Integrated Design Project

Design Proposal

Group 5: Patient Monitoring Device

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1.0 Introduction

Covid-19 pandemic highlights the weakness in the healthcare system. The Sars-cov-2 is a contagious virus and constricts the work of the healthcare workers thus crimping the healthcare system worldwide. Doctors and nurses are unable to tent or monitor their patient at close distance due to the risk of contacting the diseases themselves. In this aspect, an IoT based health monitoring system offers a practical solution to help the healthcare system in such a situation. Internet of Things (IoT) is the new revolution of internet where the network of physical objects— “things” or objects — that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.

2.0 Objective/Motivation

The core objective of this project is the design and implementation of a smart patient health tracking system that uses sensors to track patient health and uses the internet to enable healthcare personnel to access data in IoT cloud. The objective of developing monitoring systems is to reduce healthcare costs by reducing physician office visits, hospitalizations, and diagnostic testing procedure [1]. Sensors are attached to the patient body and are linked to a microcontroller to track the status which is thus interfaced to a computer and additionally remote association with have the capacity to exchange alarms. Remote Patient Monitoring arrangement empowers observation of patients outside of customary clinical settings, which expands access to human services offices at bring down expenses [2].

Other than that, the marketability and the impact to society are also taken into consideration. As in the market at the moment, there are no patient monitoring machines that implement remote monitoring systems. Physicians or doctors are required to visit the patient bed by bed to observe the wellbeing of the patient through an LCD monitor to undergo medical checkup. Although, machines such as MD9015 features a central monitoring system (CMS) which enables physicians to monitor 64 beds at time, some limitations coexist with devices. Some of the existing machine and their limitations are show below:

Product Name	Specification	Limitation
 MD9015 Multi-Parameter Patient Monitor	- Features Central Monitoring System - Holographicwaveform(ECG,RESP,CO2,Pleth,IBP) - Alarm prompt modes: sound and light wave - 15” Color TFT display - Voltage: 110-240V AC;50Hz - Battery life: 8 hours	- Storage and review only available for 240hrs - Required data transfer from the machine to access data - Big size - Expensive(Rm5596)
 Portable Multi-parameter Patient Monitor	- 12" high resolution color TFT LCD display. - 6 Standard parameters:ECG, RESP, NIBP, SPO2, TEMP, PR - Can be arbitrarily set the alarm limit, automatic sound and light alarm.	- No data storage - Expensive (RM1715.99) - No stand mount available
 LMT – 01 Fingertip Pulse Oximeter	- PR Measuring Range:30bpm~250bpm - SpO2 Measuring Range:0%~100% - Fingertip Pulse Oximeter(lightweight) - Power Requirement:2*1.5V AAAbattery - Power Consumption: 30mA - Voltage:DC 3.0V	- Limited parameter measured for patient monitoring purposes - No storage available
	- Oxygen saturation: 35% to 99% - Pulse: 35bpm to 250bpm - Real-time synchronization with free App through bluetooth to record and store the data of blood oxygen level(SpO2), pulse rate(PR) and perfusion	- SpO2 Oxygen saturation only prompt at 50% to 100%. Normal range for healthy

 PC – 60F Fingertip Pulse Oximeter	index(PI) on cloud.*	SpO2 is 95% - 100% - Limited parameter for patient monitoring purposes

Table 1: Existed device in the market

As shown in Table 1, most of the existing devices or machines do not offer remote monitoring systems. The Central Monitoring System from the MD9015 machine could benefit from an IoT system where the data of the patient can be accessed or monitored at any time and anyway by the doctors. Such a feature will be beneficial in the current covid-19 pandemic situation where healthcare personnel are safe when fulfilling their duty.

3.0 Design Code and safety concern

Patient monitoring is critical for perioperative patient safety as anesthesiologists routinely make crucial therapeutic decisions from the information displayed on patient monitors[3]. From the studies, common major problem is alarm configuration which include lack of standardization in alarm management, alarm limit setting and the requirement for different alarm threshold for different phases of care for different patients. It is also mentioned the danger of desensitization and “alarm fatigue” where the alarm did not prompt and may cause critical patient status to go unnoticed. The audible level of the alarm must not exceed 115db-127db as mention in NFPA 72F. The alarm must be audible and attention-getting rather than aversive and distracting toward other patients.

The interface of the device must display information clearly and not confuse the user as mention in IEEE 1505 RFI. The information need to be more specific set of performance requirement that employ a common scalable pin map configuration, specific connector modules, respective contacts, recommended switching implementation and legacy automatic test equipment(ATE) transitional devices. The device will be strapped to the patient body to monitor, the device is subjected to the IEC 60529 “water resistance”; the ingress protection (IP) rating of minimum IP44 code which grades the resistance of an enclosure against the intrusion of dust and liquids. The device is also under the IEC 60479-2:2019 “effect of electric current on human beings and live stocks part 2” to prevent electric shocks on the patient.

The ECG sensors, oximeter, surrounding temperature and humidity sensors will follow the code of IEEE 2700-2017 “standard for sensor performance”. The device will be monitoring the patient in real-time on an IOT cloud using the IEEE code of P1931.1 “protocols and APIs for providing Real-time Onsite Operations Facilitation”. The WiFi connection from the ESP32 connection will use the standard of IEEE 802.15.4-2015 “Standard for Low-Rate Wireless Networks”. The data will be monitored using security requirements of IOT based healthcare system PMC7004290 survey study with the code of ITU-T Q.3913 “Security for monitoring Internet of things devices” [4].

4.0 Proposed System

4.1 Product design

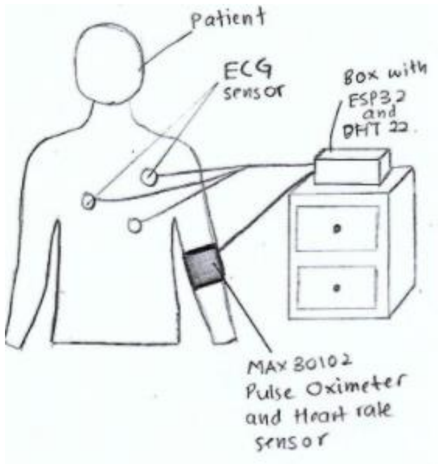


Figure 1: Design sketch of proposed product

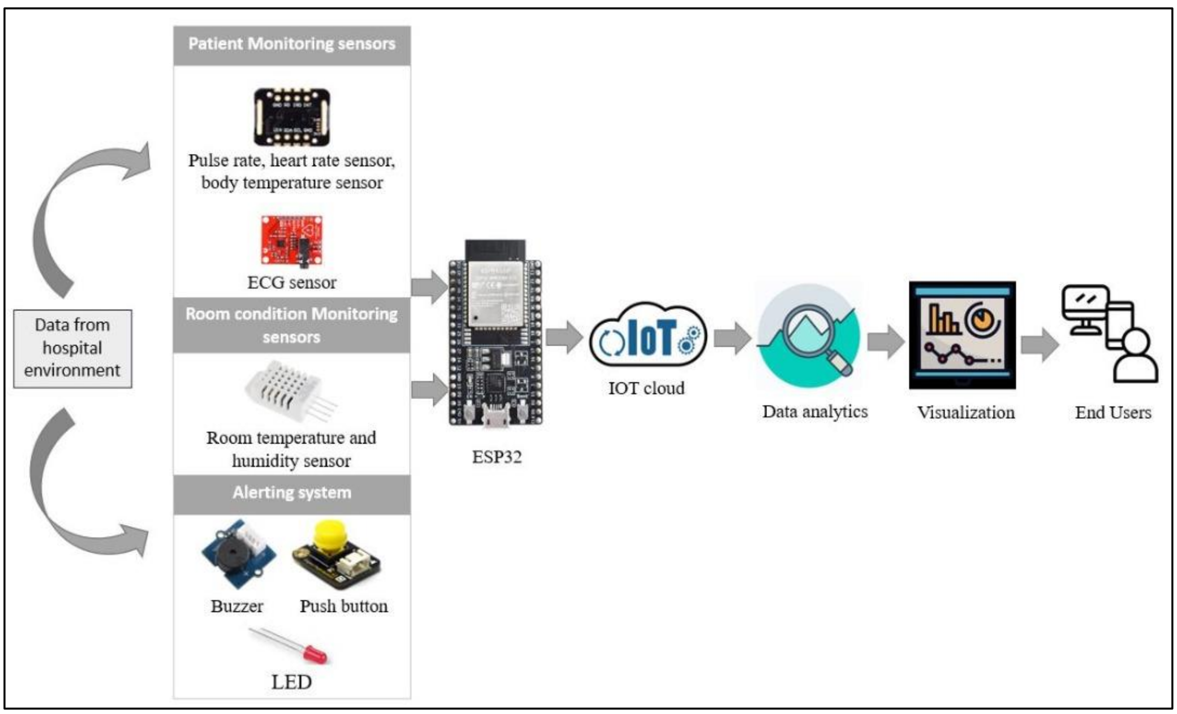


Figure 2: Design Architecture of proposed IOT patient monitoring system

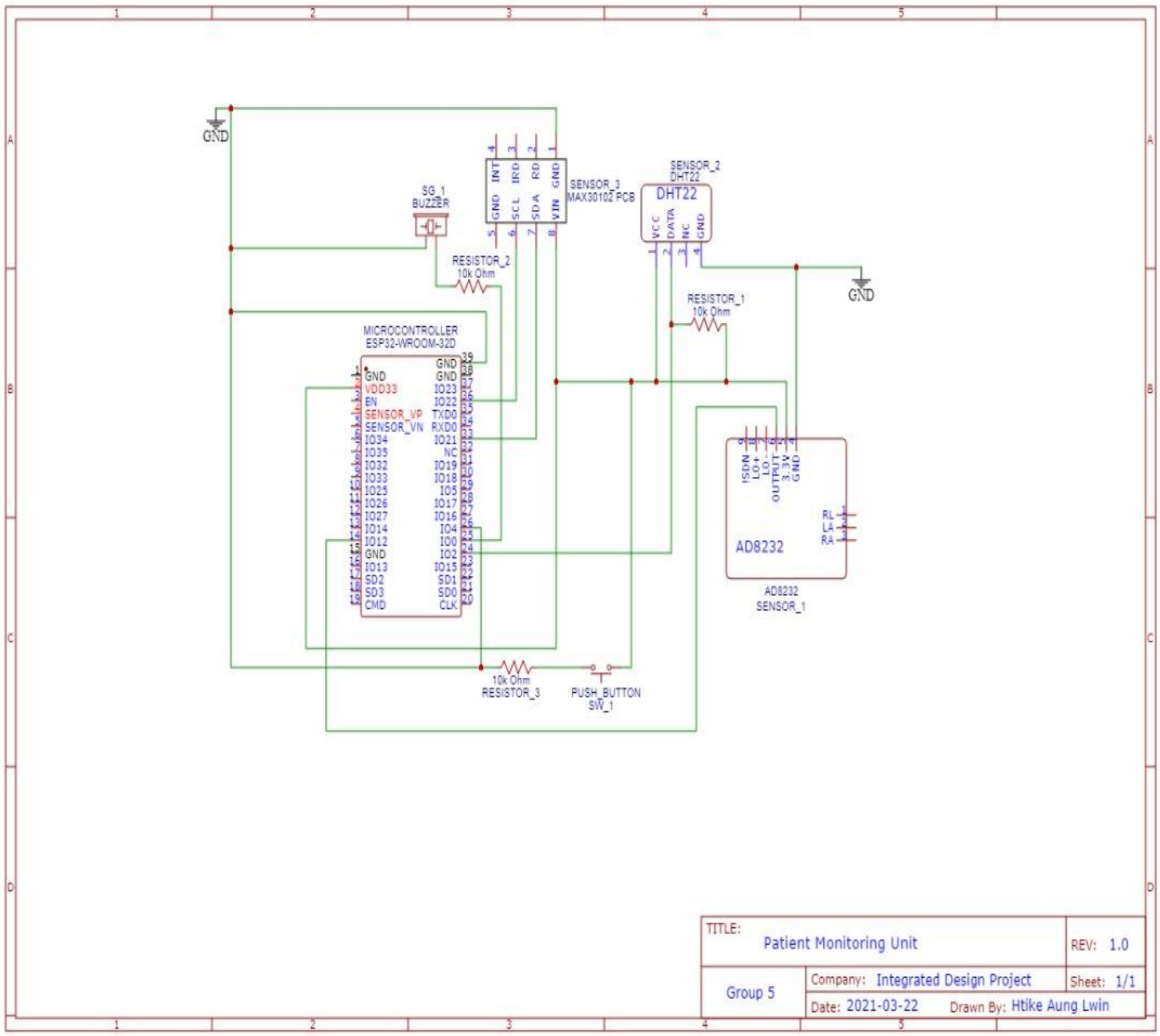


Figure 3: Circuit diagram of the proposed producct

4.2 Product description

Real-time patient monitoring system is the main concept of the proposed project, and alerting system is the innovative idea of the system. As show in Figure 1, the patient monitoring system utilizes the three-stage architectural features, which are sensor module, data processing module and web user interface. The monitoring sensors are wired and strap on patient body which are used to collect patient data and the environment data by gathering physiological signs. The patient monitoring system which records the body and surrounding temperature, surrounding humidity, electrocardiogram data, heart beat and oxygen level and also sends an SMS alert whenever those readings goes beyond critical values or sensors disconnected. The collected data are then processed via an ESP32 module and published to the Amazon Web Services IOT cloud through HTTP endpoint.

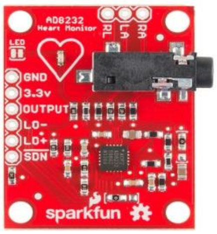
The alerting system of the patient monitoring system hardware is the special features of the patient monitoring system. The alerting system consists of a LED, a buzzer and a push button indicator. Push button indicator acts as the emergency indicator to trigger the alarm and the light which are the buzzer and alarm. This ensures that the patient or visitor can use the emergency indicator to alert the medical staffs when the patient is not feeling well even though the critical values are normal.

Amazon Web Services cloud shows the current status and process of transactions. Amazon QuickSight dashboard is the web user interface for graphical interpretation and data streaming, in which the data is updated every 10 seconds, allowing medical staffs to have a real-time tracking on patient.

4.3 Gantt chart (Project planning)

Figure 4: Gantt chart

4.4 Function and specifications of main component

Product Name	**Function of Components**	**Specifications/Features**	**Reason for selection of Components**
Pulse Heart Rate Sensor (ECG) 	- Measures heart electrical activity of patients. - Monitors condition of heart and detects any previous or possible heart attacks.	• Fully Integrated single-lead ECG front end • Low current supply required (170µA) • Common Mode Rejection Ratio (CMRR) of 80db. [8] • Uncommitted op amp • 2-pole adjustable high-pass filter • 3-pole adjustable low-pass filter • High signal gain with DC blocking • Fast restore feature for filter settling • Single supply operation (2.0V - 3.5V) • 8kV Human Body Model(HBM) Electrostatic Discharge (ESD) Rating [8] • Internal Radio Frequency Interference(RFI) filter • Shutdown pin • Operating temperature range (-40°C to 85°C)	• A portable ECG that can be used in wearable or remote monitors. • Low power supply • High CMRR blocks unwanted signal in the input from passing. • Uncommitted Op-amp good for signal conditioning at low signal voltages. • 2-pole high pass filter eliminates motion artifacts.[8] • 3-pole low pass filter removes noise. • High HBM ESD rating • Eliminates RFI with internal RFI filter[8] • Shutdown pin reduces power consumption.[8] • Acceptable operating temperature range

Pulse Oximeter & Heart-Rate Sensor  	- Uses LED to detect oxygen levels in the blood. - Measures the pulse rate of the heart. - Measure body temperature	• Tiny Optical Module with Integrated Cover Glass • Programmable Sample Rate and LED Current • Low Power Heart Rate Monitor (<1mW) • Ultra-Low Shutdown Current (0.7µA) • High Sample Rates for fast data output • High Signal to Noise Ratio (SNR) (89dB) • Operating temperature range (-40℃ to 85℃) • Ambient light cancelation (ALC) • Internal temperature sensor (-40℃ to 85℃)	• Small size allows for a more compact design. • Integrated cover class for robust performance • Low power operation enables power savings • High sample rates allow more samples per second hence more accurate. • High SNR reduces noise • Operating temperature is acceptable. • (ALC) improves accuracy during measurement. • Temperature sensor resolution is 0.0625℃ and accuracy is ± 1℃
DHT22 Temperature and Humidity Sensor  	- Measures temperature and humidity of the surrounding.	• Low cost digital temperature and humidity sensor • Uses a capacitive humidity sensor and thermistor • 3V to 5V for input power • Max current during conversion is 2.5mA • Humidity reading of 0 to 100% with 2-5% accuracy • Temperature reading between -40℃ t0 80℃ with accuracy of <±0.5 ℃ • Sampling rate of 0.5Hz • Weight 2.4 grams	• Low power consumption • Small in size allows compact design. • Long transmission distance of 20m [9] • High operating range and accuracy for humidity sensor [9] • Acceptable operating range for temperature. • Acceptable accuracy for temperature sensor. • Interchangeable pins • Long term stability of

			±0.5%RH/year [9]
ESP32 Development Board 	- Acts as microcontroller for the Patient Monitoring Device	• Operating temperature range (-40℃ to 125℃) • Ultra Low power solution (3.3V single power supply) • Integrated solutions for Wi-Fi and Bluetooth that are compatible to a wide variety of devices. • Dual core 32 bit microprocessor • Supports multiple external QSPI flash and SRAM chips • Supports hardware encryption and decryption • Multiple power modes for efficient power management • Two I2Cbus interfaces	• Low power consumption [6] • Wide operating temperature range • Dual CPU enhances the speed for microcontrollers with connectivity options. • Wi-Fi and Bluetooth enables data streaming for IOT devices [7]. • Wide variety of built in peripherals like infrared remote controller • Secure code storage for internet connection with TLS [6] • Uses freeRTOS for multitasking.
DFR0029-W Push Button 	- Used as a trigger during emergency.	• Wide voltage range from 3.3V to 5V • Standard assembling structure • Easily recognitive interfaces of sensors • Icons to simply illustrate sensor function • High quality connector • Immersion gold surface • Size:22x30mm (0.87x1.18")	• Indicator LED on board • Easy to 'plug and play' • Large button keypad and high-quality first-class hat • Interface: Digital

Grove - Buzzer 	- Produces sound to alert medical staff during emergency.	• Audio signalling device powered by piezoelectricity. • Produces sound when output is high • Can be connected to digital output • Can be connected to analog pulse width modulation(PWM) for various tones and effects	• Small in size • Cheap in price (RM 3.80) • Compatible with all push buttons. • Low operating voltage (3.3V) • Sound output >85dB sufficient to detect the source.

Table 2: Component list of the proposed product

4.5 List of Components:

Product Name	Model	Quantity	Price	Total
Breadboard 16.5x5.5cm (830 Holes)	BD-BB-0617-R	2	RM3.90	RM7.80
Wrapping Wire AWG30 1Roll (Red)	WR-WR-R	1	RM18.00	RM18.00
40 Ways Male to Female Jumper Wire	WR-JW-40MF	2	RM1.50	RM3.00
40 Ways Male to Male Jumper Wire	WR-JW-40MM	2	RM2.13	RM4.26
40 Ways Female to Female Jumper Wire	WR-JW-40FF	2	RM2.13	RM4.26
DHT22 Temperature and Humidity Sensor	SN-DHT22	1	RM20.00	RM20.00
Grove – Buzzer	GRV-BUZZ	1	RM3.80	RM3.80
LED 5mm Yellow	DS-LED-5NY	5	RM0.10	RM0.50
LED 5mm Green	DS-LED-5NG	5	RM0.10	RM0.50
LED 5mm Red	DS-LED-5NR	5	RM0.10	RM0.50
6x6x1 Push Button 2 Pins	SW-PBM-2N-060601	2	RM0.40	RM0.80
Resistor 0.25W 5% (10K)	RS-025W-10K	5	RM0.05	RM0.25
Pulse Heart Rate Sensor	AD8232 Type B ECG	1	RM34.20	RM34.21
Push Button Module, White Cap	DFR0029-W	1	RM13.44	RM13.44
Pulse Oximeter & Heart-Rate Sensor	MAX30102	1	RM13.50	RM13.50
ESP32	ESP32-wroom32	1	RM23.00	RM23.00
Single Core Wire (Red)	RLL0914 (OEM)	4	RM0.50	RM 2.00
Single Core Wire (Black)	RLL0913(OEM)	4	RM0.50	RM2.00
Double sided donut board (7x9)	EEP2610(OEM)	2	RM4.00	RM8.00
3.7V Lithium Polymer Battery	502030	1	RM6.20	RM6.20
Total (RM)				166.20

Table 3: Budget list of the proposed product

5.0 Innovation of Proposed Patient Monitoring Device

Patient monitoring devices that are commonly used in hospitals today are big in size and are often placed on a rolling stand to allow portability due to its weight making it difficult to carry. This results in the device together with the rolling stand to take up a lot of space around the patient's room making it congested. This can make the ward room feel claustrophobic and induce panic feelings for the patient as there is large medical equipment around them. The proposed device however is much smaller in its size and weight. The device is primarily a microprocessor in a clear covered box with sensors and power cable attached. No need for a monitor screen like the current devices since the patient is mostly monitored remotely allowing it to be smaller in size. However, usage of tablets and smartphones are common in healthcare today, hence medical staff can easily access patient's data immediately using tablet or smartphone during routine checks through the webserver [5]. The light weight of the proposed device also allows medical staff to remove and install on patients without any difficulty which improves portability of the device.

The proposed patient monitoring device also has a built in alerting system. The alerting system has 2 types of alerting systems which are manually triggered and auto triggered. A simple alert switch on the proposed device allows patients to manually alert medical staff if they feel uneasy and need attention. When the device is manually triggered, buzzer sound is produced and a notification message is sent to the medical staff office with the patient's details and ward number. The buzzer sound with 85dB is loud enough to draw the attention of any nearby medical staff immediately. The alert switch can be turned off once medical staff attend the patient. The second type or alerting is the auto triggered where if patients vitals surpasses a predefined threshold value the device will immediately alert the medical staff. For example, if the heart rate pulse of a patient rises above normal the medical staff are alerted with a message of patient's name, ward number and pulse rate high.

Another innovation to this proposed device compared to current devices is the data streaming and data analysis of patients through IOT cloud. This device monitors the real time condition of patient's vitals and the data is streamed to the IOT cloud (Amazon Web Services), analysed and interpreted graphically using Amazon QuickSight Dashboard. This allows medical staff to monitor patients remotely and access largely stored data more effectively especially for example during a pandemic such as Covid-19. The method commonly used now is medical staff record patient's vitals during their routine checks in a logbook and then update it into a system database. This is time consuming and hard for data analysis due to insufficient since the data recorded is based on routine checks. The proposed device solves this with easily accessible data through the IOT cloud and data analysis and also is more environmentally friendly as usage of paper is reduced. Furthermore, this device reduces the burden of the medical staff doing routine checks since they now can do it remotely too hence effective time management.

6.0 Performance and testing of proposed product

The product will be evaluated with three categories, which are data transmission and streaming rate, and alerting system.

When the patient presses the emergency indicator or the patient data is beyond the critical value, the piezo buzzer will be triggered and produce more than 85db sound output. [13] stated that the sound level reduces by 6db for every doubling of distance. This means that when moving away from 10 to 20 meters away from the sound source, the orignal sound source is reduced by 6db then the next 6db reduction means moving from 20 to 40 meters. A normal human can hear sounds between 0 to 140 db where 0 db is the hearing thereshold. In theoretically, the piezo buzzer allows medical staffs to hear the sound from 140 meters below. In pratically, the sound of the buzzer can be measured by using sound meter app to determine the limit distance travelled by a 85 db sound output.

The patient data is collected from various sensors and then transmitted to the web server through WIFI module from ESP32 development kit. The ESP32 development kit supports for the propietary of 802.11 LR mode. 802.11 LR mode a patented custom mode that can achieve 1 km line of sight range as both the station and software enabled acessing point are connected to an ESP32 device [12]. In our project, the computer is act as the gateway and will be placed 20 meters away from the ESP32. The Wifi module of ESP32 transmit the patient data at 20ms to the computer. From the data streaming dashbaord, the patient data is updated every 10 seconds, allowing medical staffs to have a real-time patient tracking.

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