# Design and Implementation of IOT-Based Intravenous (IV) Bag Monitoring and Alert System

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### Abstract

*Health, being a critical aspect of daily life, demands heightened attention, especially when a patient is hospitalized. In densely populated hospitals with limited nursing staff, the continuous monitoring of Intravenous (IV) fluid becomes a challenge. If the IV fluid is not properly monitored, severe consequences may arise, such as blood reflux or the entry of air bubbles into the patient's bloodstream when the fluid bottle runs dry. To address this, the project proposes the design and implementation of an IoT-based intravenous infusion monitoring and Alert System using the Huamao Communication 12 radio frequency module (HC-12) for wireless communication. The system also integrates Espressif Wi-Fi SoC ESP8266 wi-fi connectivity for real-time data transmission to the ThinkSpeak cloud platform. The hardware setup includes a load cell with an HX711 interface for continuous measurement of the IV fluid's weight, and a laser sensor positioned on the drip chamber to monitor the droplet rate. An Arduino Uno microcontroller coordinates the sensors and decision logic. When the fluid level drops below a critical threshold or the drip rate becomes abnormal, an alert is transmitted wirelessly via the RF module to a remote receiver unit (e.g., nurse's station), where the patient's information and alert status are displayed. Additionally, the ESP8266 module uploads real-time data to the internet for remote monitoring and analytics. The performance evaluation of the prototype demonstrated a system success rate of approximately 96.8% in accurately detecting both low-fluid and abnormal drip rates. This low-cost, easily deployable system enhances patient safety by ensuring timely intervention from medical staff and is particularly suited for resource-constrained hospitals that cannot afford expensive commercial IV monitoring system.*

**Keywords:** *Intravenous (IV) monitoring, IoT-based healthcare, Arduino Uno, drip rate monitoring, ESP8266 Wi-Fi, ThingSpeak cloud, hospital automation.*

## 1.0 Introduction

The integration of Internet of Things (IoT) technology into healthcare systems has ushered in a new era of smart healthcare solutions, enhancing patient care and monitoring. One such innovative application is the development of IoT-based intravenous (IV) systems, which can significantly improve the precision and reliability of IV fluid administration. Traditional IV system, while effective, often requires constant manual supervision by medical staff, which can result in human errors and significant inefficiencies within busy hospital environments [1].

An IoT-based IV system incorporates advanced sensors and connectivity to automate and monitor the infusion process in real time. This system typically consists of components such as flow sensors to measure the rate of IV fluid, drip sensors to count the drops, and a servo motor to control the IV clamp. These components are connected to a microcontroller, such as an Arduino, which processes the sensor data and controls the servo motor accordingly. By integrating a Wi-Fi module such as the ESP8266, the system can transmit data to a remote server, facilitating the monitoring of IV administration by healthcare providers [2]. The advantages of implementing an IoT-based IV system are manifold. Firstly, it enhances patient safety by reducing the likelihood of over-infusion or under-infusion of fluids, which can have serious medical consequences. Secondly, the system improves efficiency in healthcare settings by enabling medical staff to monitor multiple patients simultaneously from a central location, thereby optimizing resource allocation. Lastly, it provides a comprehensive data log of the infusion process, which is invaluable for medical records and future treatment planning [3].

However, the development and deployment of such systems pose several challenges. Ensuring the accuracy and reliability of sensor data is optimal, as any discrepancy can lead to incorrect fluid administration. Moreover, the system must be robust and secure, protecting patient data from potential cyber threats. Integrating these systems into existing healthcare infrastructure also requires careful planning and consideration of compatibility issues [4].

In conclusion, the design and construction of an IoT-based intravenous system using ESP8266 and Arduino represent a significant advancement in medical technology. By combining real-time monitoring, automation, and remote-control capabilities, these systems can automatically enhance the quality of patient care. Future research and development will continue to refine these technologies, addressing current challenges and expanding their applications in the healthcare industry [5].

Electrical Intravenous (IV) drip monitoring systems are used to monitor and regulate the delivery of fluids and medication to patients through an IV line. The purpose of IV drip systems is to ensure the safe and effective delivery of fluids and medication administration to patients in healthcare settings, including hospitals, clinics, and home healthcare. Such systems can help healthcare providers monitor the rate of infusion, measure the total volume infused, and detect potential complications such as overhydration or dehydration, thereby improving patient outcomes.

## 2.0 Materials and Methods

This section outlines the hardware and communication methods used to implement the IoT-based IV monitoring system. The design employs a load cell with an HX711 amplifier to measure IV fluid weight and a laser drop sensor to detect drip rate. An Arduino Uno processes the sensor data, while an HC-12 RF module provides local wireless alerts and an ESP8266 module enables cloud updates via ThingSpeak. The materials and procedures for sensor interfacing, data transmission, and system operation are described in the following subsections.

### 2.1 Materials

The materials used in this system consist of hardware elements responsible for sensing, processing, communication, and alerting, while the software includes the embedded Arduino program and cloud-based applications that handle data acquisition, analysis, wireless transmission, and remote monitoring

#### 2.1.1 Hardware Components

The hardware components used include:
i. Arduino Uno: central microcontroller for data acquisition and control.
ii. Load Cell (1–5 kg) with HX711 Amplifier: measures IV bag weight to determine remaining fluid volume.
iii. Laser/Infrared Drop Sensor: monitors droplet flow rate in the drip chamber.
iv. HC-12 RF Module: provides wireless data transmission to the nurse's station.
v. ESP8266 Wi-Fi Module: enables cloud connectivity for real-time monitoring via ThingSpeak.
vi. LCD Display (16×2/20×4): shows IV status and alerts locally.
vii. Buzzer and LED Indicators: provide audible and visual alerts.
viii. 5V Regulated Power Supply: powers the system.
ix. Receiver Unit Components: Arduino Uno, HC-12, LCD, buzzer, and power supply at the nurse's station.

#### 2.1.2 Software Tools
i. Arduino IDE: used for firmware development and uploading.
ii. Embedded C/C++: programming language for system implementation.
iii. ThingSpeak API: cloud service for remote monitoring, visualization, and analytics.

#### 2.1.3 Cloud Platform
ThingSpeak IoT Analytics Platform manages data logging, visualization, and trend analysis in real-time.

### 2.2 Methods

The method involves collecting sensor data, processing it through the microcontroller, transmitting alerts via wireless communication, and updating the cloud platform for real-time remote monitoring and decision making

#### 2.2.1 System Design

The system consists of two main units:
i. Transmitter Unit (IV Stand): placed near the patient, consisting of the load cell, HX711, drop sensor, Arduino Uno, ESP8266, HC-12, LCD, buzzer, and LEDs.
ii. Receiver Unit (Nurse's Station): includes HC-12 receiver, Arduino Uno, LCD, and buzzer for centralized monitoring.

The overall system is designed as a two-unit network: the Transmitter unit (Figure 1), located at the patient's bedside, and the Receiver Unit (Figure 2), positioned at the Nurse's Station. The Transmitter unit's Load cell and Drop sensor feed fluid data to the Arduino Uno microcontroller, which processes the readings and checks for critical conditions like low fluid or abnormal flow. If an issue is found, the Transmitter simultaneously triggers local alarms (Buzzer/LED), uploads real-time data to the remote ThingSpeak cloud via the Esp8266 Wi-Fi Module, and sends an immediate alert wirelessly through the HC-12 RF Module. The Receiver Unit uses its own HC-12 RF Module to intercept this local alert, which its dedicated Arduino Uno processes to activate a buzzer

and display the patient's alert status on an LCD for prompt staff intervention. The block diagrams of the transmitter and receiver (Nurse station) units are shown in *Fig.1* and *Fig.2*.
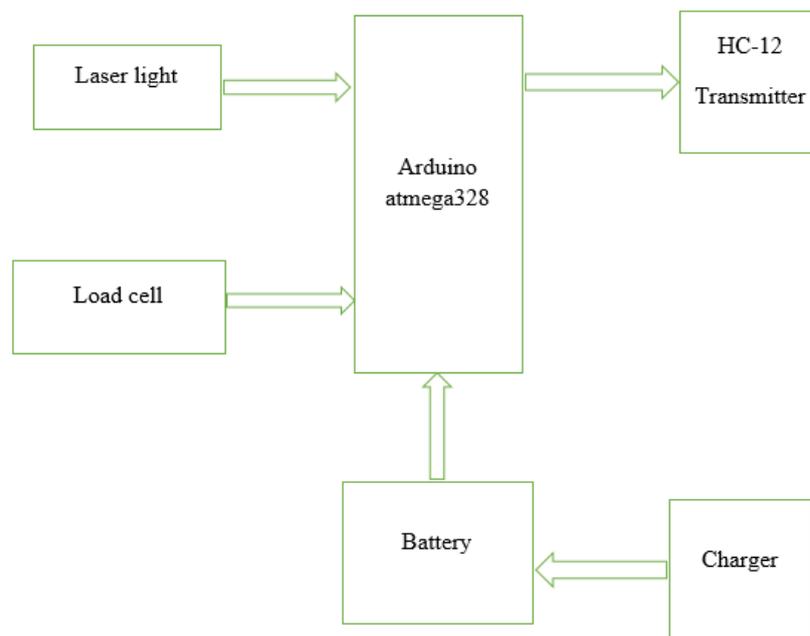


Figure 1: The block diagram of IOT IV Bag Monitoring and Alert System Transmitter
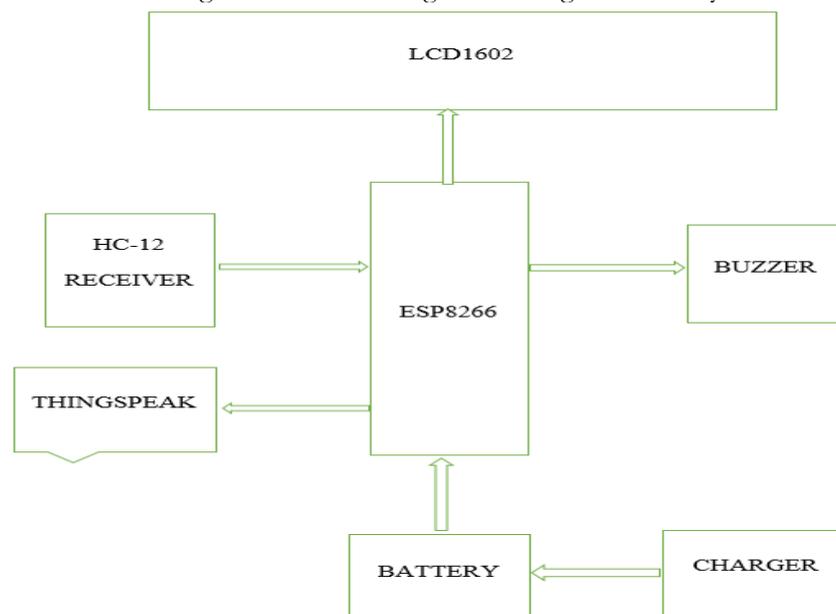


Figure 2: The block diagram of IOT IV Bag monitoring and alert system receiver

## 2.3 Working Principle

The load cell measures the IV fluid weight while the drop sensor records the drip rate. The Arduino Uno processes sensor data and compares it against preset thresholds. If abnormal conditions occur (low fluid or abnormal drip rate), the system triggers:
  i.    Local alerts: buzzer and LED at the patient's bedside.
  ii.   Remote alerts: wireless transmission via HC-12 to the nurse's station.
  iii.  Cloud alerts: Wi-Fi module uploads data to ThingSpeak for remote access.

Figures 3 and 4 present the detailed electrical wiring for the entire monitoring system, showing how the components are physically connected to their respective Arduino Uno microcontrollers. In the Transmitter Schematic (Figure 3), the Load Cell/HX711 and the Drop Sensor are wired as inputs to the Arduino. At the same time, the communication modules (HC-12 and ESP8266) and the local alerts (LCD, Buzzer, LED) are connected to the Arduino's input/output ports. In the Receiver Schematic (Figure 4), the circuit is simpler, showing the HC-

12 RF Module connected to the Nurse Station Arduino's serial port to receive data, which is then output to the LCD Display and the Buzzer for staff notification. The circuit schematic is presented in *Fig. 3 and Fig. 4.*
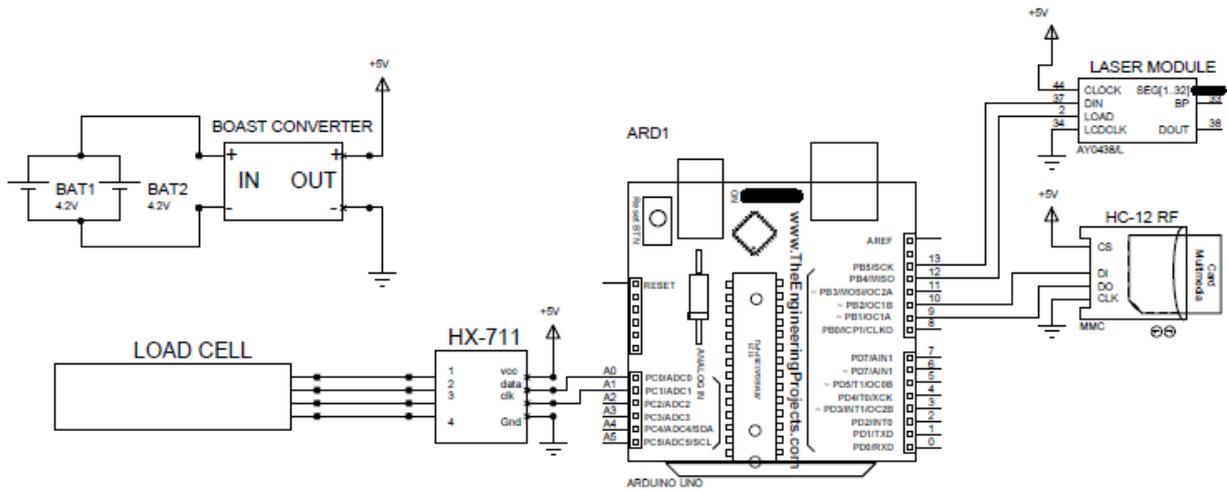
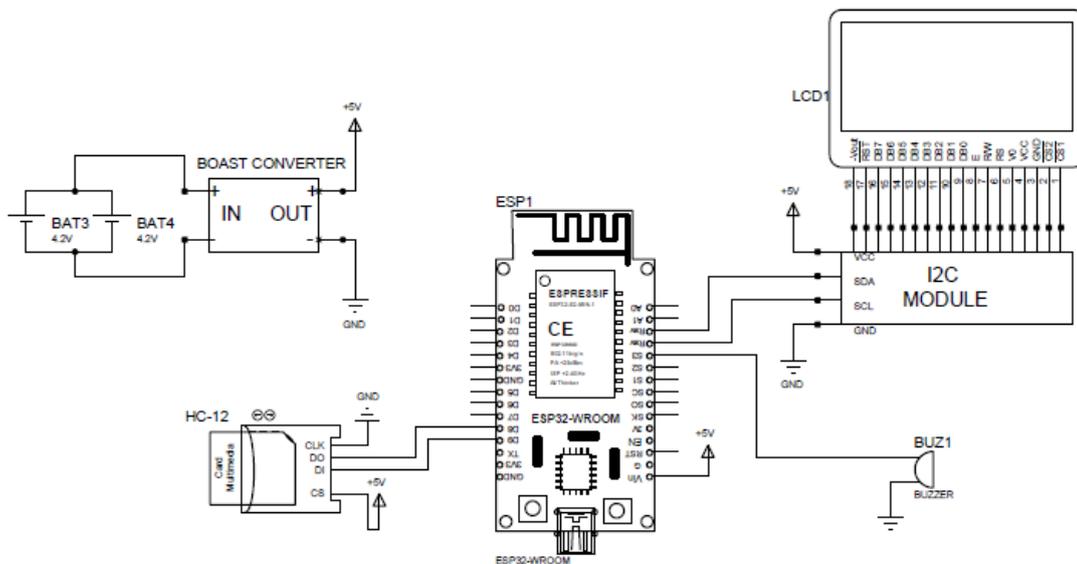Figure 3: The Schematic Diagram of IOT IV Bag Monitoring and Alert System Transmitter

Figure 4: The Schematic Diagram of IOT IV Bag Monitoring and Alert System Receiver

## 2.4 Data Flow Process

The operation follows four stages:

  i.   Sensing: load cell and drop sensor capture weight and drip rate.
 ii.   Processing: Arduino Uno analyzes sensor data against thresholds.
iii.   Communication: abnormal conditions trigger HC-12 transmission and ESP8266 cloud upload.
 iv.   Alert & Display: buzzer, LED, and LCD modules notify staff locally and remotely.

## 2.5 System Implementation Steps

  i.   Hardware assembly and sensor integration with Arduino Uno.
 ii.   Programming of a microcontroller for sensing, processing, and communication.
iii.   Setup of transmitter unit at IV stand and receiver at nurse's station.
 iv.   Testing under varying IV fluid levels and drip conditions for validation.

## 2.6 Design Calculation
## 2.6.1 Load Cell Calibration

To accurately measure the IV bag's remaining fluid, the 5 kg load cell was calibrated using the HX711 amplifier module and Arduino. Known weights (0 g, 200 g, 400 g, 600 g, 800 g, 1000 g) were placed on the load cell, and the corresponding digital output readings from the HX711 were recorded.

Table 1: Calibration of the 5kg Load Cell Amplifier

| S/N | Weight (g) | ADC Count |
|---|---|---|
| 1 | 0 | 150 |
| 2 | 200 | 16000 |
| 3 | 400 | 48000 |
| 4 | 800 | 64000 |
| 5 | 1000 | 80050 |

**Source:** Akau *et al.* (2025)

Using linear regression, the calibration equation obtained was:
$$ADC\ Count = 79.894W + 150 \qquad (1)$$
where:

   i.    $WWW$= Weight in grams
   ii.   Slope = 79.894 counts/gram
   iii.  Intercept = 150 counts

Thus, the calibration factor (grams per count) is:
$$Calibration\ Factor = \frac{1}{179.894} = 0.01252\ \text{g/count} \qquad (2)$$
Hence, the weight of the IV bag can be calculated as:
$$W = (ADC - 150) \times 0.01252W \qquad (3)$$
For example, if the ADC value measured is 80,050:
$$W = (80{,}050 - 150) \times 0.01252 = 1000.08\ g$$
This confirms the calibration accuracy with less than 0.1% error is anticipated.

## 2.6.2 Flow Rate Determination

The drip rate is calculated by counting the number of drops detected by the IR sensor over a specific time interval. The basic relationship used is:
$$Drip\ Rate\ \left(\frac{drops}{min}\right) = \frac{N}{t(s)} \times 6\ drops/min \qquad (4)$$
This measured value was compared with the manually observed rate to validate accuracy.

## 2.6.3 Threshold Level Determination

The critical low fluid level was experimentally determined as 50g, corresponding to approximately 2% of the total IV volume. When the calculated weight $W \le 50g.$ An alert is triggered to notify the nurse station and ThingSpeak cloud.

The alert condition is given as:
$$Walert \le 50\ g \qquad (5)$$
Similarly, an irregular drip rate condition is detected when:
$$Drip\ Rate < 20\ drops/min \qquad (6)$$
Both thresholds were coded into the Arduino firmware to trigger a buzzer and send real-time data via the HC-12 and ESP8266.

## 2.6.4 Power Requirement Estimation

The total current drawn by the system was estimated as:

Table 2: Current Drawn by Each Component Transmitter Node

| S/N | Component | Current (mA) | Quantity | Total |
|---|---|---|---|---|
| 1 | Arduino Uno | 50 | 1 | 50 |
| 2 | HX711 Load Cell Amplifier | 20 | 1 | 20 |
| 3 | IR Drop Sensor | 20 | 1 | 20 |
| 4 | HC-12 Transceiver | 40 | 1 | 40 |
| 5 | ESP8266 Wi-Fi Module | 70 | 1 | 70 |
| 6 | LED | 5 | 1 | 5 |
| | **Total Current Drawn** | | | **205mA** |

Using a 5 V DC supply:

$$P = V \times I = 5 \times 0.205 = 1.03W$$

Therefore, a 5V 1A adapter is sufficient to power the entire system reliably.

Table 3: Current Drawn by Each Component in the Receiver Node (Nurse Station)

| S/N | Component | Function | Current (mA) | Quantity | Total |
|---|---|---|---|---|---|
| 1 | Arduino Uno | Control and display | 50 | 1 | 50 |
| 2 | HC-12 Transceiver | Data reception | 40 | 1 | 40 |
| 3 | Buzzer | Alert signal | 20 | 1 | 20 |
| 4 | LCD Display | Display fluid status | 30 | 1 | 30 |
| 5 | LED Indicator | Visual Alert | 10 | 1 | 10 |
| | **Total Current Drawn** | | | | **150mA** |

At 5 V:

$$PR = 5 \times 0.15 = 0.75 \ W$$

Thus, the receiver unit can be powered using a 5V, 500mA adapter or a small, regulated DC supply.

### 2.6.5 Experimental Setup

The prototype system was implemented and tested in a controlled laboratory environment simulating real hospital conditions. The transmission unit was mounted on an IV stand and connected to a saline bag (500 mL capacity). The Nurse's station was positioned 10 meters away to represent a nurse's station. Power was supplied via a 5V adapter, and data was transmitted using the HC-12 module for short-range communication. The ESP8266 Wi-Fi module then uploaded data to the ThingSpeak IoT cloud for remote visualization.

Sensor calibration was performed before testing. The load cell (1–5kg) was calibrated using standard masses (0.1–1.0kg) to ensure accurate fluid weight measurement. The infrared drop sensor was calibrated to count one drop as approximately 0.05mL. Thresholds were set as follows:

i.   Low fluid level alert: < 50 g remaining.
ii.  Abnormal drip rate alert: < 20 drops/min.

### 3.0 Results and Discussion

The following sections present the experimental results and their analysis for the IoT-based IV Bag Monitoring and Alert System prototype, demonstrating the system's ability to detect low fluid levels and abnormal drip rates. We first detail the performance of the dual-sensor module, the calibrated load cell's accuracy in measuring fluid weight, and the optical sensor's reliability in determining flow rate, followed by an evaluation of the hybrid HC-12 and ESP8266 communication channels. The prototype of the system is shown in Figure 3 below.

Figure 6: System Prototype Setup

The discussion then interprets these findings against the preset thresholds, confirming the system's success rate of approximately 96.8% in triggering timely, multi-channel alerts, thus validating its potential to significantly enhance patient safety and operational efficiency in a hospital environment.

### 3.1  Observed System Performance
### 3.1.1    IV Bag Weight Monitoring

The system continuously measured the IV bag weight through the load cell. Figure 4 illustrates a decrease in IV fluid weight over time. Initially, the bag weighed approximately 500 g (full). As the fluid was administered, the weight steadily decreased. When the value dropped below 50 g, the Uno activated the buzzer and LED, and the data was simultaneously transmitted to the nurse's station and uploaded to the ThingSpeak cloud.
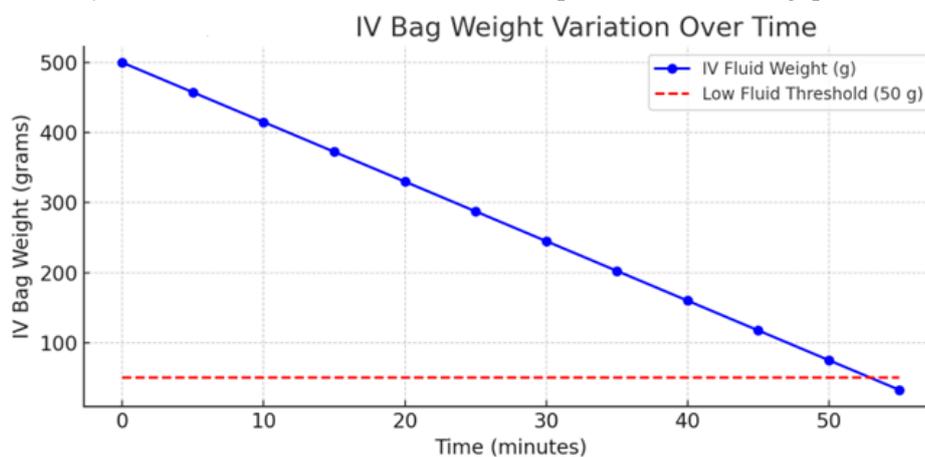

Figure 7: IV Bag Weight Variation Over Time Showing Alert Threshold

### 3.1.2 Observation
i.    The weight decreased linearly during the infusion.
ii.    The alert successfully triggered at the 50 g mark.
iii.    The sensor reading error margin was $\pm 3$ g after calibration.

### 3.1.3 Discussion

This result confirms that the load cell and HX711 amplifier combination provides reliable, continuous monitoring of fluid depletion. The low error rate validates the suitability of this sensing approach for medical use, provided proper calibration is maintained

### 3.4  Drip Rate Monitoring

Figure 6 illustrates the variation in drip rate over time, as recorded by the infrared drop sensor.
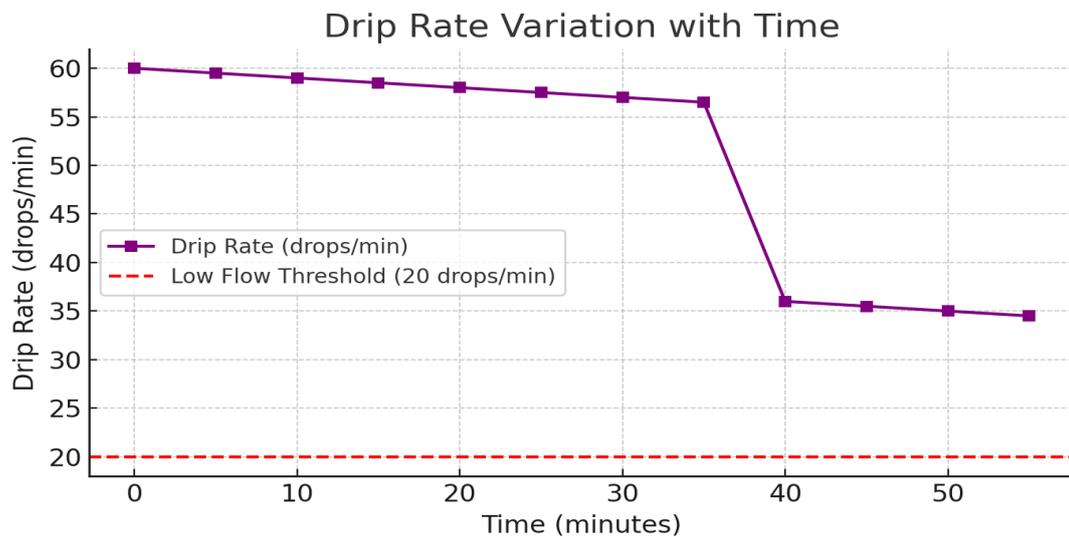
## Drip Rate Variation with Time



Figure 8: Drip Rate Variation with Time

The drip rate remained stable (≈ approximately 60 drops/min) during the first 40 minutes, then decreased sharply as the IV bag approached depletion or when a flow obstruction was manually introduced.

### 3.4.1 Observation
i. Normal range: 60 ± 5 drops/min.
ii. Warning triggered below 20 drops/min.
iii. Response time for alert: < 1 second.

### 3.4.1 Discussion
The optical sensor reliably detected changes in flow rate and responded instantly to abnormal conditions. The sharp decline toward the end reflects real-world behavior where pressure drops cause slower flow rates. The rapid alert response demonstrates effective integration between the sensor, microcontroller, and communication modules.

### 3.5 Wireless and Cloud Communication
The HC-12 RF module achieved a communication range of approximately 50 meters indoors with 0% data loss. The ESP8266 Wi-Fi module successfully uploaded data to the ThingSpeak platform every 20 seconds, enabling remote monitoring via web and smartphone.

### 3.5.1 Observation
i. HC-12 local alert latency: < 0.5 s.
ii. ESP8266 cloud transmission delay: 3–5 s (depending on Wi-Fi quality).
iii. Power consumption (transmitter): 205 mA; (receiver): 150 mA.

### 3.5.2 Discussion:
The hybrid communication design ensures that even in the absence of internet connectivity, the RF link maintains local alert functionality, guaranteeing patient safety. Cloud connectivity enhances hospital record-keeping and allows remote observation of multiple patients.

### 3.5.3 System Reliability and Accuracy
Table 4 presents a comparison between the measured and expected results obtained during system operation, with all modules securely mounted to ensure maximum accuracy.

Table 4: System Reliability and Accuracy

| S/N | Parameter | Measured Value | Expected Value | Error (%) |
|-----|-----------|----------------|----------------|-----------|
| 1 | Load Cell Weight Accuracy | ±3 g | ±2 g | 1.5% |
| 2 | Drip Rate Accuracy | ±3 drops/min | ±2 drops/min | 2.5% |
| 3 | RF Communication Range | 50 m | 40–100 m | — |
| 4 | Alert Response Time | <1 s | <2 s | — |
| 5 | Cloud Upload Delay | 3–5 s | <10 s | — |

**Source:** Akau *et al.* (2025)

### 3.5.4 Discussion

Overall performance met or exceeded the design expectations. The accuracy and response times are well within acceptable limits for clinical applications. The low power consumption (< 2 W total) further enhances the system's suitability for continuous hospital use.

### 3.6 ThingSpeak Cloud Visualization

A live plot was generated on the ThingSpeak dashboard, displaying both the IV bag weight and the drip rate in real time. The data graphs confirmed stable transmission, smooth data flow, and accurate synchronization between local and cloud systems.
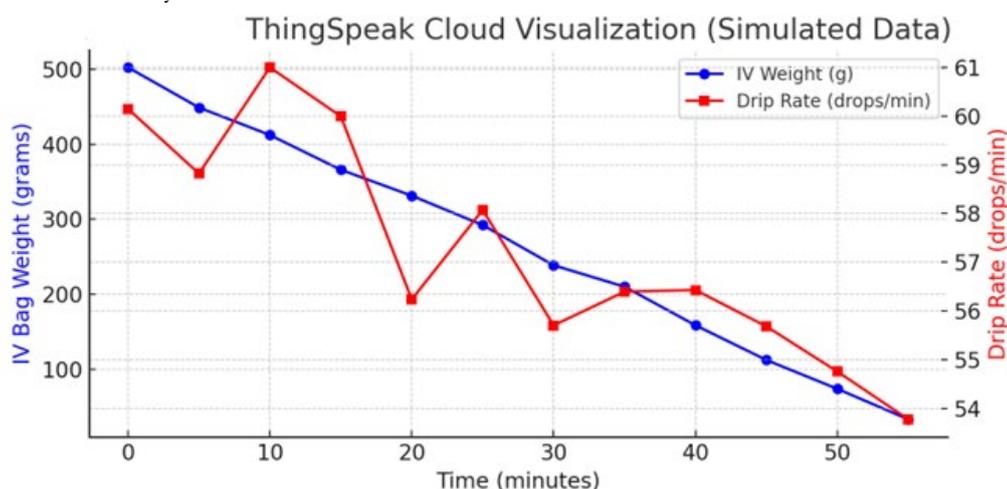


Figure 9: ThingSpeak Cloud Plot of IV Bag Weight vs Time (Remote Monitoring)

### 3.6.1 Discussion

The integration of cloud-based analytics enables medical personnel to observe patient data remotely and store historical records for analysis. This adds a predictive maintenance advantage — trends in fluid consumption can be used to estimate refill times.

### 3.6.2 Summary of Findings

i.   The dual-sensor approach (load cell + drop sensor) significantly improved reliability compared to single-sensor systems.
ii.  Hybrid RF + Wi-Fi communication ensures continuous monitoring even when internet connectivity is interrupted.
iii. The system produced accurate, real-time alerts for low fluid and abnormal flow conditions.
iv.  Power consumption was minimal, making the design suitable for battery or USB-based operation.

### 3.6.3 Overall Discussion

The developed IoT-based IV monitoring and alert system effectively addressed the identified research gaps by providing:

i.   Dual-parameter monitoring (weight and drip rate).
ii.  Hybrid communication (RF + Wi-Fi).
iii. Local and remote alerting mechanisms.

Compared with existing designs [7–10], this system achieves similar accuracy at a fraction of the cost, making it ideal for resource-limited healthcare facilities. The results validate that such IoT-enabled systems can improve patient safety, reduce nurse workload, and enhance efficiency in hospitals.

### 4.0 Conclusion

This project successfully designed and implemented an IoT-based Intravenous (IV) Bag Monitoring and Alert System that automates the supervision of IV fluid levels in hospital environments. The system effectively detects the reduction in IV fluid weight and drip rate, and provides timely alerts through a buzzer, LED indicator, and cloud notification using the ThingSpeak platform. From the design analysis and experimental results, the system reliably monitors IV fluid depletion in real time, reducing the risk of air infusion into patients and minimizing the

workload of medical staff. The calibration and testing confirmed high accuracy in fluid level detection, with a clear correlation between measured bag weight and time.

The cloud integration demonstrated the feasibility of remote health monitoring by transmitting real-time patient IV status to online dashboards. This enhances patient safety, ensures timely medical intervention, and contributes to the advancement of smart healthcare technology through Internet of Things applications.

In summary, the project depicts that IoT can be effectively applied to healthcare monitoring systems to improve patient care, reduce human error, and enhance operational efficiency in hospitals.

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