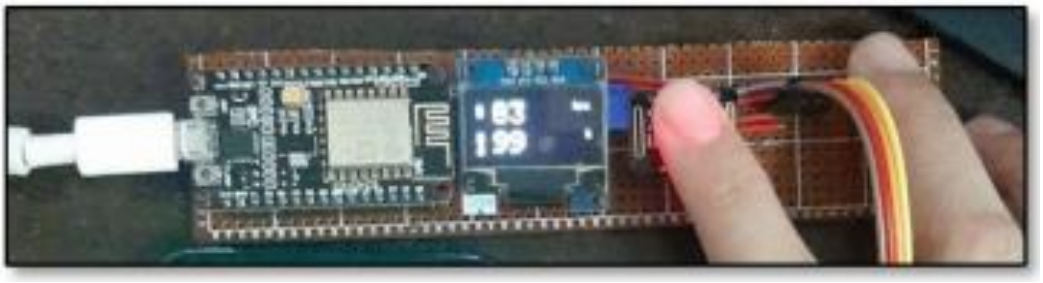

Fig. 3. The parameters shown on OLED when data measure using Vital Sign Sensors

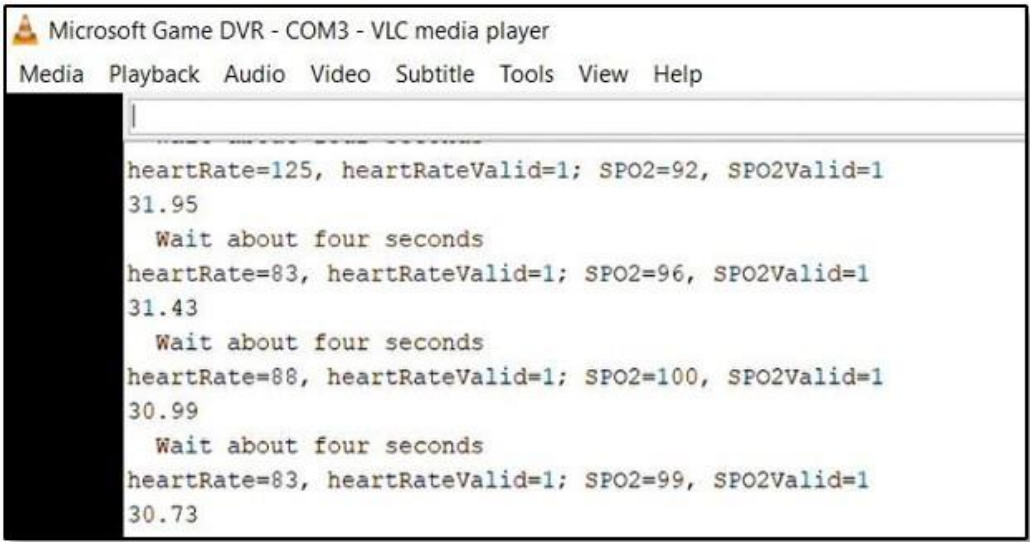

Fig. 4. The results displayed in serial monitor when system start to measure the Vital Sign Data

The serial monitor that displays the measurements of the heart rate, the SPO2 and the body temperature was shown in Figure 5. The serial monitor can be a screen to display the measurements, and this was used to compensate for the small OLED screen which only showed heart rate and SPO2 values. The system delayed for about four seconds to synchronize the data collected from the sensors to be displayed on all three screens. The measurements collected from the MAX30102 pulse oximeter and heart rate biosensor is a bit fast for the OLED to display the measurements, hence the delay was needed. The values of the heart rate can also be observed to have been increased a little over the normal range which means that the sensors also detect the abnormal values for the measurements making it reliable to be used for human's vital sign measurements. It was also observed that the system can take measurements and display the data continuously for a long period of time.

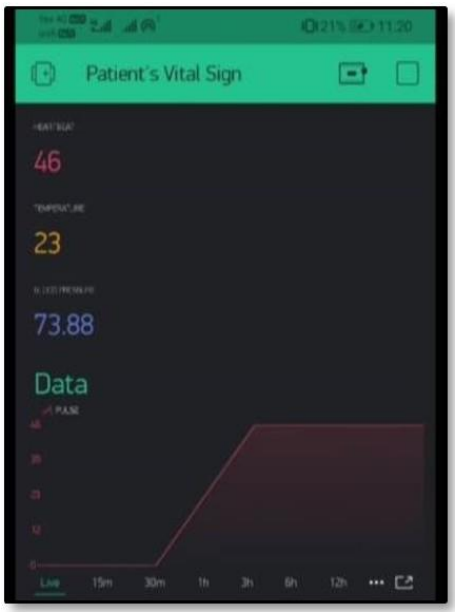

Fig. 5. The parameters of the Patient's Vital Sign shown on Blynk appearance

Data collected shown in Table I and Figure 6-8 are the analysis of the measurements taken by the hardware and compare with approved equipment to determine its accuracy. The values were compared with the values measured by approved equipment. In this case, the equipment used to measure the heart rate and SpO2 was a reliable smart-watch meanwhile the body temperature was measured by using the non-contact digital infrared thermometer with stand. The readings measured was varied by the condition of the human as the parameters are closely related to human activities. Heartbeat per minute may increase with vigorous activities as the heart beats faster to provide more blood to the muscles used. The system that can assist in emergency services by enabling the data to be transferred in real time was developed. The system's performance of using NodeMCU as its microprocessor was evaluated. Comparison of the measurements collected from the system of both simulation and hardware with the normal average measurements of the vital signs was made. In the case of hardware, the project was successful in transferring data in real time by using NodeMCU as its microcontroller and Wi-Fi module, bearing the same measurements in both Blynk and OLED display. This system has the ability to improve the existing system of emergency handling situation and emergency handoffs in the emergency department. It benefits each party in the emergency medical services which are the paramedics in the ambulance, doctors, and nurses in the emergency department. The emergency handoffs would become faster and effective. Thus, it improves patient's care in the hospital.

Table 1
The data measured from approved equipment and from hardware of the project

Measurements						
Conditions	Average recorded parameters			Hardware recorded parameters		
	Heartbeat (bpm)	SpO2 (%)	Body temperature (°C)	Heartbeat (bpm)	SpO2 (%)	Body temperature (°C)
Resting	90	99	36.8	90	99	36.8
(children)	83	99	37.3	83	99	37.4
(adult)	94	97	37.8	94	96	37.8
(sleeping)	60	100	36.4	61	99	36.5
Jogging	115	97	37.2	115	97	37.2
Running	152	95	37.4	152	96	37.4
Dancing	119	97	37.1	118	97	37.1
Exercising	131	96	36.9	131	96	36.8
Playing basketball	120	96	37.5	120	96	37.5

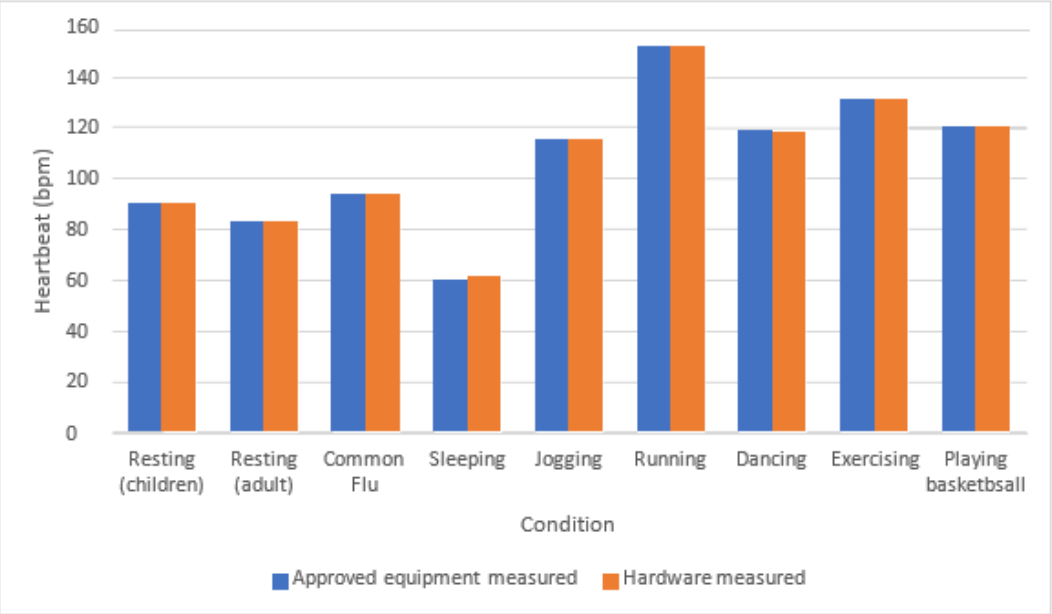

Fig. 6. The heartbeat per minute taken by approved equipment and hardware

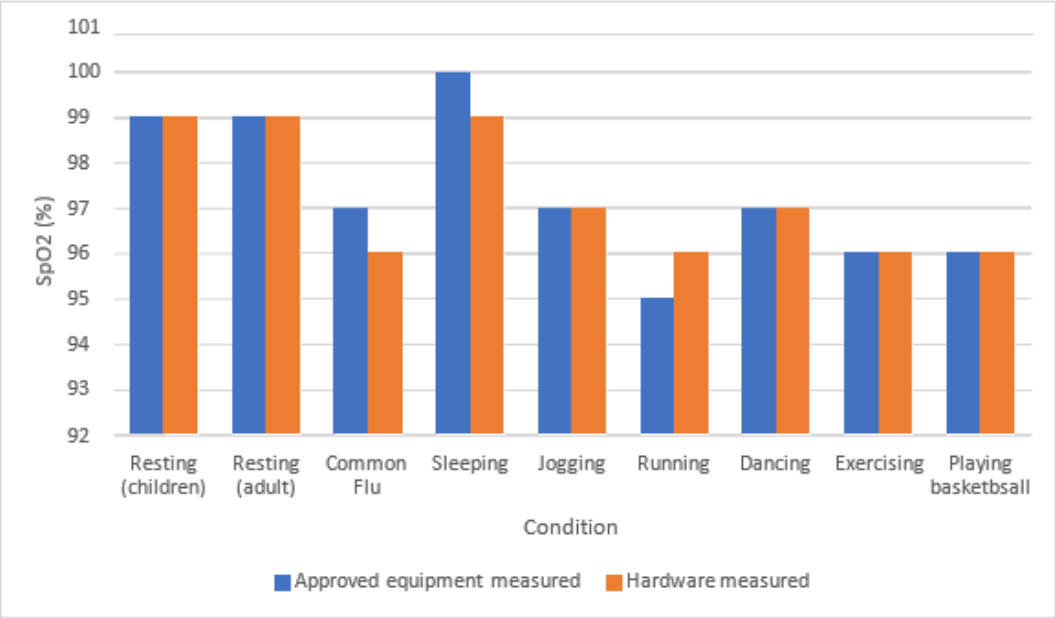

Fig. 7. The SpO2 taken by approved equipment and hardware

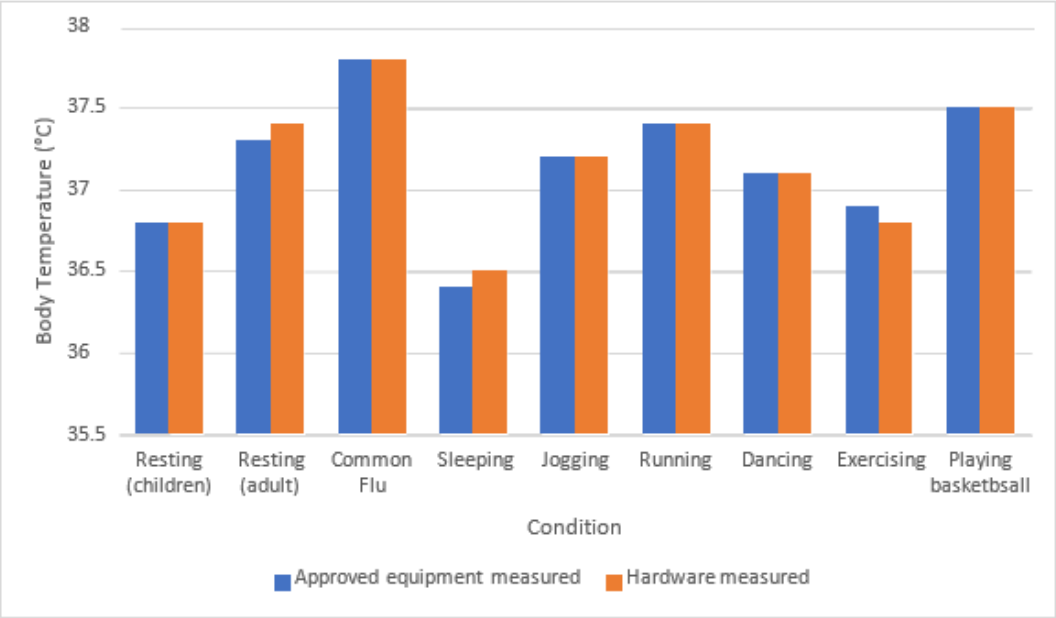

Fig. 8. The body temperature taken by approved equipment and hardware

4. Conclusions

In conclusion, overall, the objectives of this project are achieved. The system that can assist in emergency services by enabling the data to be transferred in real time was developed. The system's performance of using NodeMCU as its microprocessor was evaluated. Comparison of the measurements collected from the system of both simulation and hardware with the normal average measurements of the vital signs was made. In the case of hardware, the project was successful in transferring data in real time by using NodeMCU as its microcontroller and Wi-Fi module, bearing the same measurements in both Blynk and OLED display. This system has the ability to improve the existing system of emergency handling situation and emergency handoffs in the emergency department. It benefits each party in the emergency medical services which are the paramedics in

the ambulance, doctors, and nurses in the emergency department. The emergency handoffs would become faster and effective. For the future recommendation, good exposure to Integration with Electronic Health Records (EHR), integration of the healthcare monitoring system with electronic health records. This also can facilitate seamless data sharing, access to patient history, and continuity of care, improving the overall efficiency and accuracy of treatment.

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