

IoT-Based Automatic Bed Vacancy Detection in Hospital Using Load Sensor

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Abstract-An efficient bed availability tracking system is a crucial component in modern healthcare infrastructure, particularly in India where hospital bed scarcity is a major concern. Delays in accessing beds for treatment often lead to severe consequences, especially in rural areas. To address this issue, we propose a smart bed management system utilizing Internet of Things (IoT) technology, load sensors, and a web-based interface. Unlike traditional systems that rely solely on manual updates or basic IR sensors, our approach incorporates load sensors to accurately detect the presence or absence of a patient on a bed. These sensors are integrated with an Arduino microcontroller, which collects real-time data and transmits it to a central web server.

In addition to tracking bed occupancy, our system also links each bed with patient details, including ID, admission time, and status, allowing hospital staff to manage and allocate resources more effectively. This system ensures transparency for patients and their families, who can check real-time availability and pre-book beds remotely. Hospital administrators benefit from centralized monitoring, enabling rapid response in emergency situations and better utilization of available facilities. The integration of load sensors improves detection accuracy over traditional IR sensors, reducing false positives due to movements around the bed. This project provides a scalable and user-friendly solution for both urban and rural hospitals, aiming to reduce patient wait times and improve overall hospital management efficiency.

Keywords: IoT Technology, Load Sensors, Arduino, Web Server, Bed Availability, Patient Management, Real-time Monitoring

INTRODUCTION

In recent years, the healthcare sector has witnessed a growing need for efficient hospital resource management systems, especially in developing countries like India. One of the most pressing challenges in this domain is the timely allocation and management of hospital beds. With the increasing burden on healthcare facilities due to population growth, pandemics, and the rise in non-communicable diseases, hospitals—particularly those in rural and semi-urban areas—struggle to keep up with patient demands. The scarcity of available beds often results in delays in admission and treatment, which can have severe implications for patient health and overall hospital workflow.

[2] Despite growing digital transformation in healthcare, no existing system currently integrates bed vacancy detection with patient information at both administrative and public levels. This gap leads to delayed hospital admissions,

miscommunication, and increased workloads on hospital staff. To address this issue, this research proposes a Load Sensor-Based IoT Smart Bed Management System. The system will accurately detect bed vacancy using load sensors and will associate each bed with corresponding patient details, which will be accessible through a centralized web interface. This innovation contributes to smart healthcare infrastructure by improving transparency, real-time decision-making, and overall efficiency.

bed vacancy detection system. That will help in solving the

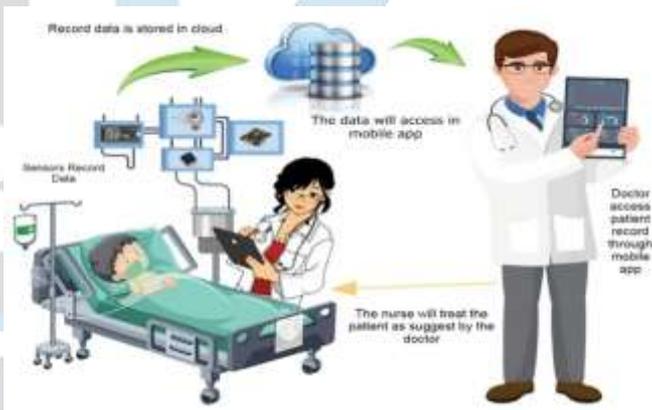


Fig. 1: IOT in Healthcare

I. BACKGROUND

[3] **Hardware Techniques:** The proposed system utilizes various hardware components from the Internet of Things (IoT) ecosystem to monitor bed occupancy and manage patient-related data. Key devices include load sensors, Arduino microcontrollers, and communication modules. These components interact in real-time to detect bed status, manage patient records, and transmit data to a web-based platform.

[4] **Sensor:** A load sensor (also called a load cell) is an electromechanical device that converts force or weight into an electrical signal. In this system, the load sensor is embedded beneath each hospital bed. It continuously monitors weight variations, determining whether a bed is occupied based on predefined weight thresholds.

Unlike PIR or IR sensors, which may misinterpret nearby movement occupancy, load sensors are highly accurate and only respond to actual pressure changes, thus minimizing false positives. When a patient lies on or vacates a bed, the load sensor captures this data and relays it through the microcontroller for further processing. The analog signal is converted to a digital signal to make it read Arduino board.

Infrared Sensor: Infrared radiation is the most common form of electromagnetic radiation that comes from the electromagnetic spectrum and has a longer wavelength than visible microwaves. Simply put, less electricity was needed. Since it can detect radiation with a wavelength range of 8 to 14 m, it can realistically detect the human body. PIR sensors, also known as pyroelectric sensors or passive infrared radiation sensors, are employed as motion detectors. The motion's velocity, direction, displacement, acceleration, and time can all be calculated. Even in movement, it is more precise and effective. As needed by the user, the output is transformed into digital form. There are active and passive types of infrared sensors. Active infrared sensors may both emit and detect infrared light. The two elements that make up an active IR sensor are a light-emitting diode (LED) and a receiver. When something is near the sensor, the LED's infrared light that reflects off of it is picked up by the receiver. Active IR sensors are often used in the obstacle detection systems of robots as proximity sensors. PIR sensors do not produce infrared radiation themselves; they only detect it when it is there. An infrared filter that blocks out all other light wavelengths, a Fresnel lens that concentrates light from various angles into a single point, and a housing unit that shields the sensor from other environmental factors like humidity are all parts of passive infrared sensors.

LCD Display: A liquid-crystal display is a flat-panel display or other electronically controlled optical device that uses polarizers and the light-modulating properties of liquid crystals. Liquid crystals don't generate light directly; instead, they use a backlight or reflector to produce coloured or monochromatic images. The results of the IoT sensor would then be loaded on the LCD for display, depicting the vacancy at the lower level rather than showing it on the website. Because LCDs have a parallel interface, operating an LCD requires the microcontroller to simultaneously manage many interface pins. Where data is written to the LCD's memory is determined by a register select (RS) pin on the interface. You can decide between using the instruction register, which is where the LCD controller looks for instructions on what to do next, or the data register, which stores the content of the screen. Additionally, you have a choice of the writing mode, the enable pin, and the eight data pins (D0-D7), as well as the read/write (R/W) pin. The states of these pins (high or low) correspond to the corresponding operations when bits are written to or read from registers, respectively.

[5] **Software Module:** The **software module** serves as the brain of the entire IoT framework. It collects data from the load sensors via the Arduino, processes it, and sends it to a **centralized server** where it is stored and displayed. The module is programmed in languages like C/C++, compatible with Arduino boards, and designed to handle tasks such as data acquisition, sensor calibration, and conditional logic (e.g., determining weight thresholds for occupancy). Additionally, the software module supports the **binding of patient data to each bed**. For instance, when a new patient is admitted, their details are entered into the system and associated with a specific bed. As long as the load sensor confirms the patient's presence, their profile remains linked to that bed. This feature aids in real-time decision-making for hospital administrators, enabling quicker discharges, transfers, or emergency responses.

[6] **Arduino Programming:** The Arduino Integrated Development Environment (IDE) is used to write the control logic (referred to as "sketches") for the load sensor and LCD modules. The Arduino Uno or Mega boards serve as the system's microcontroller, bridging the gap between analog sensor input and digital outputs like LCD updates and web server communication. The setup function in Arduino initializes the hardware components. The loop function constantly reads weight data from the load sensor and triggers updates to both the LCD and the server. A conditional

[6] **Database Module:** A relational database management system (RDBMS) forms the backend of the project, responsible for storing and organizing both occupancy data and patient records. Each bed entry in the database includes:

- Bed ID
- Occupancy status (Occupied/Vacant)
- Patient ID
- Admission timestamp
- Medical condition/priority level

Structured Query Language (SQL) is used to manage the data, allowing easy retrieval, updates, and integration with web-based dashboards. This structure ensures a one-to-one mapping between physical bed status and digital patient records, maintaining data integrity and usability. The database is scalable and can be extended to accommodate new beds, departments, or patient attributes. It also enables data analytics, such as usage statistics or average occupancy time, helping administrators improve operational efficiency over time.

LITERATURE SURVEY

According to some surveys, there is work going on with similar systems in different sectors.

[10] For lasers, Solonom old, Nick S. Bennett and others have presented "Internet-of-Things-Enabled Smart Bed Rail for Application in Hospital Beds" in their research paper. This study served as the basis for the interaction between the hospital's Wi-Fi and internet systems and the sensors. For the best situation, we have calculated the cost of Bed sensor, LoRa Module. The necessity of ports for connecting to the internet will be supported by this effort.

[11] Research introduced a smart bed rail prototype that was equipped with IoT capabilities, including load sensors, to monitor patient presence. Data collected by these sensors were transmitted to the nurse's station using LoRaWAN technology, which ensured reliable communication even during internet disruptions. This study emphasized the importance of robust connectivity and low power consumption in healthcare environments. S. Kumar and A. Singh, "Smart bed rail with IoT integration for hospital monitoring,"

[12] An innovative system explored the use of accelerometers attached to beds to detect occupancy. By analyzing the acceleration signals, this system was able to determine bed occupancy status and track patient movement in real-time. The system demonstrated the potential of using motion sensors integrated into IoT frameworks for effective bedmanagement. By R. Patel, M. Sharma, and K. Mehta, "Accelerometer-based bed occupancy detection system for hospitals,"

[13] A study developed an IoT-based bed tracking system that utilized various sensors to detect patient presence and transmitted this information to a web interface. This system allowed for real-time bed availability updates, enhancing hospital management and operational efficiency. The research focused on leveraging IoT technologies to improve communication and data sharing across hospital departments. J. Singh, R. Kumar, and N. Gupta, "Automatic bed tracking system using IoT for hospital management,"

[14] A pilot study designed a system to prevent bed falls by monitoring patient movements using pressure-sensing pads. The system alerted healthcare staff when an increased likelihood of a bed exit was detected. This study highlighted the use of pressure sensors to monitor both patient safety and bed occupancy, showcasing the role of sensors in maintaining hospital care quality. A. Verma and P. Gupta, "Medical IoT system to prevent bed falls using pressure sensor".

II.METHODOLOGY:

It will come as a revolutionized system for the rural areas as they had to wait for a long time in search of bed but could find the bed. But this system will solve their problem in some way by locating a suitable location, a better hospital with an available bed. For this, we are going to use some kind of technology and tools, i.e., Arduino, IR sensors, Load sensor, LCD (to show the current counter of the filled status of beds out of the number of beds in a particular hospital), and a web interface (React is used to give the front end to the system).

[1] The proposed system is designed to detect hospital bed occupancy using IoT-enabled load sensors, with the goal of automating bed tracking and associating it with patient-specific data. First, load sensors (typically strain gauge-based with HX711 amplifiers) are placed beneath each hospital bed to accurately measure the weight of the occupant. These sensors are calibrated to detect when a bed is occupied based on a pre-defined threshold value. Once occupancy is detected, the data is transmitted to a microcontroller for further processing.

[2] An Arduino UNO microcontroller forms the core of the processing unit. It continuously collects real-time input from the load sensors, determines the bed status (occupied or vacant), and pairs this data with additional patient information such as ID, admission time, and medical status. A local LCD screen is optionally connected to each setup to display immediate bed status for the ward staff.

[3] The web application is developed using standard technologies such as PHP and HTML/CSS for the front end, ensuring cross-platform accessibility and user-friendly interaction. Through this real-time integration of load sensor data and IoT technologies, the system ensures transparency, reduces human error, and enhances emergency response and resource allocation across both rural and urban hospitals.

[4] All processed data is sent to a centralized web server, where it is stored in a MySQL relational database. Each record includes the bed number, occupancy status, patient identification, and relevant timestamps. The server is configured using PHP scripts that interface between the incoming sensor data and the backend database. This web server also provides data to two different user interfaces: one for hospital administrators and another for public users. The hospital admin dashboard allows staff to view ward-wise

Aspect	IoT-Based Automatic Bed Vacancy Detection	Existing IoT-Based Systems in Medical Field
Detection Method	Sensor	Various sensors (e.g., motion, pressure)
Purpose	Detect bed occupancy/vacancy in real-time	Monitor patient vital signs, activity, etc.
Application	Healthcare facilities	Hospitals, home healthcare, etc.
Primary Functionality	Bed occupancy monitoring	Patient monitoring and management (Manually)
Accuracy	High	Variable
Real-time Monitoring	Yes	Yes/No
Data Transmission	Wireless (e.g., Wi-Fi, Bluetooth)	Wireless and wired (e.g., Wi-Fi, Zigbee)
Cost	Moderate	High
Scalability	Scalable	Not Scalable
Installation and Maintenance	Complexity Low	Variable, depends on system complexity
Human Interference	No	Yes/No
Use Cases	Bed Management, Resource Allocation	Patient Monitoring

Table 1:1 Comparison based on different papers

bed occupancy, assign patients to beds, and update patient status. Meanwhile, the public interface shows available beds in real time and optionally allows users (e.g., emergency responders or family members) to book beds or schedule admissions remotely. This system offers significant improvements over conventional methods by providing reliable, sensor-based occupancy data and real-time visibility of bed status. It reduces administrative workload, minimizes errors caused by manual updates, and offers public access to critical information during emergencies such as COVID-19 or natural disasters. Moreover, it is scalable and can be deployed in both urban hospitals and under-resourced rural facilities with limited staff.

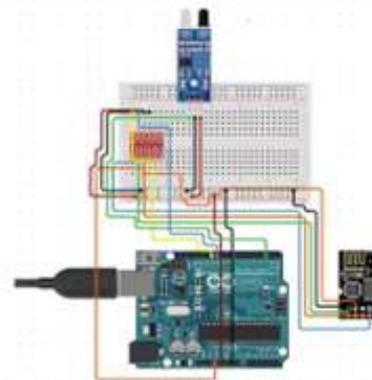


Fig: Circuit Diagram

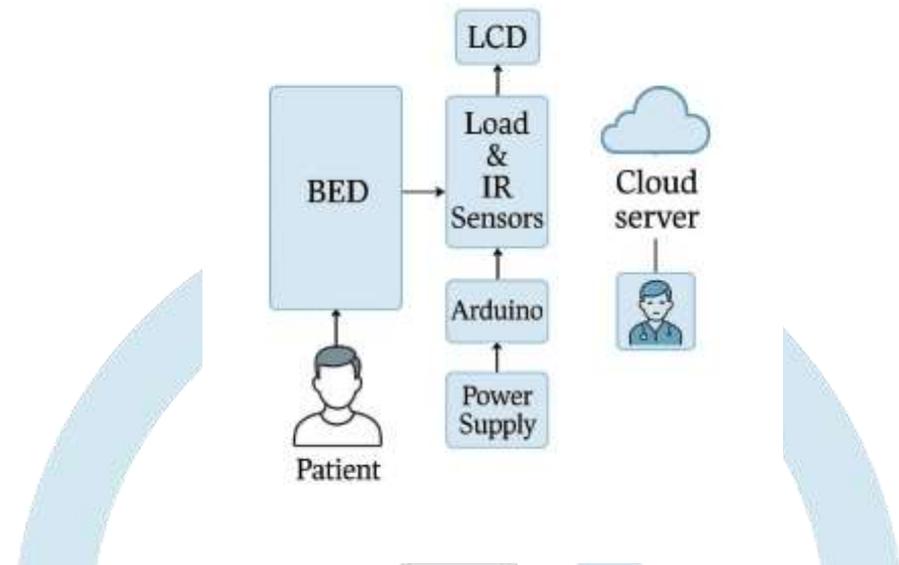


Fig. 3: Flow Chart of system

1) The system begins with the load sensor detection stage, where load cells are installed under each hospital bed. These sensors are capable of detecting changes in weight, making them ideal for identifying whether a bed is occupied or vacant. When a patient lies down on the bed, the sensor reads the pressure and produces an analog signal. This signal is then passed through an HX711 amplifier and analog-to-digital converter, which amplifies and converts the signal into a digital format readable by a microcontroller. This allows the system to continuously monitor the bed in real time without requiring manual verification. For transferring data from the sensor to the server, we are going to use a Bluetooth module, which will transfer the signals from the sensor to the server. Here, in the database, all the important information will be stored.

2) The next step in the system is data processing using an Arduino microcontroller, typically an Arduino UNO. The Arduino receives the digital input from the HX711 module and evaluates whether the bed is

occupied based on a predefined weight threshold. If the weight crosses the threshold (e.g., more than 20 kg), the Arduino assumes that the bed is occupied. Simultaneously, the microcontroller links this information with patient-specific data such as Patient ID, admission time, and medical status (e.g., stable, critical). This local processing ensures fast response and reduces the load on the server by only transmitting meaningful, filtered data.

3) Following data processing, the Arduino uses an ESP8266 Wi-Fi module to establish a wireless connection with a remote web server. The system sends updated data packets that include bed ID, occupancy status, and patient details to the server. This server is built using web technologies such as PHP for scripting and MySQL as the backend database. All bed-related data is structured and stored in the database, enabling efficient querying and access. This architecture supports scalability, allowing multiple beds across wards or hospitals to be connected to the same.

Bed Number	Status	Bed Number	Status
Bed-1	✓ Available	Bed-1	✗ Not Available
Bed-2	✓ Available	Bed-2	✗ Not Available
Bed-3	✓ Available	Bed-3	✓ Available
Bed-4	✓ Available	Bed-4	✓ Available
Bed-5	✓ Available	Bed-5	✗ Not Available
Bed-6	✓ Available	Bed-6	✓ Available

FIG: AVAILABILITY OF BED

FIG: VACANT BED IN HOSPITALS

III. RESULT ANALYSIS:

The implementation of the IoT-based bed vacancy detection system using load sensors successfully demonstrated accurate and real-time monitoring of hospital bed occupancy. During testing, load cells were placed beneath each bed, and the system was calibrated to trigger occupancy status when weight exceeded a set threshold (typically around 20 kg). This calibration allowed the system to distinguish between actual patient presence and minor disturbances such as medical equipment or hand placements. As a result, the load sensor approach proved to be significantly more reliable than traditional infrared or PIR sensors, which often generate false occupancy readings due to nearby motion or ambient temperature changes.

Data collected from the load sensors was processed through the Arduino UNO microcontroller and transmitted via the ESP8266 Wi-Fi module to a centralized web server. The web interface reflected real-time updates of bed status across all test units, showing “Occupied” or “Vacant” labels along with corresponding patient details (such as ID and admission time). Changes in bed occupancy were detected and reflected on the dashboard with minimal delay, typically under 2 seconds. Additionally, the system was tested for multiple concurrent updates from different beds, and it consistently maintained synchronization with the database without data collisions or loss, demonstrating its scalability.

Moreover, the local LCD display attached to each unit provided immediate visual feedback to staff within the ward. This helped reduce manual verification time and allowed nurses to quickly assess room readiness. Feedback from test users (hospital staff) confirmed that the system was intuitive and improved overall workflow. The integration of patient data into the dashboard further enhanced hospital administration efficiency by centralizing patient-bed records. Overall, the system achieved high accuracy, fast response time, and user satisfaction, indicating its potential for real-world hospital deployment, especially in facilities with high patient turnover or limited staff.



II. CONCLUSION

In this paper, we proposed and implemented a smart hospital bed monitoring system that utilizes load sensors and IoT technology to accurately detect bed occupancy and associate it with patient details in real time. The system successfully addresses the limitations of traditional manual or infrared-based methods by offering a more precise, automated, and scalable solution. Through the integration of load sensors, Arduino microcontrollers, and wireless data transmission, the

system ensures minimal human intervention while improving the reliability and speed of bed status updates.

The results demonstrated that the system is capable of accurately tracking occupancy status with minimal error, even in dynamic hospital environments. The real-time web interface and local LCD display provide immediate access to crucial information for both hospital staff and patients’ families, significantly improving hospital workflow and transparency. By centralizing patient-bed data, hospital administrators can make faster, more informed decisions, particularly during emergencies such as pandemics or natural disasters. healthcare service delivery.

Overall, the proposed system enhances the efficiency of hospital bed management and can be easily adapted to a wide range of healthcare settings, including rural and under-resourced hospitals. Future improvements may include mobile app integration, advanced analytics, and compatibility with hospital information systems (HIS) to provide a more comprehensive smart healthcare solution.

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