IoT Healthcare Application: Real-Time Health Surveillance System

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Abstract - The initial phase of an infant life demands vigilance since slight variations in body temperature heart rate or motion patterns can rapidly escalate into major health issues if ignored. Numerous parents struggle to keep an eye on their child because of job responsibilities, limited medical expertise or geographic separation. Conventional baby monitors primarily provide visual monitoring and fail to deliver dependable information, about the infant's vital signs. Thanks to the progress, in smart sensors and Internet of Things (IoT) technology systems can now be created to assist parents by continuously tracking an infant's health and providing immediate notifications when irregularities occur. The designed system incorporates sensors to capture body temperature and humidity, infant's activity and noise levels. These measurements are handled by a microcontroller and sent to a cloud platform, via Wi-Fi. Caregivers can access the real-time information through an app allowing them to keep track of their baby from anywhere. The system additionally sends alerts whenever a parameter exceeds the threshold guaranteeing prompt notification of possible health hazards. The outcome of this project includes a comprehensive understanding of existing infant monitoring technologies, the identification of system requirements, selection of suitable hardware components, and the formulation of an implementation methodology. The proposed solution is designed to be compact, cost-effective, and user-friendly, making it suitable for home and hospital use.

Keywords - IoT, Infant Monitoring, Health Monitoring, Smart Sensors

I. INTRODUCTION

The rapid growth of IoT has resulted in extraordinary improvements in healthcare monitoring, enabling the continuity of data collection, remote supervision, and intelligent analysis of real-time information [1] [2]. IoT is basically a system of connected devices that are embedded with sensors, microcontrollers, and wireless communication technologies that sense and transmit data without human interference [3]. That allows us to see and analyze the medical information at the very moment it arises; this is valuable in cases when it is not possible to have human supervision. In childcare, the IoT-based systems play a very important role because babies are pretty sensitive to the changes in environmental and physiological conditions [5]. Babies cannot express discomfort or disease, and thus require continuous observation [3]. Even minute variations in temperature, humidity, noise level, or movement may imply serious health issues. However, for the parents, it's challenging to carry on the continuous monitoring process due to professional commitments, sleep schedules, and daily chores. Traditional baby monitors normally have audio and video output displays with no provision for vital environmental or activity-based parameters [7]. In an effort to overcome these drawbacks, this work presents an IoT-enabled infant monitoring system that is designed to monitor various factors simultaneously. It consists of sensors for measuring temperature, humidity, motion, and sound, interfaced with Wi-Fi microcontrollers that process data collected from the previous sensors and transmit it to the cloud. The live reading is available at any location through a mobile interface so that caregivers get instant alerts in case of values moving beyond normal limits.

II. RELATED BACKGROUNDS

Cay et al. (2021) developed Baby-Guard, an IoT-enabled system that used smart textiles integrated with piezoresistive sensors and an inertial measurement unit to track respiration rate and apnea in newborns. Data were handled by an ESP32 microcontroller. Sent to an edge computing device for real-time evaluation. The system demonstrated accuracy in testing with neonatal intensive care unit (NICU) mannequins and offered a non-invasive comfortable substitute, for conventional wired sensors. This breakthrough showcased the capabilities of IoT devices, for professional infant health tracking.

Dangi et al. (2020) introduced a cradle system integrated with IoT for monitoring environmental and behavioural parameters. The design incorporated sensors detecting temperature, humidity, wetness and crying well as a live video monitoring component. The system was based on a NodeMCU microcontroller. Linked to the Blynk cloud platform to enable notifications, on mobile devices. When crying was sensed the cradles automatic movement was activated to enhance the babys comfort. Although effective the system mainly concentrated on elements instead of thorough physiological tracking.

Gare et al. (2019) created an automated crib system that included sensors to recognize crying, wetness, temperature fluctuations and motion. Upon detecting the baby's cry the cradle began swinging to calm the infant. If the crying continued beyond a period a text message was sent to the parent via GSM technology. This system offered real-time responses and functioned without internet access making it suitable, for offline settings. Nevertheless it did not include forecasting capabilities or advanced health analysis that might help in detecting term behavioural trends.

Joshi et al. (2017) created a smart cradle system. The Android application with the monitoring system employed the use of sensors to detect noise, moisture, and temperatures. The system supported a real-time video display that the user can access to enable the baby to calm down when the activated jump startup activation system registers a sensation of pain. It enabled the transmission of information via cloud intimation and sent notifications to the caregivers using their smartphones. Though successful in ensuring undisturbed sleeping processes using smartphones, the system had a display that relied on wired forms of communication like RS-232 and Zigbee cables; therefore, the system was non-portable and non-scalable.

Kaluti et al. (2023) examined the concept of an advanced baby care solution based on the Internet of Things (IoT) and machine learning. The solution automatically controlled the motion of the cradle, fan, and moisture sensing based on sensor inputs. The solution included facial emotion recognition with OpenCV. The solution included cloud access with an easy-to-use interface. Although very technical in nature, the solution needed work regarding behavioral models and also synchronization between sensing and control systems.

III. PROPOSED METHODOLOGY

A proposed IoT-based infant health care system would help in continuously monitoring the surrounding environment and behavior of the infant and would provide an instantaneous notification to the caregivers for attention. The proposed structure for the design would consist of an environmental/behavioral sensing part, processing as well as communication part, power management system, and an infant health care cloud system. The proposed methodology would help in making sure that data acquisition and processing for infant-related critical data take place effectively. The sensing component is intended to integrate a variety of low-cost and accurate sensors to record crucial parameters that could directly or indirectly impact the design of the tunnel. There is will indirectly impact the comfort and wellbeing of the babies. The DHT11 sensor is used to measure ambient temperatures, as well as humidity levels. The reasons for considering these variables are that temperatures and humidity levels can highly affect a baby's respiratory system and feeling of comfort. A Passive Infrared (PIR) sensor is also used to record baby movements. This will allow detection of if babies are restless or inactive for a longer period. The sound sensor module is utilized to record changes in sound intensity, specifically baby crying or any sudden loud sound. All sensor outputs are connected to the ESP8266 microcontroller, also known as NodeMCU, which is the processing element or central processing element for the entire system setup. The NodeMCU or ESP8266 microcontroller is capable of reading data from the sensors in real-time, processing the sensor data according to set threshold values, and performing the process of decision-making. The microcontroller has the facility to display data read from the sensors on an LCD display connected to the system, thus providing an immediate reality check on the values obtained from the sensors regarding temperature, humidity, motion, and sound. As far as the wireless communication of the data from the sensors is concerned, the

ESP8266 sends the processed data to the cloud platform 'ThingSpeak' via a Wi-Fi connection. The 'ThingSpeak' platform allows the storage, graphic display, and analysis of the collected data in a smooth and efficient manner. The data from the sensors would be uploaded to the 'ThingSpeak' platform after certain intervals, and corresponding graphical displays would be created to allow the caregivers to monitor the changes with ease. As soon as the values of any parameter go beyond the safe limit, corresponding notifications would be sent to the caregivers via the cloud platform due to abnormal temperature, noise, or motion. In this project, the DC-DC step down voltage regulator that is a buck converter is used. This is aimed at generating the required outputs of 5V and 3.3V, which the sensors, the LCD module, and the ESP8266 microcontroller require. Additionally, for effective network and power consumption, there is selective cloud communication provided. It does not stream the data to the cloud continuously. It compares the actual values of the readings and, if there is an abnormality, it compares the actual values of the reading with the limit already set. It saves power as well as the network. At the same time, it ensures that the care givers receive the notifications or notifications only if it is necessary. Now, to ensure the effectiveness of this system, it is tested in a controlled indoor environment. It is tested for its accuracy of the sensors, speed of response, reliability of data transmission, and reliability of the alerts. Then, it can also be implemented in the domestic settings, day care, or where it is required in the neonatal care segment.

IV. BLOCK DIAGRAM

The system's operational process begins with power supplied through the buck converter, which regulates the voltage delivered to each component. After powering on the ESP8266. Loads its configuration. It then connects wirelessly. Once the network link is set up the sensors begin collecting data from the baby's environment. The microcontroller is responsible for obtaining information from the DHT11, PIR, and sound sensors. It all undergoes processing to form understandable output. These outputs are immediately provided on the LCD screen to enable everyone to monitor and determine the status of the baby. Once this processing reveals a reading beyond the required thresholds, it automatically generates an HTTP POST request from the ESP8266. This request is transmitted to the ThingSpeak server, which stores all this information in a mannerized form and in graphical form. After completing this process, it successfully completes microcontroller resets of motion and sound events and subsequent environments. This forms a never-ending loop depicted in Figure 1 and allows it to work on a self-sustainable manner process while providing real-time information. It is within this conceptualized flow process that this device is able to immediately notify caregivers regarding changes in this environment or possible signs of discomfort.

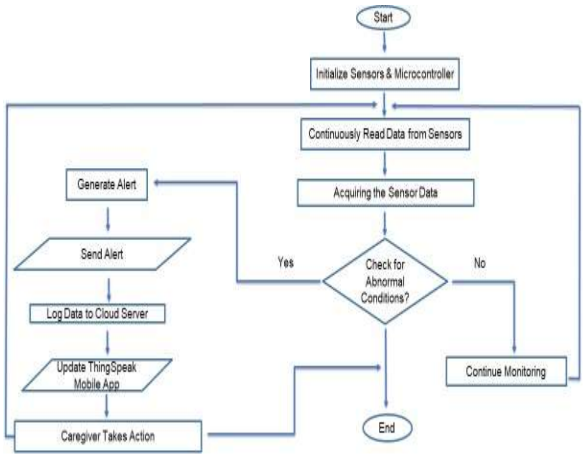

Figure 1: Block diagram of the system

V. SOFTWARE IMPLEMENTATION

A. Initialization Process:

1. Once powered on, the ESP8266 goes through a startup sequence procedure communication, with the DHT11 sensor begins.
2. The pins for the PIR and sound sensors are initialized as input pins.
3. The device aims to make a connection, with the configured Wi-Fi network.
4. During all stages involved in this process of connection, the LCD displays status information and messages, such as "Connecting…" or "Wi-Fi Established" This enables them to decide if the system is ready for use.

B. Ongoing Sensor Measurement Sequence:

It then initializes the microcontroller and sends it into a loop every 1-2 seconds. On each iteration:

1. DHT library reads data about temperature and humidity readings by interpreting a 40-bit data chain.

2. The PIR input is checked for motion detection signals.

3. These sound signals are counted based on the number of count detections, during this timeframe.

4. The LCD display is refreshed instantly to display the

measurements.

This rapid cycling ensures that the system reflects real-time situations without screen flicker and delay data.

C. Threshold Checking and Decision Logic:

1. Each incoming measurement is then verified against predetermined safety limits based on infant comfort levels
2. Maximum and minimum temperature
3. Acceptable humidity range
4. Activity-indicating motion frequency
5. Sound intensity pointing to crying
6. When all the parameters exceed their boundaries, it switches to the alert state.

D. Cloud Uploading (ThingSpeak Integration):

1. When a warning situation arises:
2. The ESP8266 structures the recent information, into the message to HTTP POST.
3. It creates a link, to the ThingSpeak server.
4. Sensor readings are sent to their designated fields via the channel API key.
5. The device holds until it receives a confirmation reply.

After confirmation it securely terminates the connection. Reverts to the monitoring cycle.

ThingSpeak then updates the graphs associated with each parameter, allowing caregivers to review patterns over time such as frequent crying, fluctuating temperature, or irregular motion activity.

VI. HARDWARE IMPLEMENTATION

The physical construction of the IoT-based Smart Infant Monitoring and Alert System was meticulously designed to guarantee dependability, precision and smooth connectivity among all parts. Every component of the system that the sensing, processing, display, communication and power management units was linked together to form a robust and operational prototype suited for real-time infant monitoring.

A. Sensing Unit:

The sensing component constitutes the core of the monitoring system tasked with gathering behavioural information from the infant's environment. Three main sensors were incorporated.

B. DHT11 Temperature and Humidity Sensor:

This device continuously monitors the surrounding temperature and humidity. Temperature changes outside of ranges may be harmful, to infants and excessive or insufficient humidity can impact breathing comfort. The DHT11 sends data to the ESP8266 providing precise real-time readings.

C. PIR Motion Sensor:

The PIR sensor detects the presence of motion when it picks up the radiation emitted by the baby. Small movements such as turning, extension, or jerking motions are also detected. This enables the system to track periods when a baby may be agitated or in discomfort. The sensor connects to a digital input pin in the ESP8266. The data is logged each time it detects motion.

D. Sound Sensor:

The sensor works like a microphone together with an onboard amplifier. The sensor converts the energy from loud scenes or crying into electrical signals. Based on the strength of the signal, the system is able to detect the differences between the background noises in the nursery and the crying that alerts the caregiver to respond to it. Each sensor is selected based on its ability to supply data without consuming much energy while at the same time not introducing noise into the system.

E. Processing Unit:

The design of the hardware revolves around the ESP8266 microcontroller, which has been considered based on its compact size, power consumption, as well as its Wi-Fi capabilities. This microcontroller processes all the data received from the sensors, besides controlling the LCD display and the cloud service. The input/output ports of ESP8266 are accurately allocated to ensure a guaranteed data communication process. It performs evaluation processes of temperature, motion, and sound values, taking decisions based on sensor constraints. All this makes sure that the microcontroller keeps observing the surroundings of the infant to trigger alerts whenever necessary without requiring intervention, from a human being, to monitor it.

F. Display Unit:

A 16x2 Liquid Crystal Display (LCD) was also incorporated for caregiver interaction. The communication protocol employed is an I2C protocol requiring just two pins (SDA - D2, SCL - D1), which reduces mess. The display indicates real-time readings for temperature, humidity, acoustic levels, and motion activity. This way, there is no need for smartphones and/or computers in order to monitor the infant's condition on-site. The caregivers also get to know the status of the infant through observation for check-ups, midnight feeding sessions, or quick visits to the nursery.

G. Communication Unit:

The communications component of the system is responsible and utilizes the ESP8266 Wi-Fi module to transmit the value from the sensor to ThingSpeak Cloud Services as soon as the values from the sensor go beyond a certain threshold; the sensor broadcasts the values using an HTTP POST request to ThingSpeak Cloud Services. ThingSpeak Cloud Services then analyzes the values it has received. Graphic images are designed to display the changes associated with temperature, movement, and crying behavior at the remote site. The system provides convenience and safety to the childcare guardians to access the information whenever they are not present.

H. Power Regulation Unit:

The accessibility of power is of utmost importance in the matter of monitoring. For the regulation of the voltage in the system, a buck converter circuit design has been implemented. The power source utilised in the design has been implemented as a DC input of 9V, 12V onwards, as required in the power source concerning the application of 5V and 3.3V as required by the LCD display, sensors, as well as the ESP8266. The buck converter has been implemented utilizing high power switching methods along with the application of inductors as well as capacitors with the application of inductors as voltage filters. Protection against overcurrent with voltage has been implemented utilizing an overcurrent and voltage protection circuit.

I. Circuit Integration and Grounding:

Each part connects to a common ground in order to create a voltage reference. It ensures an efficient flow of signals as opposed to the creation of errors due to floating or varying grounds. The circuit was designed using a breadboard. Once it was confirmed that it works properly, the design was transferred from the breadboard to the PCB. The hardware design ensures that modifications of the components will not affect the whole system.

VII. SYSTEM DESIGN

The system is created as an IoT monitoring tool that continuously observes the infant's surroundings and behaviours using a combination of sensors, a processing unit and cloud connection. The main objective of this design is to create a -intrusive system capable of functioning for long durations without constant supervision. To achieve this the architecture integrates sensing, computation, data transmission, visualization and energy management, within a device. At the centre of the system lies the ESP8266 microcontroller, selected for its built-in Wi-Fi capability, compact form factor, and energy-efficient operation. The ESP8266 functions as the command unit responsible for gathering incoming data from the sensors, processing the information, updating the display, and uploading readings to the cloud platform. The system utilizes three sensors, which are its sensing base: the DHT11, which detects temperature and humidity; the Pir sensor, responsible for sensing movement and activities, around the baby; and the sound sensor, which detects crying or irregular noises. Each sensor provides a part of the behavioral information allowing the system to form a more comprehensive understanding of the infant's condition.

The system ensures communication between all components. The sensors are always providing information, which is collected by ESP8266 at predefined intervals. Real-time readings appear on the LCD screen offering updates to those, in the vicinity. At that moment the collected data is compared to predefined safety limits to determine if the child's environment remains safe and stable. Should irregularities occur the ESP8266 compiles a data packet and transmits it to the ThingSpeak cloud service enabling remote observation of the measurements. This multi-layer design ensures that even if one monitoring method becomes inaccessible (such as a temporary loss of internet), another method such as the LCD display remains available for on-site observation. The system design of the system is illustrated in the Figure 2.

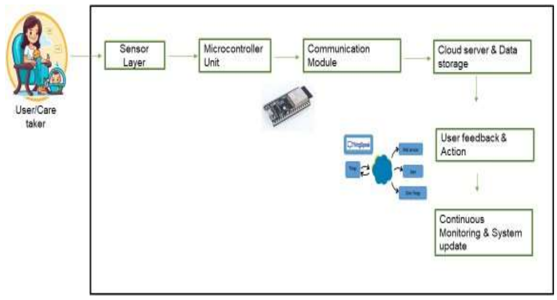

Figure 2: System Design

VIII. RESULTS AND DISCUSSION

The prototype was capable of performing on all the parameters that could be measured. The measurements were credible, and the reliable delay of communication was imperceptible, as notifications happened almost instantly. More importantly, the baby's environment and activities were modelled with very high fidelity by way of automated detection, thereby limiting the requirements for human monitoring as much as possible. These observations prove that the proposed system is fit as an inexpensive viable solution for baby monitoring at home, or the day care centre, or the smaller clinics.

Figure 3 below represents the temperature fluctuations measured by DHT11 thermistor as obtained by our system. This graph aptly denotes temperature changes in a room and its accuracy in identifying minimal variations in the temperature changes by our system. This denotes steady performance and accuracy of the data measured by our system. Some extreme pointed portions of this graph indicate that due to the accuracy of our system in temperature measurement, sometimes the temperature in its surroundings was found to be at its peak.

Figure 3: Graphical representation of Temperature readings

In particular, it can be seen from Figure 4 below how the temperature data from ThingSpeak is presented in relation to the data uploaded from ESP8266 and also from figure 4 below, it is observable that the data is uploaded at different times and different regular intervals; therefore, the data from the different locations can be accessed remotely. Each spot-on figure 4 above represents different data for a particular time; therefore, the trends of the data over a long period of time can be analysed. Data transfer to the cloud from the ESP8266 appears to be successful.

Figure 4: ThingSpeak temperature output

Figure 5 depicts the humidity readings recorded by the DHT11 sensor and posted on ThingSpeak. From the graph, obvious fluctuations are shown as per natural changes that occur inside the room's humidity levels. Such stability while recording the readings shows accurate detection and proper cloud transmission. Even minute variations between the readings are as expected inside the room and prove that the system is capable of tracking moisture levels surrounding the infant.

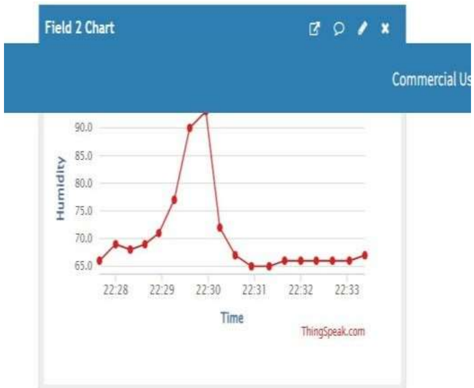

Figure 5: ThingSpeak Humidity output

Below is the Figure 6 showing the data collected from the PIR motion sensor and uploaded into the ThingSpeak platform. The dataset acquired with the use of the motion sensor has been depicted in the graphs above. The dataset acquired has been accurate, with smoother cloud interaction. The consistent pattern of readings indicates accurate sensing and efficient cloud communication.

Figure 6: ThingSpeak movement output

Figure 7 shows the complete hardware setup for the infant monitoring system. It consists of all components, including the central control unit ESP8266 microcontroller, temperature and humidity sensor DHT11, PIR motion sensor, and the sound sensor on the prototype board. All modules receive regulated supply from the buck converter circuitry. Finally, good component placement and wiring practice in the layout promotes the acquisition of reliable data and communication in the layout. The physical prototype shown will be used as the basis for real-time environmental and behavioral monitoring.

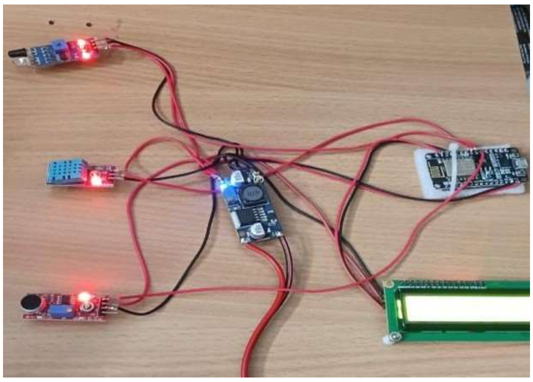

Figure 7: Infant Monitoring System

The LCD display in the Figure 8 above indicates the capability of the system to offer immediate feedback at the site without the use of a mobile device or cloud interface. As the ESP8266 is constantly collecting data from the sensors, the display updates the data at periodic instances. The display is quite clear and enables the caregivers to immediately verify the current environmental conditions, as well as the sound intensity and movement data, through a simple glance at the display.

Figure 8: LCD Display Output

Figure 9 reveals the motion detecting capability of the system, where even slight or minute changes in the baby's movement are detected by the PIR sensor. The detection of such action triggers a digital signal from the sensor, which is received and analyzed by the ESP8266 and also indicated on the display of the system or logged for cloud transmission. The captured image determines the responsiveness and sensitivity of the motion detecting unit, hence proving its ability in effectively detecting restlessness, positional change, or active behavior of an infant. The mechanism for such detection is highly relevant to the generation of alerts that support continuous behavioral monitoring.

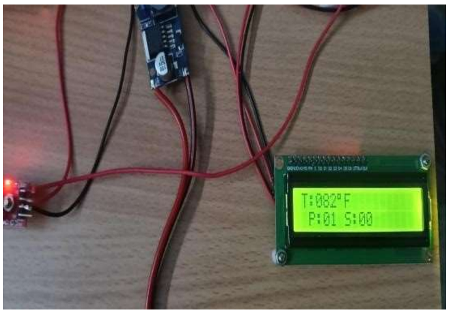

Figure 9: Movement Detection

IX. CONCLUSION

With such motivations, this project was able to design and implement a system that illustrated how to monitor the behavioral conditions an infant needed to be under. The combination of a microcontroller with sensors such as DHT11 for temperature and humidity measurement, PIR sensor for motion sensing, and sound sensor to monitor noise allowed it to monitor in real time the conditions necessary for the evaluation of infant comfort and health. During the evaluation stage, the system reported readings and reacted accordingly to changes in temperatures, humidity, sound, or motion that were triggered. Capable of dual outputs, the system used an LCD monitor and cloud monitoring on the ThingSpeak platform to show that caregivers can monitor infant health on location or from a distance. Of vital importance is the use of a buck converter to regulate voltages for ensuring stability within the system. The system has been able to ensure that all components get adequate power, hence increasing the reliability of all devices in monitoring infants. The system made use of low-cost hardware components to monitor infant safety and health, which is an indication that it can be used for safety. The aim has been achieved successfully in this project to design a low-cost, efficient, and easy-to-use infant monitoring system. The combination of real-time sensoring, cloud communication, and local visualization gives a very strong foundation to work with to design a smart child care system in the future. The system designed not only validates that it is feasible to use this IoT system for infant monitoring, but it also depicts that this system has a great potential to assist the caregiver in creating a safe, healthy, and comfortable zone for infants.

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