IOT IV Bag Monitoring and Alert System

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Abstract *– This document highlights the need of an Internet of Things (IOT) Intravenous (IV) bag monitoring and alert system in the medical industry, especially in developing countries like Sri Lanka, and how it can be designed. One of the most important tasks which should be given proper care and attention is intravenous therapy, which is a medical technique used to deliver medication, fluids and nutrition directly into a person's vein. However, IV treatment requires routine inspection and replacement which is done manually by the medical staff. This can be a difficult and worrisome task in busy hospitals as it is inconvenient to attend to every patient individually while attending to other important tasks as well. Hence, as a solution to this problem, this research introduces an IOT based Intravenous Fluid Monitoring and alert system which detects the weight of the IV bag as the fluid level goes down and displays the weight of the IV bag on an LCD display in a common place where the medical staff can easily observe. Also, the nurse in charge can monitor the IV level with her phone while alert notifications are sent at the required levels when the IV fluid is gradually decreasing.*

***Keywords*- IV fluid, Arduino, IOT**

I. INTRODUCTION

Nowadays, monitoring patients in a hospital is a very taxing task for the medical staff mostly in developing countries where the population is high and the medical staff is less. Monitoring patients and giving each patient individual attention is a very important task because it is always a life that they are dealing with. Especially in critical situations, such as the peak of Covid 19 virus spread, it must have been a chaotic situation for the medical staff to monitor patients individually as many patients were admitted to hospitals continuously, IV infusion or intravenous therapy is a medical technique which requires proper attention and care. A vein is directly injected with intravenous solutions, medications, blood, or blood products as part of intravenous therapy. In an emergency situation or for patients who are unable to take medications orally, intravenous therapy is an efficient and quick-acting way to administer fluid or medication treatment. In the hospital setting, intravenous therapy is administered to about 80% of all patients. A tiny plastic tube known as an IV catheter is inserted into the vein during IV administration. With the help of the catheter, the doctor can administer several low doses of medication safely without having to stick with a needle repeatedly (campus, 2015).

IV medication is frequently used as it helps to regulate dosage. In certain emergency situations like a heart attack, stroke, or poisoning, patients need to receive their medication very quickly. In these circumstances, ingesting pills or liquids might not be quick enough to deliver the drugs to the bloodstream. On the other hand, IV administration quickly delivers medication into the bloodstream. Sometimes it's necessary to administer medications slowly but consistently. The controlled administration of drugs via IV is another option. Certain medications may be administered intravenously (IV) only as if those medications were taken orally (by mouth), they would be broken down by the liver or stomach making such drugs useless (Case-Lo, 2016). The procedure for giving an IV infusion is as follows:

1) *Choose the appropriate IV solution:* The healthcare provider selects the appropriate IV solution, depending on the patient's needs. Common solutions include normal saline, lactated Ringer's solution, and dextrose solutions.
2) *Prepare the IV bag and tubing:* The healthcare provider prepares the IV bag by hanging it on an IV pole and connecting the tubing to the bag.
3) *Prime the tubing:* The healthcare provider primes the tubing by removing any air bubbles to ensure an uninterrupted flow of fluid.
4) *Connect the tubing to the patient:* The healthcare provider connects the tubing to the patient's IV catheter and secures it in place with a sterile dressing.
5) *Set the infusion rate:* The healthcare provider sets the infusion rate using a flow regulator to control the amount of fluid delivered per hour.
6) *Monitor the patient:* The healthcare provider monitors the patient's response to the IV therapy, including vital signs, fluid intake and output, and any adverse reactions (campus, 2015).
7) *Discontinue the IV:* Once the therapy is complete or no longer needed, the healthcare provider discontinues the IV and removes the catheter (campus, 2015).

Other IV infusion techniques are using a gravity drip, which depends on gravity to deliver the fluid at a predetermined rate, or a syringe pump, which allows for more precise control of the infusion rate. The technique selected is determined by the patient's health and the medication being taken (R. Anderson, 2018). From all these methods above, intravenous therapy cannot be monitored remotely by the medical staff. It is required to attend to each individual patient to monitor whether the dripping or pumping of the intravenous fluid is functioning properly without any issues. In some instances, the fluid may stop flowing due to some technical issues and the medical staff won't recognize that unless he/she attends to the patient physically. Further, there may be fluid backflow when the infusion is complete, if the catheter is not removed timely. Therefore, in these methods, proper monitoring is required and in busy situations, it is difficult for the medical staff to monitor multiple patients at the same time.

Therefore, it is essential to develop an automatic method to display the weight of the IV bags for each patient, in a common place where the medical staff can observe easily and a method to notify the nurse in charge as the weight decreases. When the notification goes to the nurse, he/she will attend to the required patient immediately without any delay.

II. OBJECTIVES

1) To provide the IV delivering of fluids for every patient in a proper manner.

2) To monitor the IV delivering process of the patients remotely.

3) To give proper care and attention to every patient individually by alerting the nurse.

4) To reduce the workload of continuous monitoring by the medical staff.

5) To improve the healthcare sector by incorporating technological knowledge.

III. EXISTING PRODUCTS

Some of the existing products in the market used for the IV fluid-delivering process are the normal IV drip technique, pump infusion, and smart pumps. All these techniques do not have the facility of remote monitoring and alerting. As an example, a plastic catheter is used to gently inject an intravenous treatment known as an IV drip into the bloodstream in the IV drip technique. A tiny plastic tube (catheter) is inserted into a vein using a needle to administer an IV drip. The needle is swiftly removed after the plastic tube is advanced into the vein. A typical bout of IV drips lasts 45 to 60 minutes and involves injecting 250 to 1000 ml of fluid (Opentextbc.ca, 2015). This system has to be continuously monitored by the medical staff because in some instances fluid backflow or blood loss can occur. In the IV drip system. In the pump infusion systems, the fluid movement into the vein is controlled by a pump device. The pump is suitable for delivering fluids or medications that must be given at a specific rate because it can be programmed to deliver a precise quantity of fluid over a set period of time (Health, 2018). This system also has to be monitored from time to time by physically attending to the patient to ensure proper delivery of fluids without any technical issues. Moreover, in the modern development of smart pumps, in accordance with predetermined criteria, such as drug concentration and dose, smart pumps allow the delivery of intravenous fluids and medications. Additionally, they can be programmed to autonomously determine weight-based dosing plans and give a bolus dose over a predetermined period of time (Giuliano, 2015). This modern technique also lacks the technology of remote monitoring.

IV. METHODOLOGY

A. FLOWCHART

The prototype's operation and the procedures that would be taken while it was put into use are represented by the flowchart below in Figure 1.

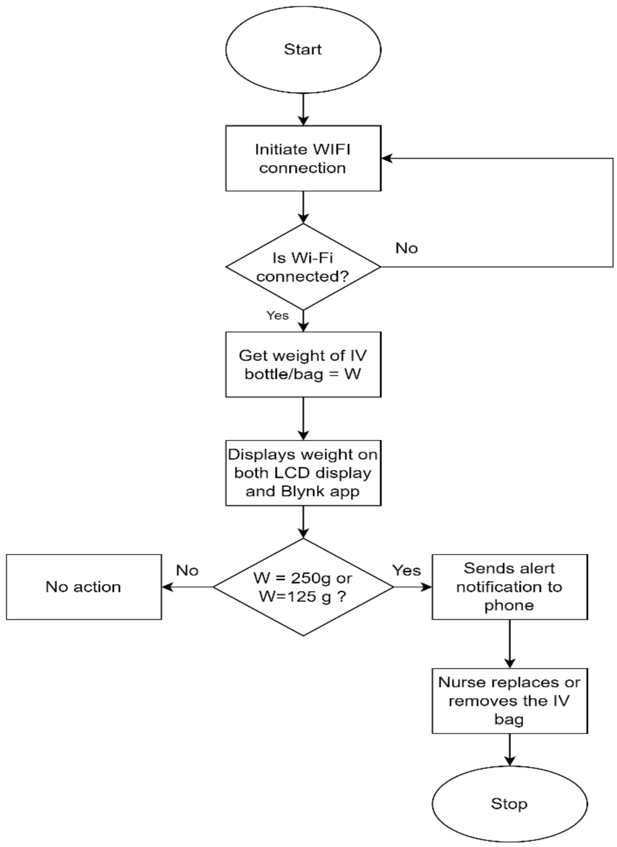


Figure 1. Flowchart

Source: Author Generated

The prototype is programmed in a way such that, when the circuit is switched ON by the manual switch, it would establish a connection with the Wi-Fi network. Once the Wi-Fi connection is established, the IV bag can be hung on the hook attached to the device. Then the circuit components get the weight of the IV bag/bottle and displays it on both the LCD display and the Blynk app. The 1kg load cell used is calibrated accurately before use so that it measures the weight accurately. The calibration factor is calculated by taking the ratio between the reading of weight shown on the LCD display and a known weight. This value is set in the Arduino code so that an accurate measurement of weight is obtained. The calibration factor may change according to the size of the load cell and its manufacturer. Since the density of saline is approximately equal to the density of water, the prototype uses water as the liquid in the IV bag, so the weight of water is approximately equal to the weight of saline. Therefore, the weight shown on the display/phone in grams is approximately equal to the volume of liquid remaining in the IV bag. As the fluid is delivered, so that the weight is gradually decreasing, alert notifications are sent to the nurse's phone through the Blynk app. When the weight becomes approximately equal to half of the full amount of IV fluid it will indicate that half of the IV is finished. Another notification alert is sent when the IV fluid level is low, therefore the nurse can replace or remove the IV bag/bottle as required.

B. COMPONENTS

1) Software Analysis

Table 1: Software Analysis

COMPONENT	FUNCTION
Weight sensor (Load cell)	To detect the weight of the IV bag
HX711 Module	To amplify and convert load cell signals into digital signals for weight measurement.
ESP -01 WIFI module	To act as a bridge between the Arduino uno board and the Blynk cloud service by connecting to the internet through Wi-Fi.
ESP 8266 WIFI adapter	To increase the capabilities of the ESP-01 module by adding more GPIO pins, making it more suitable for IOT applications.
Arduino Uno	For communication of sensor data and corresponding outputs.
Arduino IDE	To program the entire system through code as required.
LCD display	To display the weight values sensed by the weight sensor.
I2C Connector	Enables the Arduino uno R3 and LCD display to communicate with each other.

Source: Author Generated

2) Component Selection

Arduino Uno R3: The Arduino Uno R3 is a microcontroller board based on the ATmega328P chip. The board has a 16 MHz quartz crystal, 6 analogue inputs, 14 digital input/output ports, a USB port, a power jack, and an ICSP header. The digital pins are designated from 0 to 13 and can be used as input or output. Each digital pin has a 20–50k ohm internal pull-up resistor and can supply up to 40mA of power. The analogue pins, which have the letters A0 to A5, can receive analogue signals from sensors and other gadgets. The Uno R3 is a flexible platform for prototyping and experimentation because it is compatible with a variety of sensors, actuators, and other electrical parts (Arduino, 2022).

Figure 2. Arduino Uno R3

Source: (Arduino,2022)

Weight Sensor (Load Cell): A sort of transducer called a 1 kg load cell, also referred to as a weight sensor, transforms the physical force of weight or pressure into an electrical signal. A metal housing, a strain gauge, and an analogue amplifier are usually included. A thin metal wire or foil known as the strain gauge is attached to a metal part, such as a beam or plate. The metal component of the load cell deforms when weight or pressure is applied, changing the strain gauge's resistance. The analogue amplifier then transforms this shift in resistance into an electrical signal. Numerous devices, including weighing scales, material testing equipment, and industrial process management systems, use load cells. Design, calibration, and environmental factors all affect a load cell's precision and sensitivity (Flintec, n.d.).

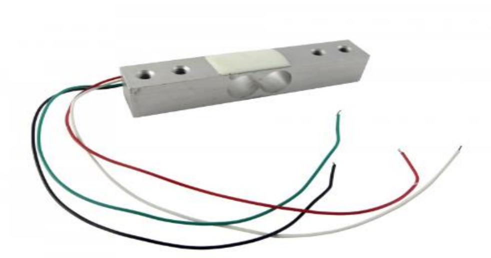


Figure 3. Load cell

Source: (Flintec, n.d)

HX711 Module: A load cell or other strain gauge monitor is connected to a microcontroller or computer using the HX711 module, an electronic component. To precisely measure weight or force, it offers amplification, analog-to-digital conversion, and digital signal processing functions.

A load cell connector, an integrated circuit (IC), and a few inactive components make up the HX711 module in most cases. The IC has a 24-bit analog-to-digital converter, a low-noise amplifier, and a configurable gain amplifier. The load cell is connected to the HX711 module using the load cell connection. Using a serial interface, such as SPI or I2C, the HX711 module interacts with the microcontroller or computer. When precise weight or force measurement is necessary, the HX711 module is frequently used in automation applications, industrial process control systems, and electronic scales. It is a common option for both professionals and hobbyists due to its small size, low price, and high accuracy (Lab, 2020) (SGBotic, 2023).

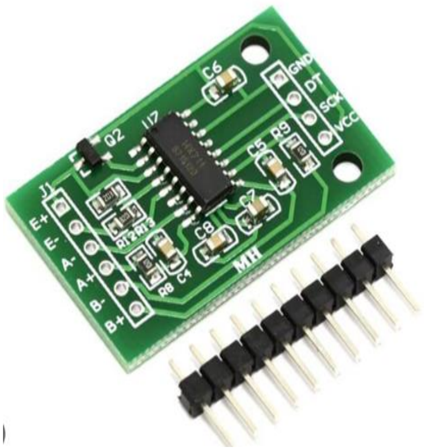


Figure 4: HX711 module

Source: (Lab,2020)

ESP-01 WIFI Module: A well-known Wi-Fi module created for the Internet of Things (IoT) is the ESP-01. It is built on the ESP8266 chip, a highly integrated microcontroller unit (MCU) and Wi-Fi radio Wi-Fi SoC (System on Chip). The ESP-01 is ideal for projects with limited room due to its small size. Two GPIO pins on the ESP-01 module can be used to operate sensors or external devices. It is perfect for connecting to the internet and interacting with other devices because it supports a wide range of communication methods, including TCP/IP, UDP, HTTP, and MQTT. C, Lua, and Arduino are just a few of the computer languages that can be used to create programs for the module. Additionally, it has integrated firmware that offers a number of Wi-Fi features, such as AP, STA, and AP+STA modes. The ESP-01 Wi-Fi module is strong and adaptable overall, and it can be used for a variety of IoT apps (SGBotic, 2023).

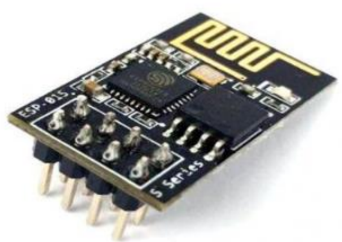
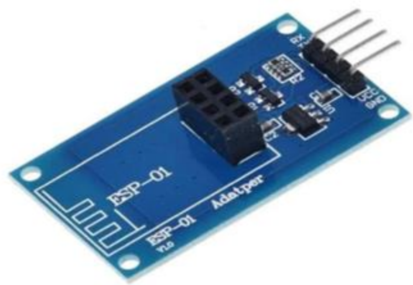


Figure 5. ESP-01 WiFi module

Source: (SGBotic,2023)

ESP-01 WIFI Adapter: A circuit board called the ESP8266 ESP-01 Adapter was created to make it simple to incorporate the ESP-01 module into electronic applications. It has a voltage regulator that can supply the ESP-01 module with a steady 3.3V power supply, guaranteeing dependable and consistent performance. The ESP-01 can be readily connected to other components with the help of this adapter's header connector, which can be plugged into a breadboard or other prototyping board. The voltage regulator on the adapter board is a flexible solution for a variety of projects that call for the ESP-01 module because

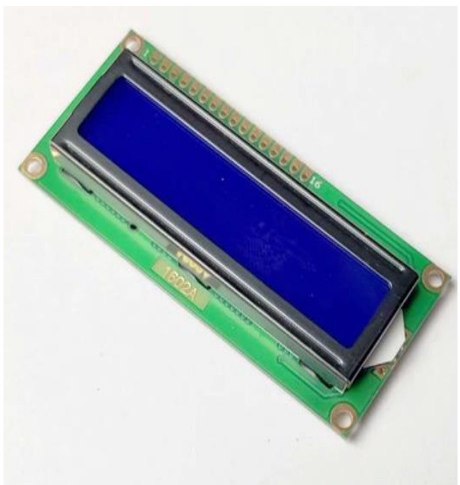


it can take input voltages between 5V and 12V (ElProCus, 2019).

Figure 6. ESP-01 WiFi adapter

Source: (ElProCus, 2019)

LCD Display (16x2): A common kind of alphanumeric display used in many electronic tasks is the 16x2 LCD display. It can show up to 32 characters at once because of to its 16 columns and 2 rows of characters. The HD44780 controller chip used by these screens enables simple interfacing with microcontrollers and other digital devices. The displays are frequently backlit, making it simple to view them in dim light. They are useful for showing data, messages, and other information in many applications, such



as digital clocks, calculators, and various electronic devices because they can display a variety of characters and symbols (ElProCus, 2019).

Figure 7. LCD Display (16x2)

Source: (ElProCus,2019)

I2C Connector: A communication protocol that is frequently used in electronic devices for connecting different components, including LCD displays, is the I2C connector, commonly referred to as the I2C interface or I2C bus. Inter-Integrated Circuit, or I2C, is a two-wire serial interface that enables several devices to interact with one another. With fewer pins needed and less complicated cabling, the I2C connector makes connecting an LCD display to a microcontroller or other devices easier. It permits numerous devices, each with an individual address, on the same bus and facilitates bidirectional data flow. An easy and effective

approach to connect LCD panels with other embedded system components is using this standardized interface.

Figure 8. I2C Connector

Source: IndiaMART website

C. CIRCUIT DESIGN

The main source of communication and processing is the Arduino Uno. All the circuit components are connected to the Arduino Uno R3 microprocessor. The 1kg load cell is connected to the HX711 module by connecting the red, black, white and green wires of the load cell to the E+, E-, A-, and A+ ports respectively and the HX711 module's Ground, DT, SCK is connected to that of the Arduino uno R3. The Vcc is given 5V by Arduino Uno. The system is connected to Wi-Fi using the ESP-01 Wi-Fi module. An ESP-01 Wi-Fi adapter is connected to the ESP-01 Wi-Fi module so that the ESP-01 Wi-Fi module can be readily connected to other components since it has a voltage regulator. Then the adapter with the Wi-Fi module is connected to the Arduino uno by giving 3.7V to the Wi-Fi module. The LCD display is connected to the Arduino UNO by giving 5V.

D. CIRCUIT DIAGRAM

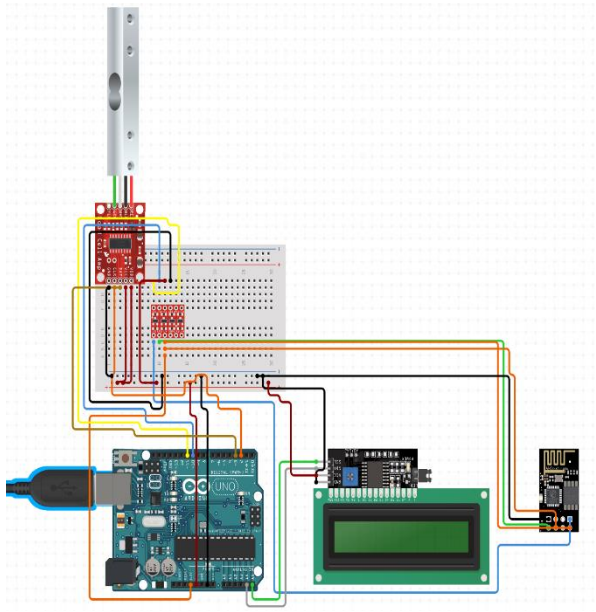


Figure 9. Circuit Diagram

Source: Author Generated

E. FUNCTIONAL ANALYSIS

The circuit for the IOT IV bag monitoring and alert system has been designed using the components mentioned above. An accurately calibrated loadcell is used here as the transducer that collects the weight of the IV bag and converts this weight to an electrical signal for better processing of data. The HX711 amplifier strengthens the signals for transmitting and receiving data. By amplifying the transmission of signals, the prototype is expected to function at a faster rate than usual. The HX711 module is connected to the Arduino UNO R3 where the data is processed and then displayed on the LCD display. The ESP-01 Wi-Fi module with the adapter, acts as the base of the circuit to perform all the IOT-based functions. It sends data over IOT to the Blynk app on the phone, therefore the medical staff can remotely monitor the delivery of IV fluid and is also responsible for sending alert notifications through the Blynk app as required. The changes taking place in the level of the IV fluid would be then displayed on the dashboard which has been developed with the help of Blynk. Blynk is an open-source service side platform that helps in monitoring as well as controlling IOT-based devices.

V. RESULTS

Figure 10. Full view of the prototype
Source: Author Generated

Figure 11. Front view of the prototype

Source: Author Generated

Figure 12. Side view of the prototype
Source: Author Generated

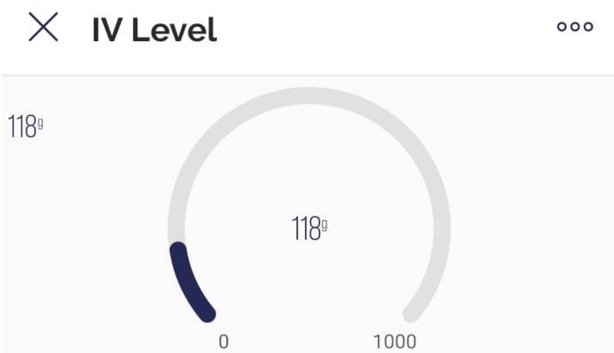


Figure 13. View of the mobile dashboard
Source: Blynk App

An IOT based IV bag monitoring and alert system was implemented successfully as seen in the above pictures. The system was tested to get the correct results. In the analysis of the prototype, it was found that since the prototype uses water, approximately equal to saline, in the beginning, for 500ml volume the weight shown was 500g, which includes the weight of saline and the bag. The weight of the empty bag is considered negligible even by medical professionals since it's significantly smaller than the weight of the liquid inside the bag. But as the liquid is delivered, the weight shown may differ by 10 grams or so because of the shrinking of the IV bag as its fluid decreases. As the bag shrinks, it weighs less because the material of the bag is folding or compressing, affecting how the weight is distributed and measured by the load cell. After the analysis following results were obtained:

- At 270 ml volume, the weight shown is 250g
- At 135ml volume, the weight shown is 125g

Figure 14. Notification when half of IV fluid delivered
Source: Blynk App

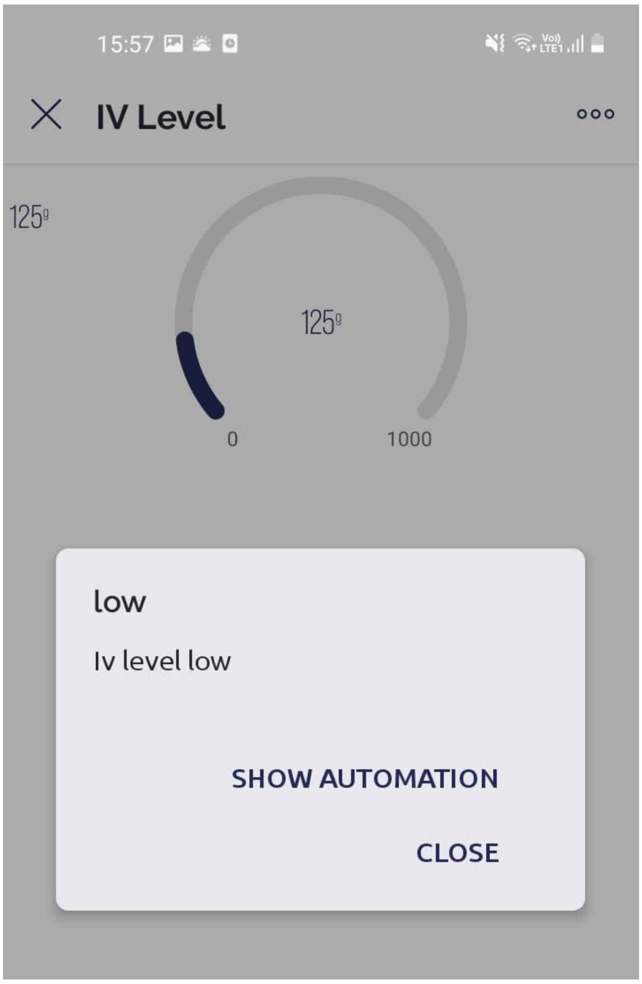


Figure 15. Notification when IV fluid level is low
Source: Blynk App

So, since the values do not differ significantly, an assumption was taken that at a weight of 250g, half of IV fluid is delivered, and at a weight of 125g, the fluid level is low. The notifications in the Blynk app were set to these values. So the below results were obtained.

When the system is turned ON by the manual switch, it gets connected to the Wi-Fi network and the device starts to get the weight of the IV bag/bottle when hung on it. The information is also sent to the Blynk app on the mobile phone so that the change in weight can be monitored by the nurse remotely while attending other work. Also, two alert notifications are sent to the mobile phone through the Blynk app, first when half of the IV fluid is delivered and the next when the IV fluid is low. These notifications can be set in the blink dashboard and can be set to our required thresholds.

VI. DISCUSSION

The system is designed for hospitals treating a larger number of patients, especially for countries with a high population and less medical staff, with a lack of attention to IV fluid delivering process for patients.

The automatic IV bag monitoring and alert system is a convenient and automatic way of giving proper care and attention and for remote monitoring of each and every patient when the IV fluid is delivered.

The system uses an ARDUINO microcontroller as the primary source of communication. It uses a weight sensor to sense the weight applied to it by hanging the IV bag/bottle on it and sending data through Arduino UNO to an LCD display which displays the weight. The LCD display is used to indicate a large screen in a common place where the medical staff can easily observe while attending to other work. Furthermore, an ESP-01 Wi-Fi module is used to send data over the internet to display weight on the Blynk app as well as to send notifications to the Blynk app as the fluid level in the IV bag decreases gradually. The first notification will be sent when the fluid level reaches half of its maximum volume, and the next notification will be sent when the fluid level is very low.

Therefore, the system is able to inform the nurse through her phone when and at what time the IV bag has to be removed or replaced so that the patient or the nurse can be at a stress-free environment with nothing to worry.

With this invention, a new technological era is entered. If this research is implemented successfully, IV fluid delivery can be handled properly, and the nurse will find it very simple to manage the process thanks to remote monitoring and alert notifications. As a result, this research encourages convenience, time savings, and reduced human effort.

VII. CONCLUSION

It can be concluded that an IOT-based IV monitoring and alert system was implemented successfully by this research.

In most developing countries and in critical situations where the hospitals and medical staff are very busy, the development of new technologies to manage, monitor and to give proper care to patients is essential. With this development, nurses can monitor the IV fluid delivery of patients remotely and receive alert notifications when the IV fluid is gradually decreasing so that the patients can be attended to on time to prevent backflow or any errors in the process.

VIII. ACKNOWLEDGEMENT

First and foremost, I would like to express my heartfelt gratitude to my university, General Sir John Kotelawala Defence University for bestowing upon me an opportunity to conduct this research in which I could address an issue in the medical field and come up with a successful solution. Next, I would like to thank the Department of Electrical and Electronic Engineering of General Sir John Kotelawala Defence University, for guiding me throughout this journey from the beginning to the end and supporting me in every step I took to complete this research.

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