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IoT & long-range radio (LoRa) based air quality sensing through hyper-automation to manage critical temperature-reducing blood and plasma product wastages

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ABSTRACT

Background: Each year, about 7 lakh units of blood and its components are estimated to be wasted in India before being used. Due to a communication gap between blood banks, donors, regulators, hospitals, and recipients, blood is wasted in India. Blood loss could significantly negatively influence the nation's healthcare system. A blood bank only accepts a minimal amount of unavoidably outdated blood and its constituent parts due to the internal obligation to maintain blood supplies and the regularly shifting demands on the inventory. Most blood banks' operations, including regulating the Refrigerator's temperature and contents, are done by hand. Observing temperature changes before they endanger the supply is possible if the storage temperature is continuously tracked in real time.

The Need: Patients may also require blood transfusions if they have cancer, sickle cell illness, anaemia, bleeding problems, or sickle cell anaemia. A cancer patient requires at least 100 units of blood. Given the ongoing need for blood products and the frequently unforeseen demands placed on the inventory, the blood bank accepts minimal inevitable blood and component ageing. Collecting 500–1000 units/bags of blood in a blood camp is acceptable and manageable; the blood may then be distributed to those in need via blood banks or centralized blood repositories. Blood is spread by blood banks to each hospital ward, expecting to be transfused within 30 minutes. The RefrigeratorRefrigerator must have a suitable temperature alarm and maintain a temperature range of +2 C to +6 C. Even though some blood loss cannot be prevented, IoT solutions will assist in reducing the amount of lost blood.

Aim: To control the critical temperatures of the blood bank by hyper-automation using IoT-based air quality sensors in the blood bank.

Method: In this paper, we practically observe, analyze, and demonstrate how to control the critical temperatures of Hospital Blood Bank (HBB) and its wastage management system with the help of a Long-Range Radio (LoRa) based air quality sensor which works on internet of things (IoT) application connected to a no code low code secure cloud platform with dashboard, text messages, LoRa alarm units, excel data analysis and reports.

Findings: Using real-time communication and temperature monitoring, reducing Blood wastage in Hospitals is possible. Compared to Manual temperature monitoring, IoT temperature monitoring through hyper-automation leads to less wastage of blood and blood products.

Conclusion: LoRa allows for better penetration even in the densest of the buildings in a hospital and can get accurate values of the critical temperature in the freezers. All these proposed systems are together called hyper-automation, and they would assist in preventing blood and its components wastage.

Keywords: Blood bank, Blood, And its components, IoT (internet of things), LoRa, Cloud platform, Data analysis.

1 INTRODUCTION

In India, more than seven lakh units of blood and its components are lost yearly before they can be appropriately administered to low-income individuals. About half of the failed units comprise blood products and features like plasma, compared to red blood cells and whole blood units, which need to be used within 35-45 days, and have a one-year shelf life. India now has a 10% blood shortage compared to its needs. Therefore, we must make up a gap of more than 12 lakh blood units. This shortage is unexpected, given that India has a population of more than 512 million potential donors. In India, there are more than 1200 traffic accidents daily, and 60 million trauma-related procedures are conducted yearly. Nearly 230 million primary operations, 331 million cancer-related systems, including chemotherapy, and 10 million pregnancy complications require blood transfusions. [1].

A potent substance in medicine is blood. For various ailments, blood is required; voluntary donors provide the blood. Blood or blood components treat conditions like anaemia, cancer, blood diseases, and those undergoing surgery. Therefore, the cost of the blood cannot be determined. Within the specified time, blood with a life expectancy of approximately 45 days must be utilized. The patient receives a variety of blood components, including plasma, platelets, and others, based on the many ailments they are suffering from. Many other conditions can be treated with each of these.

Additionally, those who have thalassemia, haemophilia, and sickle cell anaemia require a significant amount of blood each day. Each of the several blood elements that make up the blood serves a particular purpose. According to statistics, someone in India requires a blood transfusion every two seconds. Patients receiving therapy for sickle cell disease, cancer, or other illnesses, including thalassemia or sickle cell anaemia, as well as trauma victims—from accidents and burns—heart surgery, organ transplants, women who experience complications during childbirth, new-borns, and premature babies—all, require blood transfusions [2].

Table -1: Different Blood Constituents with their uses for different diseases and their functions

Blood Constituents	**Functions**	**Used in Ailments**
Plasma	Medium in which the blood cells are transported around the body	Burn patients, Shock, Bleeding disorders
Red blood cells	Carries Oxygen	Surgery, Any blood loss, Blood disorders such as sickle cell
White blood cells	Part of the immune System	Infectious disease and foreign invaders
Platelets	To facilitate blood clotting	Cancer treatments, Organ transplants, lower platelet

		counts, suffering from leukaemia

The blood can be kept in storage for only a short time, so it must be continuously and steadily collected. As managing the blood bags received from blood donation events requires proper and systematic management, blood banks must handle the loads carefully and thoroughly because the loads are tied to someone's life. As a result of blood's short shelf life and the challenges associated with maintaining ideal storage conditions, many units of blood are lost before they may be used. Broken bags, burst packs, infected packs, under donations, clotted donations, broken seals, fridge failure, improper storage, issues with the manufacturing and testing of blood components, expired units, overordering, insufficient transportation, and returned after use are just a few of the factors that contribute to the wastage of blood and blood products in India. Care must be taken to transport, manufacture, test, and store blood components to prevent blood waste. The temperature and inventory of the RefrigeratorRefrigerator and most blood banks' activities are manually managed. Observing temperature changes, if the storage temperature is continuously monitored in real-time, problems can be caught before they endanger the supply. Even though some blood loss cannot be prevented, IoT solutions will assist in reducing the amount of lost blood. Blood banks may monitor storage volume, blood kinds, temperature, and other variables using wireless IoT sensors connected to an automated management network. These data can be made available online for hospitals and other healthcare professionals. I. LITERATURE REVIEW The device will alert users if the temperature exceeds or goes below a particular pre-set level, enabling them to address the issue and keep the units from going rancid.

2 BLOOD BANK ADMINISTRATION

Researchers have thus far attempted to identify and respond to concerns and common problems regarding methods for blood bank management, movement, storage, and waste. According to the study by Ahmed AL-Kalbani (2017) [3], some hospitals employ Excel sheets on computers to keep track of the information and contact patients by phone or SMS in case of an emergency. Most hospitals, blood banks, and other healthcare organizations have a database of blood donors on MS Excel or paper, but it might be challenging to contact donors in an emergency. When donors sign up for the first time, personal information (such as name, address, age, job, gender, blood group, and GPS position) and medical information (such as diagnosis, lab results, and therapies) are sought. An automated blood management system implemented by Ashlesha C. Adsul (2018) [4] retrieves data from the database and immediately sends an SMS to the donor at his registered mobile number. In Hridoy Deb Das's (2020) [5] research on blood donors, requesters can use GPS position to discover donors within 5 km of their current or destination location, allowing them to reach their goal quickly. 2019's Fauwzziyyah [6] Because of Unstructured Supplementary Service Data Short Message Service (SMS) and a free toll line, Lifeline is a blood bank service that guarantees patients have quick access to blood donors of all types. It can survive in the most remote locations and is simple to use for both online and offline queries for both young and old. Clients can rapidly locate blood donors in their area who match their blood type using the location-based Android app, which they can access on their phones. (2014) [7]; created an Android Blood Donor Life Saving Cloud Computing Application for blood donation. Quick communication between one client and the blood group-matching donor is possible. Their application provides an inventory of donors in your city or region. Pau and Ritika (2014) [8] looked at various classification algorithms to identify an appropriate strategy for forecasting donations. Both Backiyalakshmi and Jenipha, The Maximum Blood Collection Problem (MBCP), which requires the delivery of blood collected at several donation sites using a collecting truck fleet to a single processing facility, as defined by Ekici and Ozener (2014) [9]. Vehicle Routing Problem (VRP) for Blood Transporters (BTs) based on Artificial Intelligence research by Mehmet Karakoc and Melih on Priority Based Vehicle Routing for Agile Blood Transportation between Donor/Client Sites was published in 2017 [10]. They suggest an effective vehicle routing plan for transporting blood to a region's hospitals or Donor/Client Sites (DCSs). It is intended to limit the number of BTs while taking the requests' and responses' urgency into account, keeping short travel distances taking priority. The VRP technique with GA was employed by Karakoc et al. (2015) [11] for the transportation of blood between medical facilities. However, their strategy needed to account for the blood's need for urgency.

2.1 IoT AND LORA-BASED AIR QUALITY SENSING

An intelligent long-range (LoRa) sensor node is suggested by Jabbar et al. (2022) [12] to gather air quality data timely and update it on the cloud. The designed LoRaWAN-based Internet of Things (IoT) air quality monitoring system, also known as LoRaWAN-IoT-AQMS, was used outdoors to confirm its dependability and efficiency. Truong et al. (2021) [13] used an existing LoRa network composed of three sensor nodes and a gateway to test the system's viability. Additionally, a website offers an interactive map and charts showing the easily accessible Air Quality Index data. Akram et al. (2021) [14] suggested an architecture for building and developing a customized sensor node and gateway based on LoRa technology to realize the bins' fill level with minor energy consumption. For the authority to properly manage and take the required steps to protect the environment and valuable resources, Smitha et al. (2020) [15] presented a system based on IoT and WSN, establishing an effective street light energy-saving system and providing real-time data on air quality. Intelligent monitoring and administration are possible with IoT & WSN. It keeps residents informed and involved while assisting in creating more efficient and affordable municipal services. A unique, low-cost sensor node was created by Ali et al. (2020) [16] using an infrared sensor to assess particulate matter (PM) levels and cost-efficient electrochemical sensors to measure carbon monoxide (CO) and nitrogen dioxide (NO2) concentrations. IoT-based Air Pollution Monitoring system with components distributed at all key city locations is what Walling et al. (2020) [17] propose. The core of the Air Pollution Monitoring system is the long-range wireless technology LoRa. A LoRa mesh networking architecture was implemented by Lee et al. (2018) [18] for the large-area monitoring of IoT applications.

3 METHODOLOGY

Goal: The goal is to streamline the manual work processes in the laboratory by deploying IOT sensors in storage equipment for temperature monitoring.

Objective: To analyze the data and validate the accuracy and functionality of IOT devices for temperature monitoring.

Study Duration: June 1, 2022, to July 31, 2022

Data Collection: Using the Zoho/Grafana platform and manual observation of data loggers in the laboratory.

Study area: Central Laboratory and Blood bank unit of a Multispecialty tertiary care Hospital and Research Centre in South Bangalore

Study Procedure: We collected the required data and maintained the Zoho Creator Cloud software database.

Implementation and Installation of IOT Devices in the Laboratory: LoRa Air Quality Sensor: An IOT device where the sensors are installed in the laboratory equipment, which willmeasure temperature, relative humidity, air quality, and airflow.

Fig 1. Mutelcor Device

Specifications of Mutelcor Airquality Sensor

- **Model No:** MTC-AQ01 / MTC-AQ02
- **Enclosure Size:** 95 x 95 x 40 mm
- **Net Weight:** 175 g
- **Ingress Protection:** IP30 / IP67

- **Operating Temperature**: -40°C to + 85°C
- **Voltage:** 3V (2 x AA Battery)
- **Battery Life:** 5 Years
- **LoRa Frequency**:
  - EU 863-870 MHz (CE-Certified)
  - IN 865 -867 MHz (ETA-Certified)
  - US 902-928 MHz
  - AU 915-928 MHz
  - AS 916-925 MHz
- **SF Supported:** 7 – 12
- **OTAA and ADR:** Compliant
- **RF Output:** 20 dBm
- **Sensor:**
  - Temperature: -40 to +85°C
  - Humidity: 0-100% RH
  - Pressure: 330-1100hPa
- **Sensor Accuracy:**
  - Temperature: ±1°C
  - Humidity: ±3% RH
  - Pressure: ±0.25%

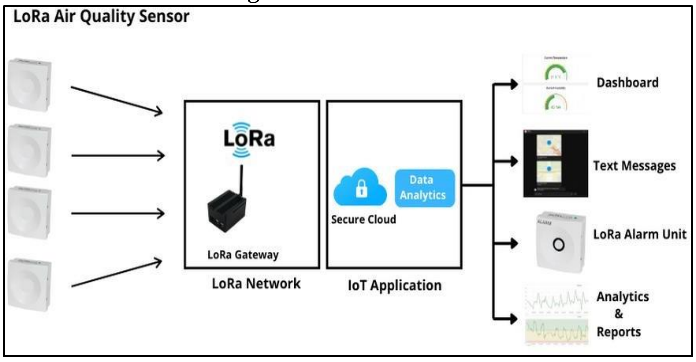
4 FUNCTIONALITY

The purpose of installing LoRa based Air Quality Sensor on the premise is to:

- Monitor Air Quality (Temperature, Humidity and Pressure)
- Notify Responders
- Direct Alert on Device (Buzzer and LED, optional)
- Communicate alerts when thresholds are exceeded
- Trend Indication and Data Analysis

4.1 WORKING ON LoRa AIR QUALITY SENSOR

Fig 2 Sensor workflow



All the Sensors are connected to the LoRa Gateway network using wireless technology, and it transmits the data to an IoT application (Grafana) using cloud technology. The IOT application generates dashboards, analytics and reports on the website, which users can view. IoT Devices are installed in the Lab and Blood bank of the following equipment:

1. The ambience of the lab and blood bank
2. Refrigerators
3. Freezers

4.2 IoT DEVICES INSTALLED IN LAB AND BLOOD BANK

Fig3: IoT device in RefrigeratorRefrigerator

We Successfully installed and placed 6 IoT devices in 6 refrigerators in the blood bank and central lab. Refrigerators had to maintain a temperature of 2 to 8 degrees centigrade to maintain and manage the reagents and samples. Temperature is monitored by data loggers and a PC-based centralized monitoring system in the lab by the hospital staff under the supervision of the lab in charge.

Fig 4. Data logger: Temperature Monitoring System for Refrigerator

Fig 5. IoT Device in Freezer

We Successfully installed and placed 2 IoT devices in 2 freezers in the blood bank. Freezers should always maintain a temperature of -25 to -41 degrees centigrade to maintain and manage the blood and its products. Temperature is monitored by data loggers and a PC-based centralized monitoring system in the lab by the hospital staff under the supervision of the lab in charge. Temperature monitoring system at the lab and blood bank for Freezer:

Fig 6 Temperature monitoring system for Freezer

4.3 IoT DEVICE IN PLATELET AGITATOR & INCUBATOR

Fig 7. IoT device in Platelet Agitator & Incubator

4.3.1 Platelet Agitator & Incubator

The platelet incubator is a device that provides accurate and steady storage conditions for platelet concentrates

- Safe storage of platelet concentrates by continuous agitation and controlled temperature.
- Constant agitation ensures no platelet clumping and maximum viability of platelets.
- The agitation motion monitoring system allows for improved safety.
- A digital temperature recorder controller unit and a unique airflow system maintain the chamber uniformly at the AABB recommended temperature of 22 +/- 2ºC.
- A digital sensor placed inside the solution-filled bottle ensures error-free readings and matches the exact temperature inside the bag.

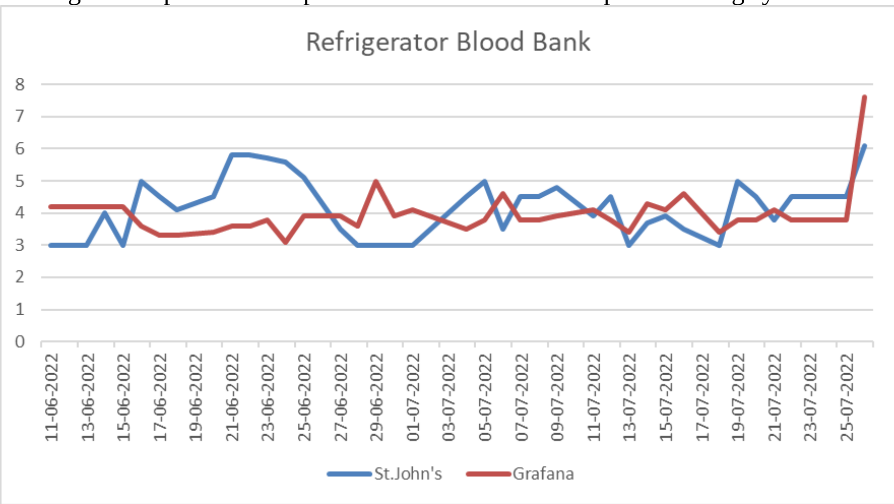
Fig 8. Thick walls of Hospital Blood Bank

5 FINDINGS

The temperatures are collected from the Zoho platform for the IoT devices and compared with the temperatures collected from the temperature monitoring system of the hospital's medical laboratory.

5.1 IoT DEVICE IN REFRIGERATOR

Fig 9. Temperature comparison IoT device and Temp Monitoring system in the RefrigeratorRefrigerator



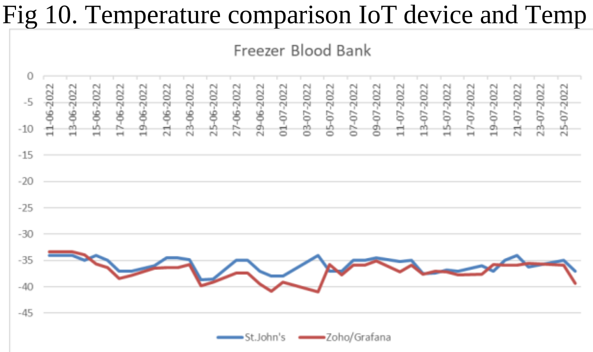
X axis: Dates
Y axis: Temperatures

As shown in the figure, the temperatures of both systems are within the range of 2 – 8 degrees centigrade for the RefrigeratorRefrigerator. The percentage change of temperatures for both methods is 3.2 %, which is acceptable.

5.2 IoT DEVICE IN FREEZER

The Freezer temperatures are gathered through the Zoho platform for IoT devices and contrasted with those collected from the St. John's medical laboratory's temperature monitoring system.

Fig 10. Temperature comparison IoT device and Temp Monitoring system in Freezer



X-axis: Dates

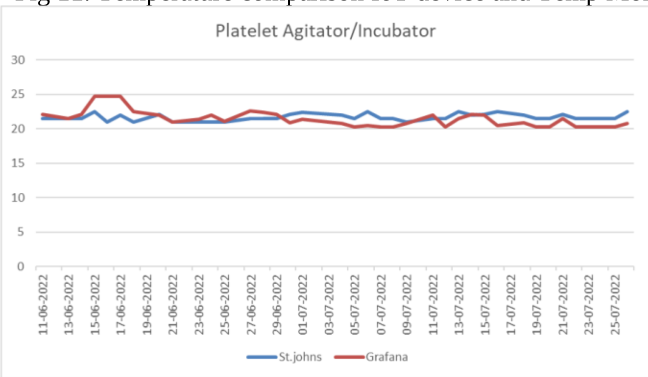
Y axis: Temperatures

As shown in the figure, the temperatures of both systems are within the range of -25 – -42 degrees centigrade for the RefrigeratorRefrigerator. The percentage change of temperatures for both methods is 3 % which is in the acceptable content.

5.3 IoT DEVICE IN PLATELET AGITATOR / INCUBATOR

The Incubator temperatures are gathered through the Zoho platform for IoT devices and contrasted with those collected from the St. John's medical laboratory's temperature monitoring system.

Fig 11. Temperature comparison IoT device and Temp Monitoring system in Incubator



X axis: Dates

Y axis: Temperature

As shown in the figure, the temperatures of both systems are within the range of 20-24 degrees centigrade for the Incubator. The percentage change of temperatures for both methods is 4.7 % which is in the acceptable content.

6 CONCLUSIONS

The IOT devices implemented in the blood bank and central lab accuracy is tested by comparing the temperatures (from Zoho) against the standard (The hospital's temperature monitoring system), and the variation observed is minimal. LoRa allows for better penetration even in the densest of the buildings in a hospital and can get accurate values of the critical temperature in the freezers. All these proposed systems are together called hyper-automation, and they would assist in preventing blood and its components wastage.

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