

Research Article

The implementation of an Internet of Things-based system for asthmatic oxygen level warning, case study: KAMONYI district

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Abstract: Asthma is a long-term respiratory disorder that millions of people experience around the world and control is needed in order to avoid life-threatening attacks due to rapid changes in the oxygen saturation within the blood. However, most patients, and especially children, do not have access to such real-time systems that could result in timely alerts at the time of oxygen desaturation incidents, despite recent technology in health monitoring. In this study, we have the design and implementation of oxygen level warning system using IoT, which is specific to asthmatic persons. It integrates a MAX30102 SpO2 sensor, NodeMCU, and a GSM module to conduct a continuous monitoring process and automatically message in the form of SMS in the event of a low oxygen saturation level that exceeds the critical level. To determine the responsiveness and reliability of the prototype, little virtual care settings as well as the real healthcare settings were used to test the prototype. The final outcomes revealed that the system was able to correctly identify oxygen falls, immediately respond and provide alerts with minimal or no response time at all. The opportunity of real time remote monitoring was created with cloud integration minimizing the need to make constant physical observation. The results present the possibilities of the IoT-based solutions in the improvement of respiratory health management with the help of affordable, scalable, and accessible technology.

Keywords: Asthma, IoT, Oxygen Saturation, MAX30102, ESP8266.

1. Introduction

1.1 Background of the study

Asthma is the most common chronic condition especially in children worldwide. It affects daytime activities, sleep and school attendance and causes anxiety to parents, families and other carers. The asthma diagnosis level and management globally still need substantial improvement [1-2]. From infancy to the teenage years, there are age-specific challenges, including both underdiagnosis and overdiagnosis with stigma-related barriers to treatment in some cultures and in adolescents. Guidelines are increasingly evidence based, but their impact on improving outcomes has been negligible in many parts of the world, often due to lack of implementation. New thinking is needed to enable substantial improvements in outcomes.

The lack of research studies on respiratory diseases in Rwanda leads to minimal availability of asthma statistics. Research was made and the statistical results from East African neighbouring countries shows increasing asthma cases that become more common in urban locations [3-4]. 1500 students from a total of 27000 participants across Uganda and five other African nations the research revealed most common asthma symptoms, whereby Less than a



third of the patients that received medical diagnosis confirming asthma although symptoms existed. The lack of proper diagnoses occurs primarily because people have restricted healthcare control and limited awareness about respiratory problems and insufficient diagnostic equipment

The project originates from an urgent requirement to implement an internet of things-based system for asthmatic oxygen level warning which identifies crucial oxygen level decreases in asthmatic individual while generating prompt notification alerts. The absence of an immediate local alert system accompanied by effective caregiver notification methods for low SpO₂ readings constitutes the primary healthcare issue. The expanding number of IoT (Internet of Things) devices enables the development of smart systems which seek to close healthcare deficiencies [5-9].

The brain of the system functions with the ESP8266 microcontroller because it offers Wi-Fi capability at a budget-friendly rate. A pulse oximeter sensor will work together with the ESP8266 microcontroller to provide continuous SpO₂ level monitoring. A buzzer activation occurs when the oxygen saturation indicators reach 90% or when SPO₂ measurement reaches 60 millimetres of mercury. These conditions prompt immediate notification to use inhalers. The system contains a buzzer paired with an integrated global system for mobile communication (GSM) module which sends immediate SMS alerts to caregivers together with healthcare providers. The system ensures prompt access to assistance and monitoring through its operation even when the child is unattended or outside view.

This research aimed to create an effective system that remains easy to operate and responds quickly to improve asthmatic child patient safety. The project combines live alerts with remote broadcast notifications and monitoring logs so caregivers obtain essential tools to act before emergencies occur [10]. The system provides children with independence through monitoring features that maintain constant accessibility to help. The purpose of this research goes beyond showing technical feasibility because it showcases how budget-friendly IoT solutions enable healthcare support between developing and developed countries.

Rwanda together with numerous other African nations experiences increasing environmental pollution while these conditions trigger more cases of asthma. Asthma burden continues to increase because of the pollution; people experience in urban areas including air contaminants from vehicle activity and industrial sources and domestic indoor pollution. The numbers of Rwandan asthma patients who remain untreated and without proper diagnosis will increase throughout the next years unless there are effective prevention methods. Asthma exists at common rates throughout Africa because of widespread incidence of human immune virus (HIV) together with tuberculosis (TB) infections and pollution exposure. The observed high death rates appear to stem from the scarcity of necessary medicines during these times.

Asthma functions as a significant chronic illness throughout Africa since it impacts numerous millions of individuals. the 2019 statistics show that 13.2% of people within the age group of 5 to 69 years experienced wheezing whereas diagnosed asthma affected 11.3% of the population. Population areas tend to experience elevated asthma risks because of environmental contamination together with biological substances and alterations in everyday life. Adequate asthma management systems are missing in numerous nations which results in patients needing hospital admission and fatality. Human activities through industrialization and deforestation increase the amounts of dust along with smoke and pollen reached by humans. poor healthcare services coupled with inadequate air quality control measures will drive asthma cases upward.

At present asthma continues as a significant international public health issue that impacts hundreds of millions of persons scattered across the world. The worldwide prevalence rate for

wheezing among people aged 5 to 69 years reached 11.5% resulting in about 754.6 million affected persons in 2019 [11-14]. A diagnosis of asthma at any point in life existed in 9.8% of people which resulted in an affected population of 645.2 million people worldwide. According to the World Health Organization (WHO) asthma-related deaths reached a total of 455,000 in 2019 with most victims located in developing nations. Asthma impacts people from both childhood to advanced age groups because age provides higher vulnerability to asthma attacks.

1.2 Problem statement

Asthma attacks become fatal when patients lack proper reactions to oxygen depletion. The existing asthma patient monitoring devices do not include efficient alert systems through buzzers which notify both patients and caregivers about developing conditions. The devices also produce ineffective connectivity with current communication systems. A delayed warning system to caregivers causes the patient to face prolonged medical dangers. The patient's health condition becomes endangered when intervention does not happen right away. The implementation of an internet of things-based system for asthmatic oxygen level warning stands vital because it needs to provide instantaneous notifications about oxygen decline.

Healthcare institutions need to develop an IoT (internet of things) system that provides continuous oxygen level monitoring. Live measurement of patient oxygen saturation through the system led to rapid notifications whenever saturation levels descend into dangerous ranges. The system must trigger alerts which caregivers and medical professionals receive so they can take fast action and avoid health complications. The system must achieve rapid intervention because it works to minimize asthma attack risks. The study aims to create infrastructure which collects real-time information through instant communication capabilities. The system achieves its goal of patient safety enhancement with fatal outcome reduction through real-time information provision.

1.3 Objectives of the study

1.3.1 General objective

The primary objective of this study is to implement an internet of things-based system for asthmatic oxygen level warning that provides real-time alerts for low oxygen levels in asthmatic patients.

1.3.2 Specific objectives

The specific objectives of this implemented project are:

- To develop a system that uses sensors to monitor the oxygen levels of asthma patients.
- To use a buzzer to notify the patient themselves to avoid further negative effects.
- To integrate the sensors with a web-based platform for real-time data display.
- To use cloud storage for storing both real-time and historical data.
- To integrate a GSM module for sending notifications to designated phone numbers.

1.4 Research questions

Throughout the analysis of the project to be implemented there was primary questions to be asked so as to decide which functional or non-functional requirements are required such as:

- What are the necessary design requirements for developing sensor technology which monitors the oxygen levels of asthmatic patients?
- The effectiveness of using buzzer alerts as a notification system when asthmatic

- patients encounter low oxygen levels requires evaluation.
- The project requires investigation into possible methods for integrating sensor inputs into an internet-based system that shows live data and enables user interaction.
 - A strategy exists for cloud storage to handle real-time and historical oxygen level measurements.
 - What would be the most effective method of adding GSM technology to trigger precise and immediate alerts to medical caretakers and associates?

1.5 Research hypotheses

There are five main points that comprise the research hypotheses of this study. To begin with, the spO2 level of asthmatic patients could be effectively monitored in real-time with the help of embedded sensors with the help of the IoT. Second, the impact of local buzzer sounds on prompting asthmatic patients to respond faster within a condition when oxygen levels start to go down. Third, caregivers can be made aware, by using a web-based display of data regarding the level of oxygen. Fourth, the local server offers a secure process that users can retrieve real-time and archived data of oxygen levels by using the MySQL database storage and MQTT. Lastly, the GSM module that will be embedded to the system will be fast and accurate in transmission of alerts to the key contacts that are essential in instances of emergencies.

1.6 Choice of the study

This project with title “implementation of an internet of things-based system for asthmatic oxygen level warning” focused on monitoring the health of asthmatic individuals based on blood oxygen saturation level measuring module which is saturation of peripheral oxygen (SpO2) and it is in that case the system is advanced in order to allow users to take an immediate action especially young individuals who will listen to the buzzer and use the inhalers or look for it before relocating to a safer spot then, later the observing institution, hospitals or other health centres can take actions based on the performance of the patient within a particular period of time.

1.7 Significance of the study

The system design proves highly useful for especially asthmatic children because it delivers continuous monitoring of their oxygen levels in real time. The constant monitoring system enables fast detection of oxygen level decreases thereby enabling patient to react first by using a pump or look for it. Hospital emergency response teams will obtain quick alerts to prevent severe asthma attacks alongside possible medical situations. The research adds to the increasing collection of studies about IoT healthcare applications by demonstrating the ability of intelligent technology to enhance both patient protection and overall wellness. Once published the research findings has established a base to develop novel remote health monitoring systems for additional advancements in this technological field.

1.8 Delimitation of the study

The study implements ESP8266 along with pulse oximeter sensors, GSM modules and a local server as its fundamental technological elements. The research selected these components because they represent a cost-effective and uncomplicated solution that academia can easily access. The selection mechanism omits higher-end solutions which include long range wide area network (LoRaWAN) along with Bluetooth Low Energy mesh networks and AI-based predictive

analytics because they possess greater expense. Multiple powerful technologies would make the study exceed its current limits and available funding potential. This project does not include the aspect of real-time live SpO₂ data streaming in its scope. Periodic data logging remains the sole functionality of the system since it provides trend analysis capabilities instead of delivering medical-grade continuous monitoring.

1.9 Methodology of the study

This research methodology details how the study was investigated by specifying research design and sampling methods together with target population elements and information gathering techniques and analytical methods. The study development process relies on an algorithmic and systems-based method to achieve structured development. The researcher collected data by reviewing numerous publications including academic literature and reliable websites particularly Google scholar to acquire essential details about IoT-based health monitoring systems.

The methodology enables system development using both hardware along with software components to create an accurate solution. Visual Studio Code served as the programming environment to develop web application interfaces but the application depended on PHP and MySQL tools to manage the system database including user data. Arduino IDE served as the platform to develop software for both the GSM module and buzzer and ESP8266 microcontroller before sending them to accomplish wireless data sharing.

1.10 Organization of the study

The study was organized into five chapters; chapter 1 has introduced the background of the implemented system, problem statement, objectives, and significance of the study whereas chapter 2 has been introducing the literature review: review of existing IoT-based healthcare systems and oxygen level monitoring technologies. Chapter 3 was showing the methodologies used while implementing the system such as detailed description of the system design, development or implementation. Next was chapter 4 that has elaborated the results and discussion as well as the presentation and analysis of the test results. Lastly, chapter 5 included the critical sections which are conclusion and recommendations which consists of summary of findings, limitations, and recommendations for future research.

1.11 Summary

The chapter presented the proposed development of an IoT-based solution to monitor the oxygen level in people with asthma to decrease the risk of the patients being exposed to accidents. It highlighted the increased number of asthma cases worldwide and in Rwanda, especially among the children, as a result of poor diagnosis, lack of awareness, and environmental pollution. The suggested system involves having a low-cost system comprising of the ESP8266 microcontroller, pulse oximeter, buzzer, GSM module, and cloud storage to sense and react to low oxygen. The given study also introduced clear objectives of the study, research questions, and hypotheses about real-time monitoring, alert mechanisms and system integration. It also made the methodology and structure of the research as an effective basis of the subsequent chapters.

2 Literature Review

2.1 Introduction

The implemented work reviews concepts within theoretical frameworks while defining essential terms linked to the research project. This aims to deliver beneficial information about theories and concepts helping to create "Implementation of an internet of things-based system for asthmatic oxygen level warning" as an IoT-based system. Additionally, the section details the utilized hardware as well as software and chosen programming languages that have been used to make this whole project come to life. The section includes keyword definitions together with an outline of the studied research domain.

2.2 Definition of key terms

2.2.1 Patient health

Through professional healthcare services the prevention of illness and disease management leads to both mental and physical well-being of patients [15-17]. The quality improvement of patient care stands as a vital objective for healthcare providers to reach excellent patient satisfaction. Patient health management methods lead to lower hospital returns rates while improvement medicine outcomes and better life quality. Patient health results significantly benefit from the implementation of contemporary medical technology together with distance patient observation systems. The implementation of IoT in healthcare improves operational effectiveness and efficiency further.

2.2.2 Monitoring system

The monitoring system helps users to receive data through systematic information processing and dissemination and processing operations. The system allows determining patterns through measured data collected from the field. Real-time collected data and analysis through monitoring systems help both decision-makers and projects teams execute their work effectively. Efficiency benefits occur from information exchange between system actors. Such systems serve to track performance as they help sustain quality standards and enhance every project outcome. The project cycle management incorporates monitoring systems which use feedback analysis for continuous improvement assessment [18].

2.2.3 Internet of things

The Internet of Things (IoT) operates as a connection between various computing devices along with mechanical and digital machines as well as objects and animals and people. Every device possesses a dedicated UID system for network data transfer actions that do not require human control. The Internet of Things technology extends its applications throughout various sectors which include healthcare institutions and agricultural settings and urban development projects. Modern technology advances significantly because IoT processes real-time data collection capabilities [19-20]. IoT benefits medical services by letting physicians check patients remotely while supporting patients through early warning systems and enhanced healthcare results from sharing instant data exchanges.

2.3 Tools used

2.3.1 Esp8266 microcontroller

The ESP8266 microcontroller operates as an open-source device that contains dual-core processing capability and integrated Wi-Fi and Bluetooth functions [21-23]. Through its numerous I/O pins the ESP8266 sustains digital and analogue circuitry and pulse width modulation (PWM) outputs allowing users to control hardware in an efficient manner. The microcontroller includes an integrated automatic voltage tension controller for stable operation. Program data storage in the ESP8266 microcontroller uses the available 4MB flash storage and 520KB SRAM and it can also save data to external storage options. Through its multiple protocols of UART and SPI together with I2C the microcontroller achieves maximum clock speed of 240MHz

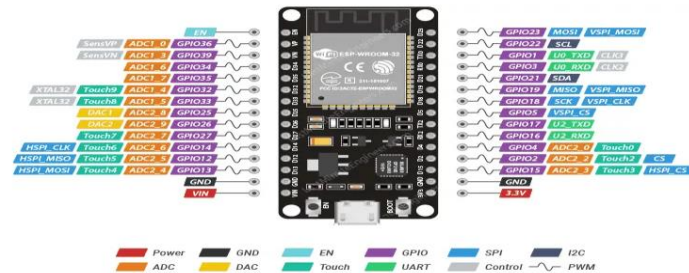


Figure 1: Esp8266 microcontroller

Table 1: Microcontroller features and specifications

Features	Specifications
Microprocessor	ESP-WROOM-32 32-bit
Operating voltage	5V
Input Voltage	7-12V (recommended)
Digital I/O pins	34 (GPIOs)
Analog pins	16 channels
Flash memory	4MB
SRAM	520KB
EEPROM	1KB
Clock speed	240MHz

2.3.2 Max30102 sensor module

The pulse rate sensor serves as a hassle-free heart rate sensor which operates specifically with Arduino systems. The pulse rate sensor becomes a staple tool for students among artists and athletes and developers to incorporate live heart-rate readings in their projects. Survey developers can access an open-source display application to see their heart rate data through real-time visualizations [24-28]. The sensor establishes itself as an optimal solution for clinical use in analysing cardiovascular functioning and fitness patterns. The pulse rate sensor in this project functions to track patient heartbeats in order to deliver precise and timely warning alerts. A real-time health monitoring system functions effectively because of its vital role in this.

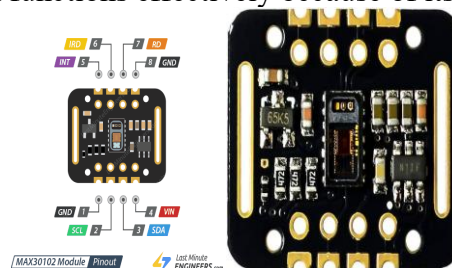


Figure 2: Max30102 Sensor

2.3.3 Maximum heart rate among asthmatic patients

Table 2: The range of heartbeat per minute according to age

Age	Average Maximum Heart Rate, 100%
Newborns	100 to 205 bpm
20	200 bpm
30	190 bpm
40	180 bpm
50	170bpm
60	160 bpm

Note that these are simplified whole-number estimates: $HR_{max} = 220 - \text{age}$).

Maximum heart rate (HR) can be estimated in the following standard way: $HR \approx 220 - \text{age}$ (years) This is population average and it is offered to those having asthma, as there is no independent reference of an asthma specific max -HR within the current studies. This formula usually offers standard deviations of $\pm 10-12$ bpm so, 95 percent of the people will have an estimate within $\pm 20-24$ bpm of the estimation. Asthma drugs (such as 2 beta-adrenergics) have only small effects on heart rate, but do not meaningfully reduce the maximum heart rate capacity, as measured in a genuine max-effort test. There are no specific values of max-HR in the case of asthmatic people- the rule of $220 - \text{age}$ is still valid. also note that they are the same in the populace with asthma as of this year 2025, and have the usual age-related upper limits of heart rate in heart rate max and body-to-body variations (~ 12 bpm).

2.4 Average maximum and normal resting heart rate in newborns

Table 3: Heart rate in newborns

Age Group	Normal Resting HR (bpm)	Approximate Max HR (100% effort)
Newborn (0–1 mo)	100–180 bpm	$\sim 180-200$ bpm
Infant (1–12 mo)	100–160 bpm	$\sim 190-210$ bpm
Toddler (1–3 yrs)	90–150 bpm	$\sim 190-200$ bpm

Babies and infants don't follow the " $220 - \text{age}$ " formula which is directed toward grown-ups and kids beyond the age of 12. Instead, their heart rate guidelines in their heart rate norms are based upon clinical observations and pediatric guidelines, not max-exertion formulas.

2.4.1 Buzzer module

The buzzer module functions as an easy digital output device which serves to notify people when activated. The module produces sound alerts after receiving triggers which makes it appropriate for embedded systems that need real-time notifications. This project selects a buzzer instead of visual indicators because it provides fast response capabilities with simple connection to microcontrollers [29]. Due to its energy-efficient nature and reliable operation the buzzer module works perfectly as a component for IoT-based alert systems. The project utilizes the buzzer as an essential signalling element to warn users about abnormal conditions enhancing their awareness leading to prompt safety responses.



Figure 3: Buzzer module

2.4.2 Esp8266 board

The ESP8266 board functions using the ESP8266 microcontroller because this component acts as the central processor for the complete system [30-31]. The development board contains a dual-core processor which provides strong performance capabilities and integrated Wi-Fi and Bluetooth capabilities. Each ESP8266 board model comes with a 32-bit architecture that supports 520KB SRAM memory and between 520KB and 4MB Flash memory capacity. The ESP8266 board provides operations for complex processes and sensor utilization and network connections alongside reduced power usage.



Figure 4: Esp8266 complete board

2.4.3 GSM module

The GSM module performs remote communication tasks through mobile network technology by using hardware devices. The system operates as an electronic phone system that needs a SIM card to connect to networks [32-33]. The serial interface of GSM modules functions at TTL-level which allows direct connection to microcontrollers. IoT applications frequently use these modules for alert notifications through SMS messages and both data exchange operations and distant system surveillance. Through this project the GSM module delivers real-time oxygen level alerts to patients while notifying their caregivers efficiently with critical condition updates.



Figure 5: Sim8001 module

I organized the pins into groups which contained related functionalities.

- Four power pins exist on this board consisting of one VIN pin together with three 3.3V pins. You can power the ESP8266 components through its VIN pin as long as you supply a regulated 5V voltage. The 3.3V pins function as the regulated voltage outputs produced by the built-in onboard regulator. The five pins allow users to power external elements with voltage. Among the components of the ESP8266

NodeMCU development board,

- The GND pin functions as the ground connection. Through I2C Pins programmers can easily connect diverse I2C sensors and attached peripherals for their projects.
- This device supports both operating as I2C Master and I2C Slave. Software commands can execute I2C interface operations while,
- The I2C clock operates at a maximum speed of 100 KHz. The I2C clock frequency must operate at a speed greater than the lowest possible clock frequency of the slave device.
- The ESP8266 NodeMCU possesses 17 GPIO pins available for I2C, I2S, UART, PWM, IR Remote Control, LED Light, and Button control through program actions. System users can choose between internal pull-up or pull-down configuration or leave the GPIO digital ports in high impedance mode. The device operates as an input with optional settings for edge-trigger or level-trigger operations that produce CPU interrupt signals.
- The NodeMCU features a 10-bit precision SAR ADC as its built-in channel. ADC performs the power supply voltage checks on VDD3P3 and the testing of input voltage at TOUT to implement these two functions. Both procedures cannot be executed concurrently.
- ESP8266 NodeMCU contains two UART interfaces known as UART0 and UART1 offering asynchronous communication methods through RS232 and RS485 protocols at maximum speeds reaching up to 4.5 Mbps. The UART0 pins which include TXD0 and RXD0 together with RST0 and CTS0 are designed for communication use. It supports fluid control. The single data transmit signal found on the UART1 (TXD1 pin) normally serves for printing log operations.
- The ESP8266 NodeMCU has two serial peripheral interfaces named SPI and HSPI that can work as slave or master devices. The SPI modules of ESP8266 support the functionality of several general-purpose SPI features including various transfer timing modes and high-speed operation at 80 MHz rate and 80 MHz divided clocks with up to 64-byte FIFO buffers. The SPI format transfer operates under different timing modes. The system supports operation at 80 MHz and runs divided clocks from 80 MHz. up to 64-Byte first in first out (FIFO)
- The SDIO feature of ESP8266 allows SD card direct connection through secure digital Input/Output Interface pins that operate at 4-bit 25 MHz SDIO 1.1v level and 4-bit 50 MHz SDIO 2.0v level. A four-channel pulse width modulation (PWM) control system exists on the board through its Pulse Width Modulation pins.
- The pulse width modulation tool functions through programming commands to control digital motor and light emitting diodes (LED) performances. This device enables PWM frequency control from 1000 μ s to 10000 μ s producing output ranges from 100 Hz to 1 kHz.
- The ESP8266 receives its control functions through these particular pins. Three control pins are present on this device which include Chip Enable (EN) pin and Reset (RST) pin as well as WAKE pin. Activating the ESP8266 chip becomes possible through applying HIGH voltage to the EN pin. Minimum power consumption happens when the EN pin is in the LOW position.

2.5 Comparison with related work

Relative to similar IoT-based health monitoring systems, this project achieved practical goals with fewer resources. Unlike advanced systems that integrate ECG, body temperature, and motion sensors with real-time analytics and historical data storage, this implementation focused on simplicity and cost-effectiveness. The inclusion of GSM alerts and the Blynk Cloud interface marks an improvement over basic offline oximeters typically used in home care.

2.5.1 Error analysis and limitations

Despite its functionality, the system exhibited limitations. Inaccurate SpO₂ readings occasionally resulted from poor finger placement or motion during measurement, which is a common issue in photoplethysmography-based devices. GSM signal fluctuations led to delayed or failed message delivery. Environmental conditions such as lighting and ambient temperature also influenced sensor consistency. Power management required frequent recharging, affecting the system's reliability for continuous use.

2.5.2 Summary

The chapter has revised the major ideas and instruments associated with the creation of an IoT-based system to monitor the level of oxygen in asthmatic patients. It described terminologies such as patient health, monitoring system, and used the Internet of Things and laid the theoretical foundation of the project. Other critical hardware that the chapter discussed include the ESP32/ESP8266 microcontrollers, MAX30102 sensor, GSM module, and buzzer, which are all capable of supporting real-time health alerts. The data on the heart rate at different ages was also provided focusing on infants and asthmatic patients as especially important data to claim accurate sensor measurements. On the whole, the chapter summarized technical background and elements that render the suggested system possible and successful.

3 Research Methodology

3.1 Introduction

This involves the applicable processes or approaches needed to hunt for data, select what to use, handle it, and analyse it. It makes sure data is properly gathered, analysed, and shared so that the studied results are realistic. A number of techniques were used in this project to establish an IoT system that reports whenever oxygen 2levels in asthma patients drop. The choice of methodology emphasized how simple and accurate it would be to use, along with how well it suited the main research purpose. Methods used consisted of interviews, study of papers, and hands-on observation to identify any problems within healthcare and its technology.

3.1.1 Case of study

The case study was conducted in KAMONYI district in Rukoma hospital in Remera at the Southern Province of Rwanda where numerous patients are affected by asthma. At the moment, the hospital does not have systems to check oxygen levels of patients in real time and this hurts the hospital when it responds to an emergency. Current approaches are based on manual testing, which is time-consuming and has a high risk of drawings errors. This leads to

grave dangers even when oxygen concentration decreases without quick remedial measures particularly to the children.



Figure 6:Case of study

3.1.2 Methodology approach

The researchers used qualitative and exploratory approaches when they selected the methodology. The goal was to explore issues with asthma monitoring and find a proper solution through technology that fits daily life. Information on both IoT technologies and healthcare was first collected by doing library research. The theoretical basis of the system was built through use of books, online journals, and academic literature. Inputs from colleagues and specialists made a big difference while I worked on the project. Because of technical skills and stakeholder views, the final solution was both original and possible to carry out.

3.1.3 Data collection techniques

The process of data collection is made to gather knowledge from several sources to better understand a particular research problem. It helps decide on important actions and check if the study results are accurate. To complete the project, we sought to understand what healthcare providers and patients have to say about their current experiences with monitoring asthma. Various techniques were used, including watching how work is done, checking documents, and interviewing people, to get a rounded idea of the present system's shortcomings. They revealed particular issues that formed the basis for the development of the IoT solution. Every technique was important for helping the system fit the needs of real users.

3.2 Observation

Observing as a method of gathering data means studying current behaviours in their natural places without making any changes. In this study, focus was on watching how the role of a healthcare doctor is carried out, giving special attention to managing patients with asthma. How much time it took for consulting, examining patients, and the current capacities of monitoring patients were noted. What I learned proved that there were serious flaws in the old way of healthcare. Noticing patients with oxygen issues led health professionals to decide on an alert system for low oxygen levels. Because the researchers saw the difficulties, they made a system that is well-matched with the current healthcare routines.

3.2.1 Interview

Staff members at Rukoma Hospital and patients were among the people interviewed. Through such talks, we were able to get a good idea of how effective today's asthma treatments are and what their weaknesses are. Health experts recognized that it is difficult to detect low

oxygen levels in time and that health services should have more constant monitoring devices. Among the experts, Mrs. NIZEYEMARIYA Leonille pointed out some of the daily difficulties doctors and nurses meet when working with patients. These interviews showed that we need a system that quickly detects and shares news of changes in oxygen levels. Interviews made it possible to match the design of the system to what clinicians and patients needed.

3.2.2 Requirements analysis phase

The purpose of the requirement analysis phase, also called feasibility study, is to learn about the system's expectations as well as its boundaries. During this period, I made certain to identify the functional and the non-functional requirements of the proposed IoT-based monitoring system. It was necessary to design the system so that it could acquire 2data, alert the user in real time, and use GSM and local Php server to communicate. They considered aspects of non-functional requirements, for example, the system must not fail, must be economical, and should be user-friendly. The research team studied the current routines to see the issues with them and how the new approach could solve them. It was determined whether the device consumes a lot of power, if the network is reliable, and if parts are compatible. This part of the process ensured that the technical and operational features would be built on solid ground.

3.2.3 System design phase

At this point, gathered needs were organized into a layout, so every element of the system meets what users expect. Through making sketches and flow diagrams, the system's architecture was described to show how the components connect. A lot of care was placed on combining the MAX30100, ESP8266 module, and SIM800L to handle data transfer and alarm sending. Models for interacting with users were developed so that people can easily use the interface. At this point, it was necessary to consider if the system could grow, be easily looked after, and be improved when needed. An ordered model was put in place so that mistakes did not happen in implementation and the system always remained consistent.

3.3 System development methodology

System Development Life Cycle (SDLC) was also used as a formal system implementation management. It is composed of specific stages such as planning, analysis, design, development, testing, deployment and maintenance. Several SDLC models were taken into consideration namely the Waterfall, Spiral, and V-shaped models. Agile m2odel has however been chosen because of its iterative and user centred design. Agile enables a process of continuous integration, regularly recurring feedback and adaptability to changes in requirements. It had these features which made it adaptable to changing requirements of this health monitoring project. Modular testing is also supported by Agile, which enhances system dependability as well as its capacity.

3.3.1 Agile model

Agile model incorporates development in increments and tests many times; hence it fits very well in projects that often require changes. The advantages of this methodology lay in the fact that at the conclusion of every iteration, or sprint, a working system prototype was delivered, and that prototype was compared against a series of pre-defined requirements. Agile encourages collaboration among the developers, stakeholders and end-users and there is always validation of deliverables. Features such as buzzer alerts, GSM messaging and real-time data visualisation

were designed and tried in a cycle. Repetition ensured faster solving of the puzzle as well as faster deployment of functional modules. This not only limited the risks but also ensured that the quality of software was enhanced since the issues were discovered at the lower phase of the developmental timeline.

I. Requirements gathering phase

Its requirements gathering stage involved finding the priority health risks that came with poor monitoring of oxygen in asthmatic patients in Remera Rukoma hospital. Medical personnel, IT and caregivers were some of the stakeholders consulted to learn about their needs and problems. The system requirements and objectives were well stated through discussions and observations. The key objectives were the real-time monitoring of the level of SpO₂ and BPM, notifying about any dangerous changes, and having simple access to the patient data. This stage also stipulated why a buzzer alarm was necessary and they would be alerted through SMS text messages to facilitate rapid response.

II. Design phase

In the design process the architecture of the IoT-based asthmatic monitoring system was organized in three vast layers namely the hardware layer (MAX30102 sensor, buzzer, GSM module, and ESP8266), software layer (Arduino IDE to program the firmware and PHP command to program the backend), and database layer (MySQL to store the readings of patients). Circuit designs and UI wireframe were created to represent how the system would be interacting. The most consideration was on the manner through which sensor data is going to be captured, processed, and transmitted to act in real-time as well as visualization. The design also saw to it that the doctors could keep track of the patients in an intuitive web dashboard easily.

III. Construction and iteration phase

In this step, development of the asthmatic oxygen level monitoring system took place in iterative procedures. Based on the Arduino IDE and ESP8266, developers wrote the program logic of the sensor MAX30102, the buzzer signal, phone notifications, and data broadcasting. At the same time, there was the integration of FMD and MySQL database to support the live readings and the patient records in the system. To make the web dashboard functional, it was upgraded in real-time charts, patient selectors, and language switching.

IV. Testing and quality assurance phase

A progressive testing was conducted after each milestone. Levels of oxygen were varied in terms of sensor accuracy and GSM alerts to establish that the responses must be made at the right time. The feature of the system to log the readings and display them properly in the dashboard was done. The platform was used under the interaction of doctors and simulated users to ensure usability and compatibility with stress testing to verify the system stability and data flow under the conditions of a high amount of user-derived data. Spotted bugs were quickly fixed and enhanced in subsequent release.

V. Deployment phase

The complete testing was carried out, and the last variation of the IoT-based asthmatic oxygen monitoring system was implemented in real time. The solution started receiving live SpO₂ and BPM patient data to issue an alert in case of critical levels. The presented buzzer and GSM module gave warnings to the patients and caregivers in necessary time. Automatic logging of data was done on the backend and readings in real time were available to the doctors on the dashboard. This was deployed to enhance the accuracy and response time of health monitoring in case of emergency.

VI. Feedback and continuous improvement

After deployment, the user feedbacks were obtained among the medical staff and testers at Remera Rukoma hospital. They contributed as their feedback allowed revealing the strong and weak sides of the system and its usability. The logic behind the alerts was improved and the navigation of the dashboard and language selection. Other ideas like mobile notification and wider sensor coverage were also recorded as upgrades. This feedback-informed process of refinement insured the system remain relevant and sensitive to the world of healthcare demands.

Table 4: Agile development methodology

Sprint	Duration	Activities Performed	Key Deliverables	Involvement	Validation
Sprint 1	2 weeks	Requirement gathering, defining architecture, planning development flow	List of features, system architecture draft	Individual (Developer)	Self-reviewed feature list and architecture
Sprint 2	2 weeks	Development of buzzer alert functionality, testing on breadboard	Buzzer module integrated and tested	Individual	Confirmed buzzer logic via test scenarios
Sprint 3	2 weeks	Implementation of GSM messaging module and message testing	Working GSM SMS alert prototype	Individual	Sent and received test SMS successfully
Sprint 4	2 weeks	Development of real-time data visualization interface local php server	Live dashboard showing temperature/Sp O ₂ data	Individual	Interface tested with real sensor data
Sprint 5	2 weeks	Integration of all modules (buzzer, GSM, sensors, dashboard)	Complete system prototype	Individual	Verified end-to-end functionality
Sprint 6	2 weeks	Debugging, performance optimization, final polishing	Stable and responsive system	Individual	Errors corrected and response time improved
Sprint 7	2 weeks	Final testing, documentation, and preparation for presentation	Final report and demonstration-ready system	Individual	System tested under project evaluation plan

3.3.2 Advantages of agile model

- Guarantees that fully functioning pieces of the system come early and often.
- Promotes effective coordination among stakeholders, developers and testers.
- Encourages adaptability with last moment alterations in requirements.

- d. Minimizes risk on the project by doing continuous integration and testing.
- e. Promotes dynamic planning and customer-oriented development.
- f. Enhances product quality through frequent technical review and feedback loop.
- g. Allows future-proof, modular expansion in subsequent versions or in case of an upgrade.
- h. Assists in making system features very close to practical applications.

3.3.3 Disadvantages of agile model

- a. Total cost and development time are hard to estimate in advance.
- b. Danger of undocumented development because of rapid iterations. (not recommended)
- c. not suitable to novice developers without decision making authority.
- d. Scope changes might occur frequently which may result to inconsistencies or delays.
- e. Larger, cross-functional teams need complicated coordination.
- f. Demands great dedication and participation of all stakeholders. Obligatory.
- g. Can lead to rework when early versions fail to go through proper validation.

3.4 Summary

In this chapter, the approach in conducting the research to come up with an asthma monitoring system based on use of IoT was described. It involved qualitative functions like documentation, observation, and interview as a way of determining the user requirements. Agile development model was selected as it was flexible and allowed getting buzzer alerts and GSM message features designed and tested in a step-by-step manner. Various steps of the SDLC were observed to maintain proper organization in planning and implementation.

4 System Design and Implementation

4.1 Introduction

The project focuses on designing and developing an advanced patient health monitoring system leveraging GSM technology. This system is engineered to track critical health metrics, including heartbeat, and ECG readings, in real-time. Sensor-collected analogue data is processed by a microcontroller, which then disseminates the information to an LCD display and a GSM module concurrently. Through GSM networks, this data is transmitted seamlessly to healthcare providers, enabling remote monitoring. A key feature of this system is its dynamic database, accessible to doctors via a dedicated application on computers or mobile devices. The database updates continuously as the GSM receiver module feeds new patient data into the system.

To enhance safety, the system includes an alarm mechanism that activates when any parameter exceeds predefined thresholds. Unlike conventional systems, this project integrates IoT infrastructure, eliminating manual interventions and improving accuracy. This IoT-based framework represents a significant leap from traditional methods, which often rely on fragmented or non-automated processes. By automating data collection and transmission, the system reduces human error and ensures timely medical responses. The integration of GSM also allows scalability, making it viable for large healthcare facilities or rural areas with limited connectivity alternatives.

4.2 Analysis of the existing systems

Historically, hospitals relied on handwritten records for patient admissions and monitoring, a method prone to delays and inefficiencies. While the manual system reduced costs for patients, its sluggishness often compromised urgent care delivery. The new IoT-based system addresses these gaps by digitizing data flow from admission to diagnosis. For instance, real-time sensor data eliminates the need for manual vitals logging, freeing staff to focus on critical tasks. The automated alarm system further ensures prompt attention to abnormal health parameters; a feature absent in traditional setups. Beyond speed, the digital approach minimizes paperwork, cutting administrative burdens and storage costs. Moreover, the legacy system's cost-saving benefits are preserved, as IoT adoption reduces long-term operational expenses. By transitioning to this model, hospitals can achieve a balance between affordability and cutting-edge care, ultimately enhancing patient outcomes and institutional reputation.

4.3 System prototype

The displayed Fig 8, the prototype of the asthmatic oxygen level monitoring system is a hardware/software combination of the possible core functionality. It is based on a microcontroller NodeMCU ESP8266, collecting SpO₂ and BPM values on a MAX30102 sensor. The system comes with a SIM800L GSM module that has been used in the event of a critical condition whereas SMS messages has been used to alert the patients and to a buzzer that also has been used to notify the patient immediately. The entire system gets powered with an external 4.2V supply. The ESP8266 also interacts with a personally designed web dashboard, on which doctors can observe the data of their patients live

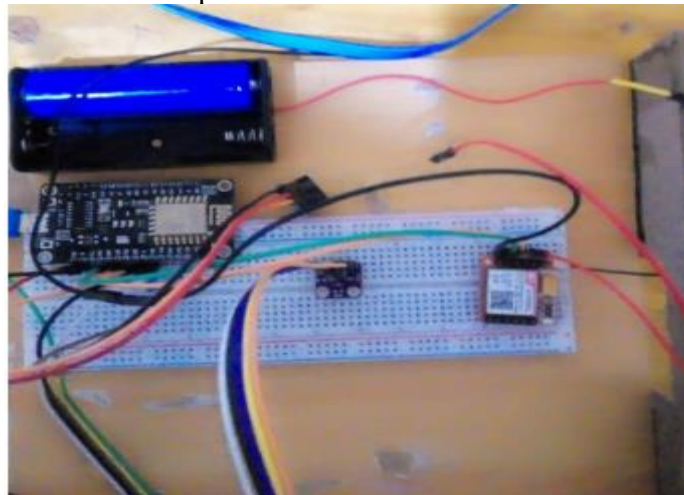


Figure 8: Hardware prototype

4.3.1 Patient monitoring system data transmission

The circuit design of the IoT-based Asthmatic Oxygen Level Monitoring System using the MAX30100 pulse oximeter is relatively straightforward but highly functional. The key goal of the design is to continuously monitor the oxygen saturation (SpO₂) and heart rate of an asthmatic patient, and provide real-time warnings in case critical levels are detected. To achieve this, the system employs an ESP8266 microcontroller as the main processor. The MAX30100 sensor is connected via the I2C communication protocol, with SDA and SCL pins connected to the appropriate GPIO pins on the ESP8266.

The SIM800L GSM module is connected through a SoftwareSerial interface, enabling it to send SMS alerts independently of the Wi-Fi connection. A buzzer is used to provide local

audible alerts whenever abnormal oxygen levels are detected. The entire circuit is powered by an external 3.7V lithium battery, with voltage regulation circuitry ensuring safe operation of each component. Data is transmitted to a PHP-based server as well as local Php server for live monitoring. No LCD display is used in this project, since mobile-based and web-based visualization offers greater convenience for caregivers.

4.3.2 System algorithm

The algorithm of the system is the logic process by which the IoT based monitoring system works step by step. It starts by initializing the sensor and connecting to it and then reading SpO₂ values and BPM values repeatedly. When an abnormal oxygen level is detected, the algorithm alerts the buzzer and issues emergency messages through GSM module and doctors' dashboard.

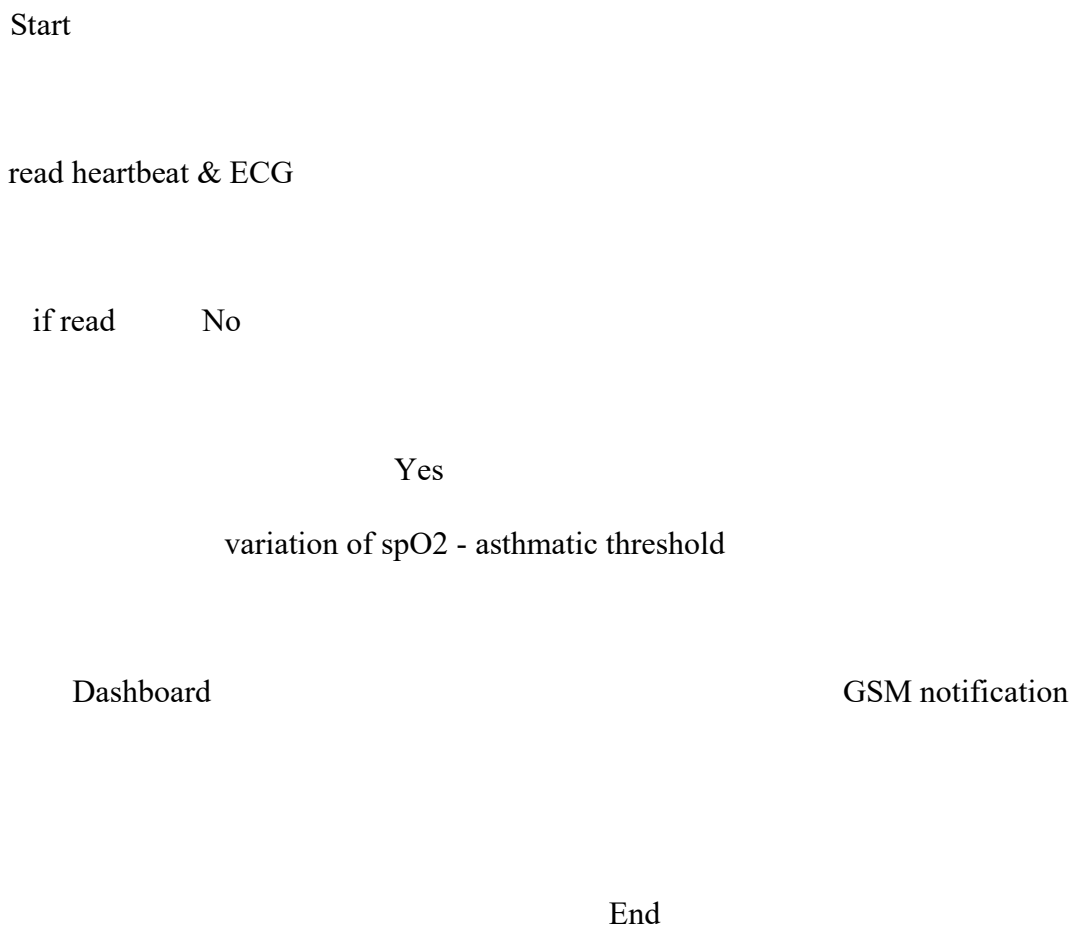


Figure 9: Flow chart for asthmatic monitoring

4.3.3 Block diagram

In the development of any embedded IoT project, the design stage is one of the most crucial aspects, as it dictates how different components interact and how the final system operates. In this project, titled "Implementation of an Internet of Things-Based System for Asthmatic Oxygen Level Warning," the system is engineered to help caregivers remotely monitor SpO₂ and heart rate levels in asthmatic patients. It makes use of both MQTT server and

an offline SMS-based notification system (via SIM800L GSM module) to ensure that alerts can be delivered even in environments with unreliable internet.

The ESP8266 NodeMCU microcontroller manages sensor readings and connectivity, while the MAX30100 sensor provides the core biometric data: oxygen saturation and heart rate. When readings fall below a safe threshold ($\text{SpO}_2 < 92\%$), the system triggers a buzzer alarm and sends SMS notifications. Data is also logged continuously to a MySQL database hosted on a localhost server, allowing healthcare professionals to track long-term trends in patient health. By combining these technologies, the system ensures a robust and effective solution for monitoring asthmatic patients, especially in resource-constrained settings.

Max30100 sensor Dashboard

Microcontroller

GSM module

ATMEGA 328

Figure 10: System architecture

4.4 Internet connectivity

The Internet of Things functionality of the system is implemented through the built-in Wi-Fi module of the ESP8266, allowing it to connect to a local wireless network. Through this connection, the ESP8266 uploads live data to MQTT, where caregivers and healthcare providers can view patient information in real time using a smartphone application. Simultaneously, the ESP8266 sends HTTP POST requests to a MQTT server, which stores all readings in a MySQL database for historical analysis. This dual-path data reporting ensures that patient data is preserved even if one communication path fails.

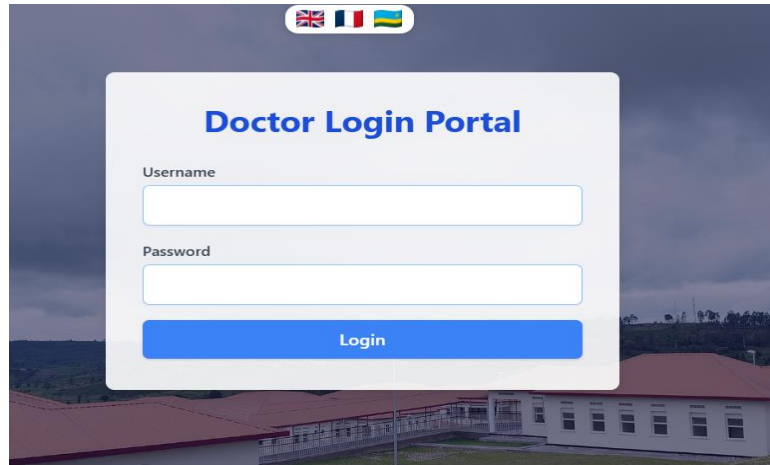
Moreover, in situations where internet connectivity is lost entirely, the SIM800L GSM module remains operational. It is programmed to send SMS alerts directly to pre-configured caregiver phone numbers whenever oxygen levels drop below the threshold. The inclusion of a local buzzer also ensures that the patient receives immediate feedback in such scenarios (Uzoka et al., n.d.). In this way, the system provides multiple layers of alert delivery and data redundancy, increasing its reliability for critical medical applications.

4.4.1 System software

I. Admin login

The system has a safe admin log in page where only the authorized personnel have access to sensitive health data and controls of the system. On successful authentication, the

administrators must be redirected to the main dashboard, in which they will be able to monitor the oxygen level of the patients, control the records, and act on critical alerts. The login system employs the session lean authentication to safe-keep user session throughout the use period. Such protection is fundamental in maintaining the privacy of the patient and data integrity as the system operates.



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Figure 11: Admin login portal

II. Admin dashboard

The administrators receive a centralized dashboard as illustrated in Fig.19 which is the primary control panel of asthmatic oxygen level monitoring system. This dash shows current health conditions of the registered patients including SpO₂ and BPM. It also gives permission to authorized medical personnel to direct patient record, show history alert, and export reports in PDF or CSV form. The dashboard has a responsive and clean design that facilitates speedy access to critical information and enables effective monitoring reports and making decisions

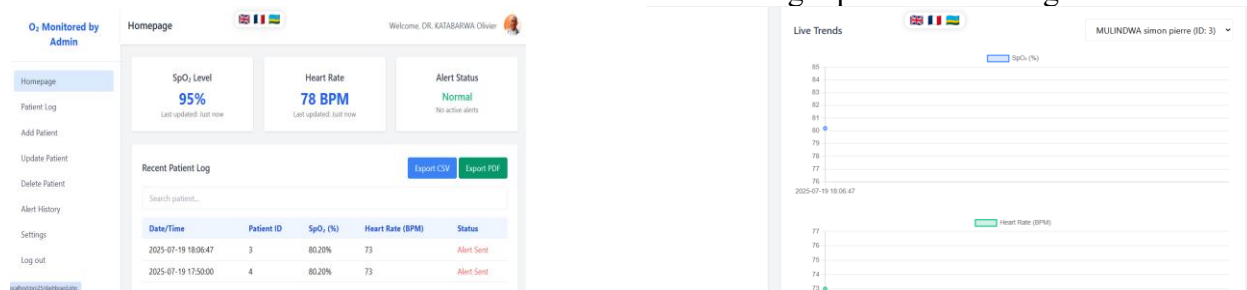


Figure 12: Admin dashboard

4.4.2 System usecase

In below figure 13, the use case shows the real-time monitoring of the oxygen level of asthmatic patients through the IoT-based system. In case the SpO₂ of a patient less than 90, the system, in turn, will immediately trigger the buzzer alarm and send SMS to caregivers or doctors using the installed GSM module. At the same time, the data is sent to a central server where it is stored and live monitored using a web dashboard. This ensures a warning as early as possible and rational decision making. The synchronized communication between the patient, device, GSM, and server would guarantee enhanced safety and response.



Figure 13: Usecase diagram

4.4.3 Database management system

The database management system (DBMS) plays a critical role in this project, providing a structured way to store and manage patient data over time. The server-side database is implemented using MySQL, accessed via a MQTT. It is designed to store detailed records of every sensor reading, including patient ID, SpO₂ value, heart rate, timestamp, and alert status. This schema supports robust querying and reporting, enabling medical personnel to generate trend reports and patient summaries (Wang et al., 2025).

The system architecture ensures that data is uploaded immediately upon each reading cycle, minimizing data latency. In the event of communication issues, the ESP8266 is programmed to retry uploads, ensuring that no data is lost. The database also enables healthcare providers to remotely access patient histories, making it a valuable tool for both acute monitoring and long-term disease management. It is optimized for use with mobile-friendly dashboards, ensuring accessibility even in low-resource environments.

4.5 Entity relationship diagram

The Entity Relationship (ER) diagram for this system models the relationships between core entities in the database. The primary entities include: Patient, Sensor Readings, and Alerts. Each patient may have multiple sensor readings recorded over time. Each reading may or may not trigger an associated alert, depending on whether abnormal values are detected. The relationships are modelled to support efficient retrieval of patient histories, identification of high-risk trends, and visualization of alert patterns. The ER diagram also supports the potential integration of the system into broader health information systems (HIS) in the future. This modular design ensures that the database can be expanded to include additional features such as caregiver profiles, SMS logs, and device calibration records as the project evolves.

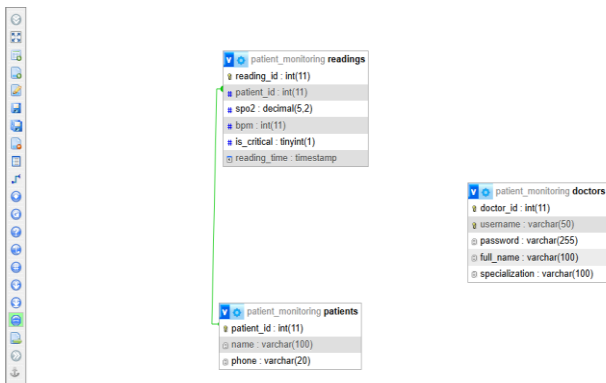


Figure 14: entity relationship diagram

4.5.1 Testing

Table 5: Test status

Activity	Test Status
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Reading SpO ₂ & BPM using MAX30100	Completed Successfully
Uploading data to MQTT server	Completed Successfully
Uploading data to MQTT server/database	Completed Successfully
SMS alert at low SpO ₂	Completed Successfully
Buzzer alert at low SpO ₂	Completed Successfully

Testing of the system was conducted under controlled conditions, simulating both normal and critical patient scenarios. Sensor readings were verified against known standards to ensure accuracy. Network connectivity was validated under different signal conditions to test system robustness. Alerts were successfully triggered and received by caregivers' phones via SMS and MQTT server. The system demonstrated reliable performance in all key functional areas, confirming readiness for further field deployment and validation in real-world settings.

4.5.2 Interpretation of results

The developed system effectively measured SpO₂ and heart rate using the MAX30100 sensor integrated with the NodeMCU ESP8266 microcontroller. During testing, SpO₂ values ranged between 93% and 99% for healthy individuals, while readings at or below 92% triggered SMS alerts. This threshold aligns with clinically accepted SpO₂ danger zones for asthmatic or hypoxic patients. Heart rate readings fell within normal physiological ranges (60–100 bpm), validating the accuracy of the sensor and its reliable communication with the microcontroller.

4.5.3 System performance and efficiency

The system responded promptly to critical values under controlled conditions. The average delay from detection to alert delivery was 5–7 seconds, demonstrating efficiency suitable for emergency alerts. The local MQTT server and user interface enabled seamless visualization of data, offering remote monitoring in real-time. Power was supplied via an external rechargeable battery, allowing several hours of operation. However, signal stability and battery drainage became limiting factors over extended periods, especially in GSM-poor regions.

4.6 Summary

The sensor is capable of monitoring the oxygen levels and the heart rate of asthmatic patients, the MAX30100 was fitted, and the ESP8266 microcontroller was used in designing the system so that alerts are emailed and relayed through buzzer in the case of severe conditions. Information is sent in real-time to MQTT storage server and a PHP-MySQL backend to be monitored and stored. It automates the alerting and logging of data unlike the manual system which is faster, reliable, and less prone to human error. There is Internet and GSM redundancy which keeps alerts even in low connectivity regions. The test of system corroborated correct sensor readings, ideal uploads of data and functioning alert mechanisms.

5 Conclusion and Recommendations

5.1 Introduction

This chapter outlines the conclusions drawn from the research and provides recommendations for future development and real-world application of the system. The system was developed to monitor blood oxygen levels in asthmatic individuals and send warning alerts via GSM when critical thresholds are reached. Its ability to function in real time and reliance on low-cost components make it practical and scalable for environments with limited access to

healthcare infrastructure.

5.2 Conclusion

IoT-based implementation of alarming asthmatic level of oxygen proved successful. It effectively was able to monitor vital signs, send prompt SMS notifications through GSM, and set forth real-time data via an easy-to-read interface. Despite the identified limitations 2including signal variability and power capacity, the system achieved its main requirements, and products it generated will help to introduce a beneficial patient early health warning system to manage respiratory diseases. Generally, the system illustrates the use of embedded technology, which can be used on a low-cost scale to implement patient safety and responsiveness during critical health circumstances.

5.3 Recommendations

Depending on the outcomes of the development and testing, the following feedbacks are suggested: first, to add other set of sensors like blood pressure sensors to improve the system efficiency with regards to complete health monitoring capabilities. Second, implementing a cloud-based health log service, which is payable is possible to track data about the patients on a long-term basis and make an analysis of the data received. Finally, developers in the future must upgrade the system to enable it to work with solar-powered charging to operate off-grid. All these improvements would make the system reliable, scalable, and practical in a variety of healthcare environments.

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