INTELLIGENT INTERNET OF THINGS (IOT) PATIENT DATA MANAGEMENT AND HEALTHCARE INFRASTRUCTURE MONITORING SYSTEM WITH ESP CONTROLLER

Dr. K. SRINIVASULU[1], RAGHAVA RAO KODALI[2]

[1]Associate Professor, Department of Electronics and Communication Engineering, Ellenki College of Engineering and Technology, Patelguda, Patancharu, Hyderabad, Telangana.
ksrinivasulu40@gmail.com

[2]M.Tech Student, Department of Electronics and Communication Engineering (Embedded Systems), Ellenki College of Engineering and Technology, Patelguda, Patancharu, Hyderabad, Telangana.

Abstract - A high demand for integrated systems capable of managing patient information and monitoring the status of healthcare infrastructure in real time has been generated by the fast expansion of smart healthcare technology. Manual patient identification, long wait times for medical records, and inadequate monitoring of environmental factors like humidity, temperature, and hazardous gasses are common problems in healthcare facilities. Hospital efficiency, patient safety, and the likelihood of medical & operational mistakes may all be negatively impacted by these constraints. In response to these issues, this study introduces an ESP controller-based Healthcare Infrastructure Monitoring & Data Management System that is Intelligently Internet of Things (IoT) based. In order to provide a cohesive smart healthcare platform, the suggested solution integrates RFID-based identification of patients with real-time environmental monitoring. Radio frequency identification tags are used to track patients and obtain related information such berth number and patient ID, while gas and temperature sensors constantly keep an eye on vital infrastructure conditions in the hospital. The ESP controller is responsible for collecting data, processing it locally, creating alerts, and communicating wirelessly with an Internet of Things server. When the system detects potentially dangerous situations, it will trigger a buzzer other control mechanism like a fan and provide the relevant patient and environmental data on a local LCD interface. Furthermore, all information is sent to an Internet of Things dashboard so that it can be accessed and monitored remotely. The suggested design enables effective hospital automation while simultaneously improving patient management, decreasing the likelihood of human mistake, and increasing environmental safety. When it comes to digital patient data management and smart healthcare infrastructure, the created system provides an affordable and scalable option.A high demand for integrated systems capable of managing patient information and monitoring the status of healthcare infrastructure in real time has been generated by the fast expansion of smart healthcare technology. Manual patient identification, long wait times for medical records, and inadequate monitoring of environmental factors like humidity, temperature, and hazardous gasses are common problems in healthcare facilities. Hospital efficiency, patient safety, and the likelihood of medical & operational mistakes may all be negatively impacted by these constraints. In response to these issues, this study introduces an ESP controller-based Healthcare Infrastructure Monitoring & Data Management System that is Intelligently Internet of Things (IoT) based. In order to provide a cohesive smart healthcare platform, the suggested solution integrates RFID-driven recognizing patients with real-time environmental monitoring. Radio frequency identification tags are used to track patients and obtain related information such berth number and patient ID, while gas and temperature sensors constantly keep an eye on vital infrastructure conditions in the hospital. The ESP controller is responsible for collecting data, processing it locally, creating alerts, and communicating wirelessly with an Internet of Things server. When the system detects potentially dangerous situations, it will trigger a buzzer and control mechanism like a fan and provide the relevant patient and environmental data on a local LCD interface. Furthermore, all information is sent to an Internet of Things dashboard so that it can be accessed and monitored remotely. The suggested design enables effective hospital automation while simultaneously improving patient management, decreasing the likelihood of human mistake, and increasing environmental safety. When it comes to digital patient data management and smart healthcare infrastructure, the created system provides an affordable and scalable option.

Keywords - Hospital automation, gas detection, temperature monitoring, ESP controller, RFID, intelligent health care, information administration, healthcare infrastructure monitoring, and the Internet of Things are all part of smart healthcare.

I. INTRODUCTION

Digital technologies are being used more and more in healthcare with the goal of enhancing the quality of medical services, the efficiency of hospitals, and the safety of patients. Healthcare administration in contemporary hospitals include not only the treatment of patients but also their identification, record access, tracking of beds or berths, environmental monitoring, and management of infrastructure safety. Patient identification while recording management are still handled by many healthcare facilities using largely manual procedures. This may lead to delays, human mistakes, and poor data synchronization. Meanwhile, air quality, humidity, and temperature are not often continually monitored in hospitals, despite the fact that they have a direct impact on patient comfort, medication storage, infection control, even staff safety.

In a healthcare setting, patient identification is a crucial procedure. Incorrect treatment, prescription mistakes, care delays, and ward or bed administration difficulties may result from patient misidentification. Quick access during crises is made more difficult in many hospitals because patient data are held via unconnected digital systems or manual input methods. A similar problem arises with infrastructure monitoring: it is frequently done via separate systems or with periodic human inspection, neither of which allow for real-time reaction to dangerous environmental situations like high temperatures or gas leaks. Hospital operational efficiency and proactive action are hindered by the absence of connection between infrastructure monitoring and patient information management.

Management, analysis, and monitoring of physiological indicators have been profoundly affected by the exponential expansion of the worldwide web of Things, or IoT for short, in healthcare. Traditional healthcare methods rely on patients visiting the hospital on a regular basis and doctors keeping close tabs on their health, which may lead to gaps in treatment and delays in diagnosing unusual occurrences. Health monitoring devices that are Internet of Things (IoT) enabled and wearable, on the other hand, may continuously gather physiological information including heart rate, temperatures, saturation of oxygen, hypertension, and activity patterns. Through real-time sensing as well as information transfer, these systems seek to improve prompt detection, streamline personal wellness monitoring, and facilitate remote patient supervision. This has led to a recent uptick in studies investigating topics including secure IoMT architectures for real-time healthcare applications, cloud-connected health monitoring systems, edge and fog computing for data processing, and sensors that wear on the body.

Research and development of Internet of Things (IoT)-based wearable health monitoring devices to continue vital sign observation has recently dominated the literature. As an example of how small wearable devices may continually collect physiological data and enable real-time monitoring, Madavarapu et al. presented HOT Watch, an Internet of Things (IoT)-based worn health monitoring system [1]. Emphasizing the significance of continuous sensing & linked healthcare communication for prompt medical observation, Chen and Sheng presented an innovative IoT-based vital signs monitoring system [2]. Connected wearable platforms may enhance personal healthcare tracking including remote patient supervision, as Ahmed et al. highlighted in their discussion of wearable healthcare including continual vital-sign tracking with IoT integration [4]. A intelligent healthcare system built on cloud computing and wearable Internet of Things sensors was also introduced by Rghioui et al. [7]. In this system, patients have their data gathered via their wearable devices and transferred to the cloud for ongoing monitoring and control. Taken as a whole, these studies show that wearable IoT devices are a viable option for ongoing health evaluation, particularly for those who need constant monitoring and for those who are interested in preventative healthcare and fitness tracking [1, 2, 4, 7].

Making wearable monitoring systems flexible and scalable is another key trend in the literature about real-time healthcare processing information and intelligent analysis. Matsumura et al. demonstrated that edge computing using multimodal wearable sensors may increase the efficiency and minimize latency of data health interpretation [3] by proposing a real-time private medical data analysis framework. By integrating fog & cloud computing with wearable sensors, Hassan et al. created a powerful health surveillance system that reduces network overhead and helps doctors make decisions faster [12]. By bringing computational intelligence closer to the sensing layer, these studies imply that smart health analytics is replacing traditional healthcare monitoring methods such as data collecting. This will allow for more efficient system functioning, quicker warnings, and decreased reaction time.

Wearable sensing's function in smart medical settings and the larger architecture of healthcare systems enabled by the Internet of Things have been the subject of several research and evaluations. In order to remotely observe patients, Rahman et al. [8] suggested an Internet of Things (IoT)-based smart healthcare surveillance system that combines sensors with communication infrastructure. Prior to this, Islam et al. [11] provided an extensive overview of the Internet of Things (IoT) in healthcare, including topics such as sensing equipment, communication models, and healthcare applications focused on providing services. Connected healthcare systems present unique security risks, and Chhetri et al. [15] examined smart healthcare architectures enabled by IoMT and included topics such as innovative apps, communication frameworks, and these issues. Because cloud platforms provide persistent storage, remote access, plus large-scale processing between health data, Botta et al.'s examination of combining the use of cloud computing with IoT is very pertinent to healthcare applications [13]. Evidence from these research suggests that healthcare IoT architectures that include sensors, communications, storage, analytics, as well as safe patient data access are optimal for wearable medical surveillance systems [8, 11, 13, 15].

The many kinds of wearable sensing devices and the medical uses for them constitute an additional area of active investigation. In their discussion of the main sensing technologies used to detect physiological parameters within medical applications, Dias and Cunha [9] analyzed health devices that can be worn for vital-sign monitoring. The significance of improved sensing materials & flexible sensor designs is growing in wearable medical systems, as shown by Leal-Junior et al.'s investigation into optical fiber sensors' function in future healthcare devices [5]. Quality, precision, and dependability of sensors have a direct impact on how well smart healthcare solutions work, according to an assessment by Gopichand et al. [14] of the Internet of Things (IoT) sensor devices used for effective healthcare administration. Wearable healthcare is a sensing-design challenge, according to these research, where the comfort, accuracy, and long-term usage of a surveillance system are determined by the choice connected sensor technology. This problem also arises from internet of things (IoT) connection.

The use of wearable sensors for niche monitoring tasks, such as fitness and sports analytics, is increasingly gaining traction in the academic communities. Through their research on athlete fitness monitoring with wearable IoT devices, Chinthamu et al. [6] shown that wearable health systems are valuable for more than just clinical monitoring; they can also measure movement patterns, creativity, stamina, and wellness-related performance metrics. This viewpoint is very pertinent to fitness-focused health monitoring systems as it broadens the utility of wearable IoT beyond only patient care to include exercise tracking, preventative health management, and continuous evaluation of physical state. These findings highlight the growing field of personal health surveillance, where the same communication and sensing technology may be used for both supervised healthcare and wellness applications focused on lifestyle [6].

Because wearable devices continually produce sensitive personal health data, security and privacy are particularly critical concerns in healthcare IoT systems. Emphasizing the need of healthcare monitoring frameworks for anonymity, secure communication, and reliable access control, Gope and Hwang presented BSN-Care, a secure healthcare system based on the Internet of Things (IoT) that utilizes a body sensor network [10]. The hands-on component adoption of peripheral health monitoring systems is critically dependent on safety, confidentiality, authentication, and secure cloud integration, according to more recent evaluations on IoMT-based healthcare [11], [15]. Wearables, mobile apps, gateways, & cloud servers are just a few of the layers that data must traverse in remotely health monitoring, making this an especially critical consideration.

II. SUGGESTED FRAMEWORK

A. SYMBOLIC LAYOUT

The suggested system is built on an ESP controller and is intended to serve as a platform for managing patient data and integrating healthcare monitoring. Two key functional areas make up the block diagram: healthcare infrastructure monitoring and patient identification as well as information retrieval. The ESP controller mediates between the two domains and serves as the brains of the operation, coordinating processing, communication, and decision-making.

A reader with an RFID module operates in the patient managing information area to identify patients by means of RFID cards or tags that are issued to them. You may find basic medical information, berth numbers, and patient IDs linked to each RFID tag in the system database. The RFID reader communicates with the ESP controller by transmitting tag data whenever an individual card is scanned. The controller checks the patient's identification and gets the relevant information. In addition to being transferred for the IoT platform allowing remote surveillance and digital record access, the recovered information is shown on the LCD.

Connected to the ESP controller, environmental sensors in the medical care infrastructure monitoring area keep a constant eye on vital hospital conditions. A gas detector may identify dangerous gasses, deteriorating air quality, or unusual atmospheric conditions inside the healthcare facility, while a temperature sensor can monitor the temperature of a room or ward. Ensuring optimum ventilation, safeguarding sensitive healthcare facilities including wards, labs, and storage rooms, and preserving patient safety are all areas where these sensors shine. The ESP controller checks the sensor readings at regular intervals and compares them to safety limits that have been previously set.

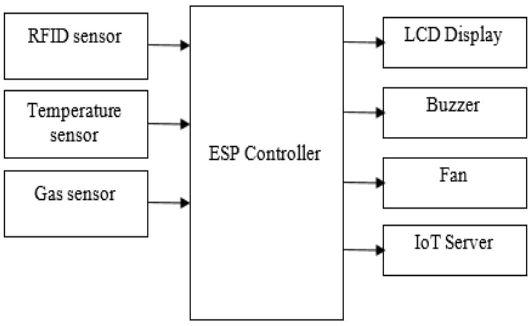

Fig. 1. Patient data management and healthcare infrastructure block diagram

Additionally, the system comes with an LCD screen that can be used to see patient information, temperature data, gas concentrations, and network status on a local level. The presence of potentially hazardous situations may be signaled via the use of an attached buzzer. Also included is a fan control device that will activate automatically if the gas concentration or temperature becomes too high. In order to increase air circulation and decrease environmental danger, the ESP controller may activate the fan, for instance, if the gas concentration becomes excessively high or if the space temperature surpasses the threshold. A online or mobile dashboard allows healthcare personnel to remotely see all data, including monitored values and alarm circumstances, transferred by Wi-Fi to an IoT server.

The block diagram's operational sequence is shown below. The ESP controller receives patient identifying data sent by the RFID reader after scanning their tags. At the same time, gas and temperature monitors keep tabs on the hospital's atmosphere. The ESP controller takes in data from various sources, displays it on the LCD, checks whether the readings are within the set limits, triggers the buzzer or fan as needed, and updates the IoT server with patient data and infrastructure status. The suggested approach therefore offers a unified system for the automation of healthcare facilities, the identification of patients, and the monitoring of infrastructure safety.

B. FIRST VERSION OF HARDWARE

We used an ESP-based embedded controller, RFID scanning device, temperature sensor, gas detector, LCD screen, buzzer, and fan control circuit to build the hardware prototype of the suggested healthcare monitoring system. Our prototype proves that it's possible to integrate infrastructure monitoring and patient data access into one affordable Internet of Things (IoT) device, making it ideal for intelligent healthcare applications.

The prototype's brain is the ESP controller. Data reading from RFID tags, gathering readings from environmental sensors, comparing those readings to safety criteria, managing warning outputs, and data transmission to the IoT platform are all its responsibilities. Thanks to the ESP's integrated Wi-Fi, the device can transmit data about the patient and their surroundings to a web dashboard that can be accessed remotely.

One use of the RFID module is patient identification. Every patient has their own RFID tag / card, and the controller can read their unique code whenever the tag is near an RFID reader. The system is able to access vital patient information, including name or ID, bed number, and ward data, by drawing on the recorded mapping or programmed association. In addition to being visible on the LCD, these facts may be recorded in the IoT dashboard. In healthcare settings, this method facilitates rapid patient identification while simultaneously decreasing the requirement for human search.

A temperature sensor is installed in the hospital ward / monitoring area to continually measure the temperature. Ensuring a consistent temperature range is critical for the well-being of patients, the efficiency of medical equipment, and the preservation of biological or medicinal materials. When there is a dangerous gas present or when the air quality is bad, the gas detector will go off. When air quality is an issue that affects both patients and workers, this kind of monitoring is helpful in places like hospital labs, oxygen-supported settings, pharmaceutical storage facilities, and general wards.

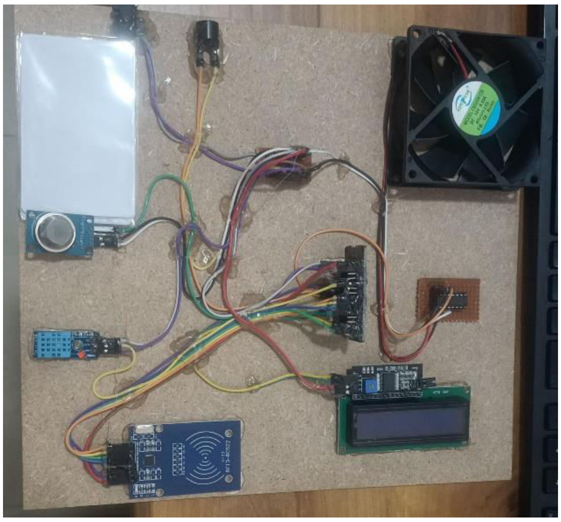

Fig.2. Prototype hardware for healthcare data management and infrastructure monitoring system

Important information such as system status, sensor data, patient identity, and Wi-Fi connection details are shown on the LCD display in real time. When environmental values go above safe limits, a buzzer will sound an audible alarm. As a self-correcting mechanism, the fan controlling stage is included. The ESP controller has the capability to activate the fan in order to stabilize the monitoring environment and increase ventilation when the temperature surpasses the set limit or the gas concentration goes over the threshold.

It is possible to create the suggested healthcare monitoring system utilizing small and inexpensive components, as confirmed by the produced hardware prototype. This architecture is well-suited for scalable intelligent medical systems due to its modular design, which allows for its deployment across various wards in hospitals, patient rooms, labs, and healthcare facilities.

III. DYNAMIC GRAPH

Starting with system startup, the suggested solution healthcare monitoring & patient data management system's flowchart details the steps taken to identify patients using radio frequency identification (RFID), track their surroundings, generate alerts, and transmit data collected from the internet of things (IoT). Turning on the ESP controller & connecting it to Wi-Fi are the first steps. To use the web interface, the controller has to be connected to a network. The IP address and connection status may be seen on the LCD.

After setup is complete, the ESP controller runs two processes in parallel: one processes patient data collected by RFID, while the other monitors the surrounding environment. To begin, it detects whether the RFID reader is in close proximity to any patient tags or RFID cards. When the controller detects an RFID tag, it reads the data from the tag and gets the patient's information, including their ward, berth number, or ID. The information is shown on the LCD for transferred to the Internet of Things server at the same time, allowing for online surveillance and access to hospital data. The controller will keep scanning and monitoring the surroundings in the event that no RFID chip is found.

The environmental monitoring route includes the ESP controller's constant readings of the gas and temperature sensors. At regular intervals, the LCD displays the current sensor values and uploads them to the IoT server. After that, the controller checks the gas and temperature readings against the limitations it has set. The system may engage the fan to promote air circulation, send a warning to the web server, plus trigger the buzzer if the gas level surpasses the safety threshold. Similarly, when the temperature goes beyond the set point, the system considers it a dangerous state, updates the web server with the alert status, sounds an alarm if needed, and adjusts the fan speed accordingly.

The system will keep monitoring without sounding an alarm if all readings stay within the safe range. The continual repetition of this cycle allows for real-time handling of both patient identification & infrastructure issues.

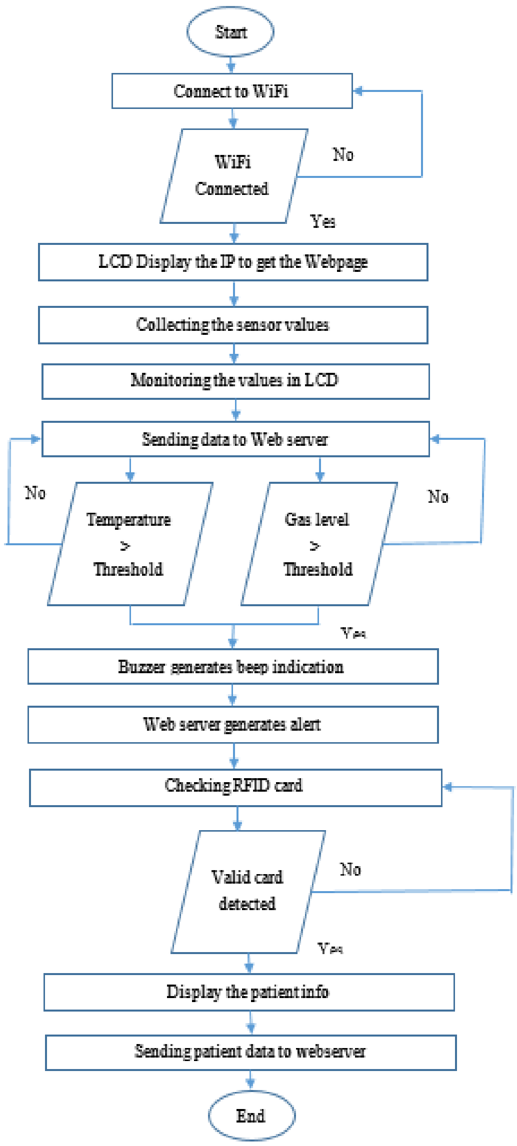

Fig. 3. System for managing patient data and monitoring healthcare infrastructure flow diagram

The system's ability to automatically and integratedly handle patient data and monitor the hospital environment are both guaranteed by this flow.

IV. INDUSTRY-RANDOM FINDINGS

A functional hardware prototype of the suggested Intelligent Internet of Things (IoT)-based Healthcare Facilities Monitoring & Client Data Management Systems using ESP Controller was developed and tested under varying patient identification & environmental environments. An Internet of Things (IoT) online monitoring interface, gas detector, temperature sensor, ESP controller, LCD screen, buzzer, and fan control circuit were all part of the experimental setup. The experimental study aimed to confirm that the system could identify patients, display their information, track the hospital's environmental parameters in real-time, sound alarms when dangerous situations arise, and update the relevant data on the Internet of Things dashboard (IoT) shown in Figures 7 and 8.

Fig.4. Displaying sensor data on an LCD

Numerous RFID tags were used to represent distinct patients in the hospital setting during patient identification testing. Details like client ID, bed number, or berth position were part of each RFID card's corresponding patient profile. Upon proximity to the smart card reader, the system was able to recognize authentic RFID cards within 1-2 seconds and provide the corresponding patient information on the LCD. By scanning a tag associated with Patient ID: P102 the Berth No: B-12, for instance, the same data was shown on the LCD the IoT dashboard in one set of test cases. Additionally, in a different test situation, the tag associated with Patient ID: P118 & Berth No: C-05 had been effectively detected and shown in figure 6. Under short-range scanning circumstances, the RFID accuracy of recognition was found to be very dependable throughout repeated testing, confirming the the system can provide speedy patient identification & digital record retrieval without human data search.

Both typical and out-of-the-ordinary settings were used to test the temperature monitoring feature. The temperature readings on the ward normally stayed between the 26–30°C range, which was deemed acceptable for patient care & the smooth running of the hospital. At this point, the system was running normally; the fan was not turning on, and no alerts were sent out. The environment around the detecting device was artificially raised to 38°C-42°C in order to test for anomalous behavior. The prototype's alarm level for unusual room temperature was set at 35°C. The ESP controller alerted the IoT dashboard, refreshed LCD screens with the newly acquired temperature reading, and activated the fan to enhance the surrounding environment when the temperature reading exceeded this threshold, deeming the situation dangerous. Confirming the viability of autonomous thermal control and surveillance in hospital settings, the system reaction happened instantly after threshold crossing in the extremely hot test condition.

Fig.5. Display of alert status on LCD

Experiments were also conducted to confirm that the suggested method could effectively detect gas levels. Gas sensor readings were consistently within the permitted range of 180-260 ADC counts when tested indoors under typical circumstances. Exposing the gas sensor to a regulated gas source caused the output of the sensor to climb to 420-560 ADC counts, simulating a strange air quality event. In the prototype, an unhealthy gas concentration was identified using a threshold threshold of 400 ADC counts. The ESP controller promptly triggered the buzzer, displayed a warning message on the LCD, actuated the fan, and alerted the IoT server as soon as the gas value exceeded this level. The existence of an environmental threat was indicated by the dashboard status changing from Safe to Warning. Particularly helpful in oxygen-related healthcare settings, labs, medication storage rooms, and wards, this finding validated the system's capacity to provide real-time quality of air or gas-leak alert capabilities.

To see how the system responded when the temperature and gas levels exceeded their respective limits at the same time, an integrated environmental test was run. While the gas sensor's output reached 485 ADC counts, the temperature climbed to about 39°C in this test. The ESP controller deemed the circumstance as a high-risk ambient state as both metrics were higher than the established safety limits. In addition to updating both warning parameters simultaneously, the IoT dashboard showed the anomalous readings on the LCD, a buzzer sounded an alarm, and the fan ran continually. This experiment proved that the framework can handle several infrastructure issues at once and fix them without any help from humans.

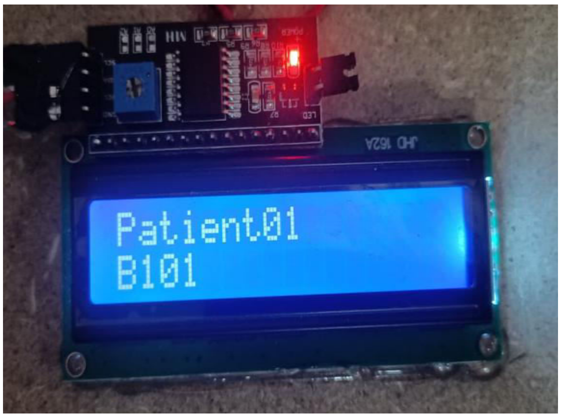

Fig.6. Display of patient's scanned RFID card data allowing them to identify their room and berth number

Experimentation also confirmed the system's IoT communication capabilities. The ESP Wi-Fi connection was used to successfully upload every patient id events and ambient sensor values to the online platform. During testing, the average refresh interval varied between 3 and 5 seconds, depending on factors like Wi-Fi response and when the dashboard was refreshed. As seen in figure 6, the patient's information was shown on an interactive dashboard almost instantaneously after the scanning of a valid RFID tag, following the local display. The status of the alarm was remotely updated with little delay on fig. 5 if gas or temperature criteria were reached. This proves that the system is capable of supporting hardware node and central digital platform real-time hospital monitoring. Personnel and administrators may use this platform with ease.

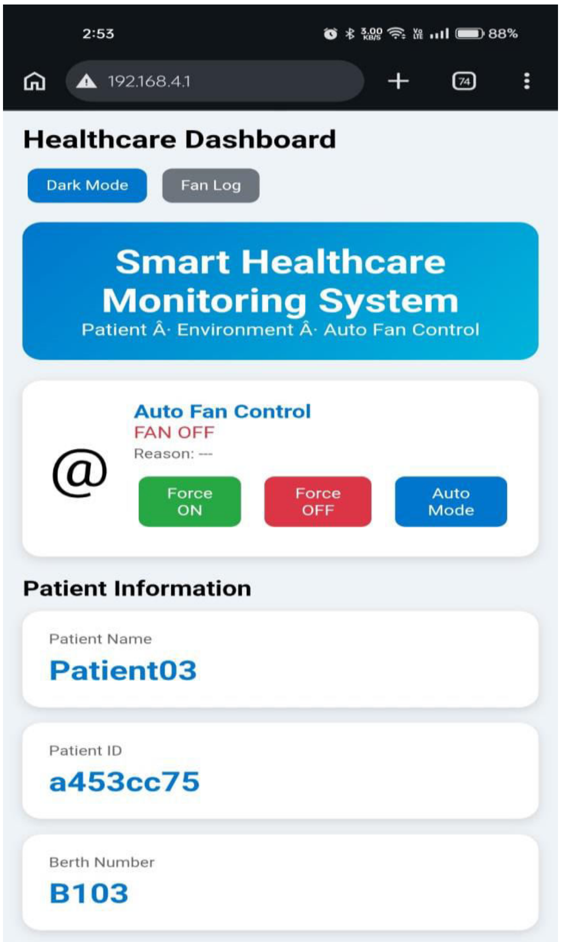

Fig.7. Automatic fan control via online interface in addition to RFid-scanned patient data

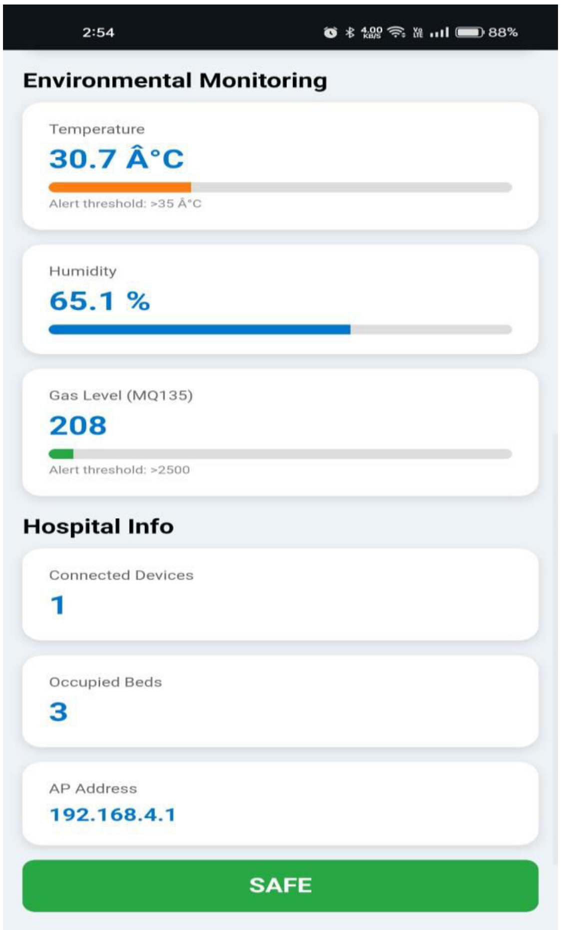

Fig.8. web dashboard for monitoring sensor data

Extensive testing was carried out under various operating conditions to evaluate the prototype's integrated performance. Under typical, risk-free scanning circumstances, the device accurately presented patient data, revealed temperature readings around 28°C, gas readings close to 220 ADC, and kept the fan and siren turned off. When the temperature rose above 35°C, the fan kicked on and a warning message was sent out. In the event of abnormal gas circumstances, the alarm and fan would activate when the gas value exceeded 400 ADC. Whenever both metrics were out of the ordinary at the same time, the system would sound an environmental alarm and keep the remedial action going until the values were back within acceptable limits. These findings demonstrate that the suggested design is capable of integrating infrastructure safety monitoring with patient information management inside an Internet of Things (IoT) healthcare platform.

The suggested smart healthcare monitoring system, which is based on ESP, was shown to be practically feasible according to the trial findings. Using radio frequency identification (RFID), the system was able to identify patients, monitor gas and temperature levels in real-time, provide alerts via buzzers, regulate fans to fix errors, and report on the results using an Internet of Things dashboard. This embedded system combines patient data management with infrastructure monitoring, making it ideal for smart wards, healthcare facility management, hospital automation, and next-gen medical support systems based on the internet of things.

V. FINAL THOUGHTS AND PROSPECTS

Using ESP Controller, this article demonstrated a smart medical facility monitoring and data management system based on the internet of things. As a whole, the proposed system is an innovative hospital management platform that combines RFID-based recognizing patients with continuous monitoring of the environment of healthcare facilities. The system enhances efficiency in hospitals, security for patients, and infrastructure response by seamlessly integrating information collection, monitoring temperature, gas detection, a LCD local display, buzzer alarms, fan control, and Internet of Things (IoT) dashboard communication.

The prototype proved that the suggested model can detect patients with RFID tags, provide patient information in real-time, and continually monitor environmental factors. The system would send out local notifications, turn on corrective control, plus update the distant IoT platform if gas or temperature circumstances were deemed harmful. These features make it easier to respond to environmental dangers in hospitals with less human intervention and less room for human mistake. Consequently, the system offers a scalable, low-cost option for managing smart hospital infrastructure, digital patient monitoring, and healthcare automation.

Several avenues exist for expanding the reach of this work in the future. Integrating additional healthcare sensors like heart-rate monitors, SpO_2 detectors, electrocardiogram modules, or temperature sensors allows for the monitoring of both the infrastructure and the physiological status of the patients. To provide safe access to patient records, it is possible to integrate electronic medical records stored in the cloud. Anomaly detection in the environment and patient assistance requirement prediction are two applications of AI-based analytics. When it comes to developing intelligent healthcare ecosystems and deploying large-scale hospitals, the system may be further improved using GPS/GSM warning systems, mobile apps, and a variety of distributed sensor networks.

REFERENCES

[1] J. B. Madavarapu, S. Nachiyappan, S. Rajarajeswari, N. Anusha, N. Venkatachalam, R. C. Bose Madavarapu, and A. Ahilan, "HOT Watch: IoT-based wearable health monitoring system," *IEEE Sensors Journal*, vol. 24, no. 20, pp. 33252–33259, Oct. 2024, doi: 10.1109/JSEN.2024.3424348.

[2] Q. Chen and N. Sheng, "A novel health monitoring system for vital signs using IoT," *Scientific Reports*, vol. 14, Art. no. 19189, 2024.

[3] G. Matsumura, S. Honda, T. Kikuchi, Y. Mizuno, H. Hara, Y. Kondo, H. Nakamura, S. Watanabe, K. Hayakawa, K. Nakajima, and K. Takei, "Real-time personal healthcare data analysis using edge computing for multimodal wearable sensors," *Device*, 2024.

[4] J. Ahmed, M. H. Rahman, and S. H. Islam, "Wearable healthcare and continuous vital sign monitoring with IoT integration," *Computers, Materials & Continua*, vol. 81, no. 1, pp. 79–104, 2024, doi: 10.32604/cmc.2024.054378.

[5] A. Leal-Junior, J. Silva, L. Macedo, A. Marchesi, S. Morau, J. Valentino, F. Valentim, and M. Costa, "The role of optical fiber sensors in the new generation of healthcare devices: A review," *Sensors & Diagnostics*, vol. 3, pp. 1135–1158, 2024, doi: 10.1039/D4SD00032C.

[6] N. Chinthamu, V. Moyal, R. Sharma, T. A. Mohanaprakash, S. F. Waris, and K. Renuka, "Athlete fitness monitoring with the application of wearable IoT devices," in *Proc. 4th Int. Conf. Smart Electronics and Communication (ICOSEC)*, 2023, doi: 10.1109/ICOSEC58147.2023.10276361.

[7] A. Rghioui, A. Lloret, M. Harane, and R. Oumnad, "A smart healthcare system based on IoT wearable sensors and cloud computing for patient monitoring," *Sensors*, vol. 23, no. 2, Art. no. 414, 2023.

[8] A. Rahman, M. Z. Chowdhury, and Y. M. Jang, "IoT-based smart healthcare monitoring system," in *Proc. IEEE Int. Conf. Information Networking (ICOIN)*, 2019, pp. 1–6.

[9] D. Dias and J. P. S. Cunha, "Wearable health devices—Vital sign monitoring, systems and technologies," *Sensors*, vol. 18, no. 8, Art. no. 2414, 2018.

[10] P. Gope and T. Hwang, "BSN-Care: A secure IoT-based modern healthcare system using body sensor network," *IEEE Sensors Journal*, vol. 16, no. 5, pp. 1368–1376, 2016.

[11] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain, and K.-S. Kwak, "The Internet of Things for health care: A comprehensive survey," *IEEE Access*, vol. 3, pp. 678–708, 2015.

[12] M. M. Hassan, A. Gumaei, S. Huda, and M. R. Hassan, "A robust health monitoring system using wearable sensors and fog/cloud computing," *Future Generation Computer Systems*, vol. 93, pp. 569–576, 2019.

[13] A. Botta, W. de Donato, V. Persico, and A. Pescapé, "Integration of cloud computing and Internet of Things: A survey," *Future Generation Computer Systems*, vol. 56, pp. 684–700, 2016.

[14] G. Gopichand, T. Sarath, A. Dumka, H. R. Goyal, R. Singh, A. Gehlot, L. R. Gupta, A. K. Thakur, and N. Priyadarshi, "Use of IoT sensor devices for efficient management of healthcare systems: A review," *Discover Internet of Things*, vol. 4, Art. no. 8, 2024.

[15] S. R. Chhetri, S. Faezi, A. Canedo, and M. A. Al Faruque, "IoMT-enabled smart healthcare: A review of architecture, applications, and security challenges," in *Proc. IEEE/ACM Int. Conf. Connected Health / healthcare IoT systems*, 2021.