International Journal for Modern Trends in Science and Technology
Volume 12, Issue 02, pages 14-21.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol12issue02.html
DOI: https://doi.org/10.5281/zenodo.18450000

Implementation of a Child Rescue System from Borewell using IoT for Long Range Applications

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To Cite this Article
Nakka Amrutha, Maamillapalli Nagasindhu, Nakka Mahesh, Kandukuri Tharun & Mallavalli Ganesh (2026). Implementation of a Child Rescue System from Borewell using IoT for Long Range Applications. International Journal for Modern Trends in Science and Technology, 12(02), 14-21. https://doi.org/10.5281/zenodo.18450000

Article Info
Received: 02 January 2026; Revised: 22 January 2026; Accepted: 30 January 2026.

KEYWORDS

Child rescue, Borewell, ESP32, Robotic hand, Gas sensor

ABSTRACT

The increasing number of tragic incidents involving children falling into borewells highlights the urgent need for an effective rescue solution. This project proposes the Implementation of a Child Rescue System from Borewells using IoT for Long-Range Applications, leveraging ESP32 as the central controller with Bluetooth-based robotic control. The system integrates a robotic hand capable of vertical and gripping movements, controlled wirelessly via mobile application to safely reach and rescue the child. To ensure the safety of the trapped child, the system employs a gas sensor to detect harmful gases, a DHT11 sensor to monitor temperature and humidity levels, and an ultrasonic sensor to measure the depth and positioning of the child. An air pump is incorporated to supply oxygen in real time, maintaining breathable conditions until rescue is complete. The ESP32 enables data logging and remote monitoring through IoT integration, ensuring that rescue teams receive critical environmental and positional updates instantly. By combining automation, sensing technologies, and IoT-enabled long-range communication, this system provides a practical, safe, and cost-effective approach to borewell child rescue operations.

1. INTRODUCTION

Accidental falls of children into uncovered borewells have become a critical safety concern, particularly in rural and semi-urban regions. Borewells are typically narrow, deep, and poorly ventilated, making manual rescue operations extremely difficult and time-consuming. Delays in rescue often result in severe health complications or fatalities due to suffocation, toxic gases, or extreme environmental conditions. These challenges emphasize the need for a reliable, technology-assisted rescue system capable of operating safely within confined vertical spaces.

Robotic systems designed for narrow and constrained environments have demonstrated significant potential in inspection and rescue applications. Articulated and cable-driven robotic mechanisms offer improved maneuverability and control in vertical shafts, enabling precise movement and positioning. Previous studies on borewell and pipeline inspection robots have shown that robotic platforms can be effectively deployed in deep underground environments where human access is limited. However, many of these systems focus primarily on navigation and inspection rather than rescue and life-support functions.

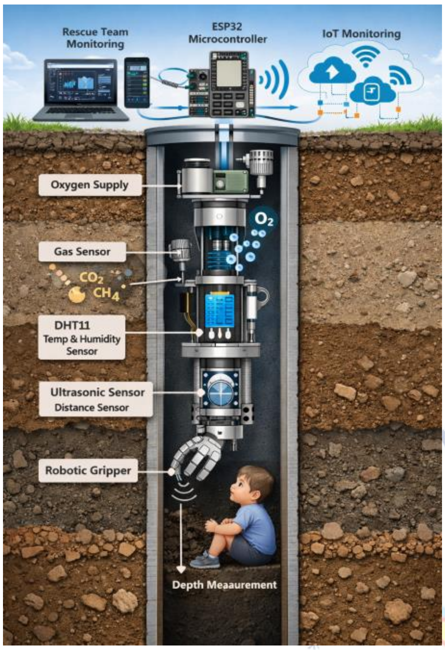

Figure 1. Conceptual overview of the IoT-based child rescue system.

Dedicated borewell child rescue robots have been proposed to address gripping and retrieval challenges. These systems typically include robotic arms, cameras, and basic control mechanisms to assist rescue teams. While such approaches reduce physical risk to rescuers, they often lack continuous environmental monitoring and adequate life-support provisions, which are crucial during prolonged rescue operations. Furthermore, limited communication range restricts real-time coordination between the robotic system and remote rescue teams.

Recent advances in robotic mobility, adaptive motion control, and human-centric robotic design have improved the reliability and safety of rescue-oriented robotic systems. Dynamic reconfiguration of motion control strategies allows robots to adapt to varying borewell geometries and child positioning. Additionally, safe and modular robotic architectures enhance operational robustness during emergency scenarios.

The integration of Internet of Things (IoT) technology enables long-range communication, real-time data acquisition, and remote monitoring—features that are essential for time-critical rescue missions. Modern microcontrollers such as the ESP32 support wireless connectivity, sensor integration, and remote control through mobile applications. By incorporating gas sensing, temperature and humidity monitoring, depth measurement, and oxygen supply into a single IoT-enabled robotic platform, a comprehensive rescue solution can be achieved.

Figure 1 illustrates the conceptual overview of the proposed IoT-based child rescue system deployed inside a borewell. The figure highlights the vertically movable robotic structure equipped with a robotic hand, environmental sensors, and an oxygen delivery mechanism. The ESP32-based IoT framework enables real-time transmission of environmental and positional data to remote rescue teams, ensuring informed decision-making throughout the rescue operation.

II. Related Work

Rescue robotics and inspection robots for confined spaces have received sustained attention in the literature. The following review highlights the most relevant contributions and positions the present IoT-enabled borewell rescue system within that context.

Cable-driven articulated and snake-like robots. Racioppo and Ben-Tzv [1] present the design and control of a cable-driven articulated modular snake robot. Their work demonstrates how cable actuation and modular articulation promote high dexterity and maneuverability in narrow and tortuous environments. The cable-driven approach offers advantages in weight reduction and remote actuation, which are valuable for vertical shaft operations. However, [1] largely focuses on locomotion and control strategies rather than environmental sensing or life-support integration—areas critical for borewell rescues. Our system adapts the modular maneuverability concepts but emphasizes sensor fusion (gas, temperature/humidity, ultrasonic) and life-support (air pump), integrated through IoT for remote monitoring.

Pipeline and borewell inspection robots. Kaur et al. [2] discuss a pipeline inspection and borewell research robot prototype tailored to constrained subterranean environments. Their mechanical design and stabilizing strategies for vertical shafts provide practical insights for deploying robots in narrow wells. While [2] concentrates on inspection and navigation, it lacks a rescue-focused end-effector and real-time remote telemetry suited for long-range coordination. The present design builds on such mobility and stabilization techniques and extends them by incorporating gripping mechanisms, oxygen delivery, and continuous IoT-based telemetry for rescue teams operating at a distance.

Borewell child rescue robots. Arthika et al. [3] explicitly address borewell child safeguarding with a robot equipped for retrieval tasks, including gripping and visual feedback. This paper is directly relevant as it explores many rescue-specific mechanical aspects and operational scenarios. Limitations in [3] include limited discussion on environmental sensing for breathable air and restricted communication range. Our work complements [3] by integrating gas detection and air-supply modules to sustain the child, plus leveraging ESP32-based IoT for long-range data logging and remote monitoring to support distributed rescue teams.

Robotic mobility mechanisms and omnidirectional drives. Tadakuma Osaka [5] investigates omnidirectional driving gears and input mechanisms using passive rollers, which can improve maneuverability on uneven or confined surfaces. Although developed for ground-mobile platforms rather than vertical rescue systems, the kinematic insights and passive compliance ideas can inform stabilization mechanisms and retraction/repositioning strategies for borewell robots, especially when negotiating irregular internal surfaces or supporting the rescue frame near the well mouth.

Social and humanoid robot testbeds for safety and human-centric design. Shukla et al. [6] present SMART, a social mobile advanced robot testbed that emphasizes safety, human–robot interaction, and modular hardware/software frameworks. While targeted to humanoid research, the principles of safe human-centric design, modular testing, and robust communication architectures are transferable to rescue robotics. Incorporating such design philosophies into a borewell rescue system enhances reliability, ensures safer human–robot interactions during delicate rescue manipulations, and eases iterative prototyping and validation.

Dynamic reconfiguration and motion-control adaptation. Schwiegelshohn, Kästner, and Hübner [7] focus on enabling dynamic reconfiguration of numerical methods for robotic motion control tasks. Their work underscores the benefits of adaptable control strategies that can respond to changing environmental conditions or task requirements. For borewell rescues, adaptive control is essential: shaft geometries, child orientation, and environmental conditions may vary rapidly. Implementing reconfigurable control schemes improves robustness and allows the rescue manipulator to adapt grip strategies and movement profiles in real time.

Cross-cutting observations and gap analysis. Collectively, these works provide a strong technical foundation in robotic locomotion, manipulation, testbed design, and adaptive control for confined-space applications. However, few studies combine the mechanical rescue capabilities with continuous environmental life-support monitoring and long-range IoT-enabled telemetry. Specifically, the literature often lacks an integrated solution that (1) provides real-time hazardous gas and microclimate monitoring, (2) supplies breathable air during prolonged rescues, and (3) transmits environmental and positional data to remote rescue teams over long distances. The proposed system addresses these gaps by integrating sensors (gas, DHT11, ultrasonic), an air-pump module, a Bluetooth-controlled robotic manipulator, and an ESP32-based IoT layer for long-range monitoring and data logging—thereby combining the mobility and control strengths from [1], [2], [5], and [7] with the rescue focus of [3] and the human-centric reliability principles from [6].

III. Proposed System

The proposed system aims to provide a safe, efficient, and IoT-enabled solution for rescuing children trapped inside borewells. The system integrates a robotic rescue mechanism, environmental monitoring sensors, life-support components, and long-range communication using IoT technology. An ESP32 microcontroller acts as the central control unit, coordinating sensing, actuation, communication, and data logging during rescue operations.

The rescue unit is mechanically designed to move vertically inside the borewell using a controlled lifting mechanism. A robotic hand (gripper) is attached at the lower end of the system to securely hold the child without causing injury. The gripper's movement and positioning are controlled wirelessly through a mobile application using Bluetooth communication, enabling precise and safe manipulation by rescue personnel.

To ensure the child's safety during rescue, multiple sensors are integrated into the system. A gas sensor continuously monitors the presence of harmful gases such as carbon dioxide or methane inside the borewell. A DHT11 sensor measures temperature and humidity levels, providing information about the internal environment. An ultrasonic sensor is used to determine the depth of the child and the distance between the rescue unit and the child, ensuring accurate positioning of the robotic hand.

An air pump and oxygen supply module is incorporated to provide continuous oxygen delivery to the child during the rescue process. This life-support mechanism is automatically or manually controlled based on sensor readings and operator commands. All sensor data, including gas concentration, temperature, humidity, and depth, are transmitted in real time using IoT connectivity, allowing rescue teams to remotely monitor conditions and make timely decisions.

The integration of IoT enables long-range monitoring, real-time alerts, and data logging, making the system suitable for deployment in remote areas where immediate physical access may be limited. The proposed system thus enhances rescue efficiency, reduces response time, and significantly improves the survival chances of trapped children.

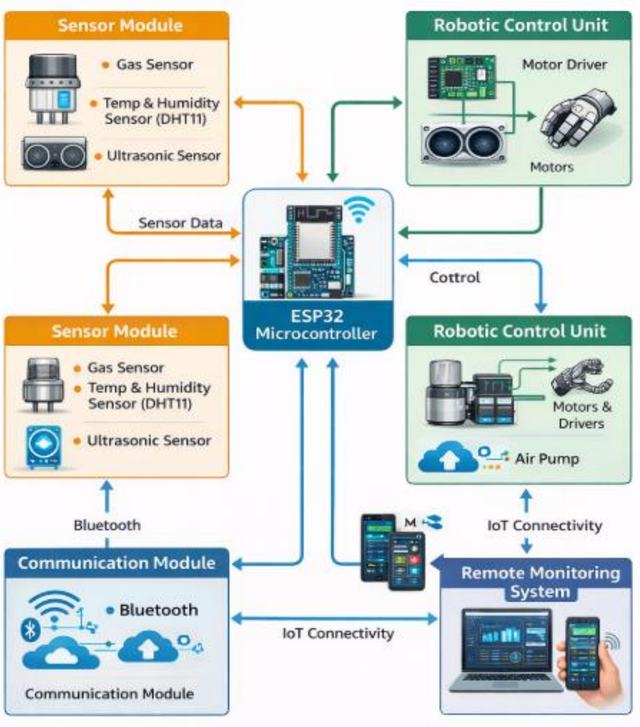

Figure 2. Block diagram of the proposed IoT-based child rescue system from borewells

A.Block Diagram Description

The block diagram of the proposed system consists of the following main components:

1. ESP32 Microcontroller: Acts as the central controller, interfacing with sensors, actuators, and communication modules. It processes sensor data and controls robotic operations.
2. Sensor Module: Includes a gas sensor for detecting harmful gases, a DHT11 sensor for temperature and humidity monitoring, and an ultrasonic sensor for depth measurement and child positioning.
3. Robotic Control Unit: Comprises motors and drivers responsible for vertical movement and robotic hand operation. The gripper ensures safe handling of the child.
4. Oxygen Supply Unit: An air pump mechanism that provides continuous oxygen to maintain breathable conditions inside the borewell.
5. Communication Module: Bluetooth is used for short-range robotic control via a mobile application, while IoT connectivity enables long-range data transmission and monitoring.
6. Remote Monitoring System: Displays real-time sensor readings and system status on a mobile device or web interface for rescue personnel.

IV. Methodology

The methodology of the proposed IoT-based borewell child rescue system focuses on integrating sensing, robotic manipulation, life-support mechanisms, and long-range communication to ensure a safe and efficient rescue operation. The system follows a sequential approach starting from environmental monitoring to robotic rescue and continuous remote supervision.

4.1 Working Principle

The rescue system is deployed vertically into the borewell using a controlled lifting mechanism. Once positioned, the ESP32 continuously collects data from environmental sensors to assess safety conditions. The ultrasonic sensor determines the depth and distance to the child, enabling accurate positioning of the robotic hand. If harmful gases or unsafe temperature conditions are detected, alerts are sent to rescue personnel, and the oxygen supply is activated. The robotic hand is controlled remotely via a mobile application to safely grip and secure the child for extraction. Throughout the process, sensor data and system status are transmitted to a remote monitoring platform using IoT connectivity.

4.2 Algorithm

The step-by-step algorithm followed by the proposed system is given below:

- Initialize ESP32 microcontroller and establish Bluetooth and IoT connections.
- Initialize gas sensor, DHT11 sensor, and ultrasonic sensor.
- Deploy the rescue unit vertically into the borewell.
- Measure borewell depth and child position using the ultrasonic sensor.
- Continuously monitor gas concentration inside the borewell.
- Monitor temperature and humidity conditions using the DHT11 sensor.
- If hazardous gas levels are detected:
  a. Activate the oxygen supply system.
  b. Send alert notification to the rescue team.
- Transmit all sensor data to the remote monitoring system using IoT.
- Receive control commands from the mobile application via Bluetooth.
- Control vertical movement and robotic hand positioning accordingly.
- Secure the child using the robotic gripper.
- Lift the rescue unit carefully along with the child.
- Stop the system once the rescue operation is successfully completed.

4.3 Hardware Implementation

The hardware implementation consists of a compact and modular rescue unit designed to operate inside narrow borewells.

ESP32 Microcontroller

The ESP32 acts as the central processing unit, interfacing with all sensors, actuators, and communication modules. It supports Bluetooth and Wi-Fi connectivity, making it suitable for both short-range control and long-range IoT communication.

Sensor Module

Gas Sensor: Detects harmful gases such as carbon dioxide and methane to assess air quality.

DHT11 Sensor: Measures temperature and humidity inside the borewell.

Ultrasonic Sensor: Calculates the depth and distance between the rescue unit and the trapped child.

Robotic Control Unit

DC motors and servo motors are used for vertical movement and robotic hand operation. Motor driver circuits interface the motors with the ESP32, ensuring precise speed and direction control. The robotic gripper is designed to securely hold the child without applying excessive force.

Oxygen Supply Unit

An air pump system is integrated to supply oxygen continuously. The pump is controlled by the ESP32 and activated automatically or manually based on environmental sensor readings.

Power Supply

A regulated power supply or rechargeable battery pack provides power to the ESP32, sensors, motors, and air pump. Voltage regulators ensure stable operation of all components.

4.4 Software Implementation

The software implementation includes embedded programming, mobile application control, and IoT-based monitoring.

Embedded Software

The ESP32 is programmed using the Arduino IDE. The firmware handles sensor data acquisition, motor control, Bluetooth communication, and IoT data transmission. Sensor values are processed in real time to trigger alerts and control the oxygen supply.

Mobile Application Interface

A mobile application is used to control the robotic movements via Bluetooth. The application provides directional controls for vertical motion and gripper operation, allowing rescue personnel to safely maneuver the robotic hand.

IoT Platform

Sensor data such as gas concentration, temperature, humidity, and depth information are transmitted to a cloud-based IoT platform. This enables real-time visualization, data logging, and remote monitoring by rescue teams.

Alert and Monitoring System

Threshold-based alerts are generated when hazardous conditions are detected. These alerts are displayed on the mobile application or web dashboard, ensuring immediate response during rescue operations.

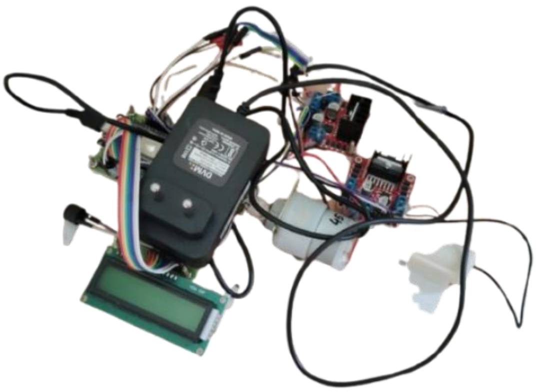

Figure 3. IoT-based remote monitoring interface displaying real-time sensor data and system status.

V. RESULTS AND DISCUSSIONS

This section presents the experimental results obtained from the prototype implementation of the IoT-based child rescue system for borewells and discusses the system's performance under various test conditions. The evaluation focuses on sensor accuracy, robotic control efficiency, communication reliability, and overall system effectiveness during simulated rescue scenarios.

Figure 4. Prototype implementation of the IoT-based borewell child rescue system showing the ESP32 controller, sensor modules, robotic gripper, and oxygen supply unit.

5.1 Experimental Setup

A prototype of the proposed system was developed using an ESP32 microcontroller, gas sensor, DHT11 sensor, ultrasonic sensor, robotic gripper mechanism, and an air pump unit. The system was tested in a simulated borewell environment with controlled depth and environmental conditions. A mobile application was used for Bluetooth-based robotic control, while sensor data were monitored through an IoT dashboard in real time.

5.2 Sensor Performance Analysis

The gas sensor successfully detected variations in air quality inside the borewell model. When the concentration of harmful gases increased beyond predefined thresholds, the system promptly triggered alerts and activated the oxygen supply. This ensured a safer environment during prolonged rescue operations.

The DHT11 sensor provided continuous temperature and humidity readings, enabling effective monitoring of microclimatic conditions inside the borewell. These readings helped assess the risk of heat stress or suffocation and allowed rescue teams to make informed decisions.

The ultrasonic sensor accurately measured the depth of the borewell and the distance between the rescue unit and the target position. This information was crucial for precise vertical positioning and safe operation of the robotic gripper.

5.3 Robotic Control and Rescue Operation

The robotic control unit demonstrated stable and responsive performance during testing. The vertical movement mechanism allowed smooth descent and ascent within the borewell model. The robotic gripper was able to securely grip the dummy object representing the child without causing abrupt motion, indicating its suitability for delicate rescue tasks.

Bluetooth-based control provided real-time responsiveness for robotic movements. The operator could accurately position the gripper using the mobile application, reducing the risk of accidental injury during the rescue process.

5.4 Oxygen Supply Effectiveness

The air pump system effectively supplied oxygen when activated, improving air circulation inside the borewell model. This feature is critical in real-world rescue operations, where oxygen deficiency is a major cause of fatalities. The timely activation of the oxygen supply significantly enhanced the safety aspect of the system.

5.5 IoT Communication and Monitoring

IoT-based communication enabled reliable long-range transmission of sensor data to the remote monitoring interface. Rescue personnel could observe gas levels, temperature, humidity, and depth information in real time. Data logging functionality ensured that all environmental parameters were recorded for further analysis and post-operation review.

The combination of Bluetooth for local control and IoT for long-range monitoring proved effective, offering both precision and situational awareness during rescue operations.

5.6 Discussion

The experimental results demonstrate that the proposed system successfully integrates robotic manipulation, environmental monitoring, and IoT-based communication into a single rescue platform. Compared to traditional manual rescue methods, the system reduces human risk, improves response time, and enhances decision-making through real-time data availability.

Although the prototype performed effectively in controlled conditions, certain limitations were observed. The DHT11 sensor provides moderate accuracy, and higher-precision sensors may further improve environmental assessment. Additionally, the system's performance in deeper or irregular borewells could be enhanced with advanced stabilization mechanisms and camera-based visual feedback.

Overall, the results validate the feasibility of the proposed IoT-based borewell child rescue system as a practical, low-cost, and scalable solution for emergency rescue operations.

VI. Conclusion

This paper presented the implementation of an IoT-based child rescue system for borewells, designed to address the critical challenges associated with rescuing children trapped in narrow and deep underground shafts. By integrating a robotic rescue mechanism, environmental sensing, life-support features, and long-range communication, the proposed system provides a safer and more efficient alternative to conventional manual rescue methods.

The system employs an ESP32 microcontroller as the central control unit, enabling real-time acquisition and transmission of sensor data, including gas concentration, temperature, humidity, and depth information. The incorporation of a robotic gripper controlled via a mobile application allows precise and secure handling of the trapped child, while the oxygen supply unit ensures breathable conditions during prolonged rescue operations. The IoT-enabled monitoring framework enhances situational awareness by providing continuous remote access to critical environmental parameters.

Experimental evaluation of the prototype demonstrated reliable sensor performance, responsive robotic control, and stable communication, validating the feasibility of the proposed approach. The results indicate that the system can significantly reduce rescue time, minimize risk to rescue personnel, and improve the survival chances of trapped children.

In conclusion, the proposed IoT-based borewell child rescue system offers a practical, cost-effective, and scalable solution for emergency rescue scenarios. With further refinement and real-world deployment, this system has the potential to serve as a valuable tool for disaster response teams and improve child safety in borewell-related accidents.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

References

[1] Peter Racioppo, Pinhas Ben-Tzv," Design and control of a cable-driven articulated modular snake robot", in IEEE/ASME transactions on mechatronics, VOL. 24, no. 3, June 2019.

[2] Palwinder kaur, Ravinder kaur, Gurpreet singh "Pipeline Inspection and bore well Research Robot" International Journal of Research in Engineering and Technology (IJRET) volume April 2014.

[3] S.Arthika, S.Chidammbara Eswari, R. Prathipa And. Devasena "Borewell Child Fall Safeguarding Robot," 2018 International ConferenceOn Communication And Signal Processing (Iccsp) , November 2018.

[4] Zhang, Peng & Zhang, Junjie & Chen, Minpeng, "Economic Impacts of Climate Change on Agriculture: The Importance of Additional Climatic Variables Other than Temperature and Precipitation," Journal of Environmental Economics and Management. pp. 8-31, Dec. 2016.

[5] Kenjiro Tadakuma Osaka, "Omnidirectional driving gears and their input mechanism with passive rollers" in Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on 7-12 Oct. 2015.

[6] Shukla, Jainendra, Jitendra Kumar Pal, Faimy Q. Ansari, Gora Chand Nandi, and Pavan Chakraborty. "SMART-A Social Mobile Advanced Robot Test Bed for Humanoid Robot Researchers." in Contemporary Computing, pp. 463-470. Springer Berlin Heidelberg, 2012.

[7] Fynn Schwiegelshohn Florian Kästner Michael Hübner, "Enabling Dynamic Reconfiguration of Numerical Methods for the Robotic

Motion Control Task" in Parallel and Distributed Processing Symposium Workshops, 2016 IEEE International 23-27 May 2013.