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EMERGING IoT SOLUTIONS: DEVELOPING A TEMPERATURE MONITORING SYSTEM

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Abstract **- Internet of Things (IoT) is gradually evolving to become a critical domain for application of IoT. From smart cities to healthcare, logistics and retail to smart living in smart environments, IoT has infiltrated into diverse applications. This paper deals with the use of sensors to develop a temperature monitoring and alert system that updates users with notifications at regular intervals. Since temperature varies in industrial applications it is important to keep it within the threshold range to avoid fire hazards and consequent damage to devices. The IoT based temperature monitoring system uses Bolt IoT platform to do the task. It controls the temperature 24/7 and raises an alarm in case of any discrepancy. It finds its use mainly in the cold storage industry where staff at the lowest level can detect a potential fluctuation and send warnings. The proposed device uses a Bolt IoT board with the LM35 sensor to pick up the temperature. The temperature is monitored through this device and in case of any fluctuation the user is alerted.**

Keywords: IoT, Bolt, Unique identifier, Python

I. INTRODUCTION

As the field of software engineering and development expands beyond limits the rapidly growing field of Internet of Things (IoT) is hard to predict. In future it will address applications with varying degrees of processing, sensing and actuation capabilities that can operate and interact through the Internet as their platform. The development of this device involved creating software that worked with development cycle, development period, APIs, scripting, adopting new technology and easy complex processes. Gillis (2022) has argued that Internet of Things (IoT) comprises interrelated computing devices, mechanical and digital machines, objects etc. that are provided with unique identifiers (UIDs) thereby gaining the ability to transfer data over a network sans human or human-to-computer interaction. Since IoT is much more than just software, the device prepared by us was tested and proved to be fully functional and operational in doing the assigned tasks.

II. INTERNET OF THINGS (IoT)

In this impersonal world of inanimate quasi-intelligent devices, a “thing” on the internet of things can be a person with a heart monitor implant, a farm animal with a biochip

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transponder, a driverless automobile that has built-in sensors to alert the oncoming traffic or any other natural or man-made object that can be assigned an Internet Protocol (IP) address and is able to transfer data over a network. It is a collective system of interconnected computing devices that are linked through sensors with an ability to share data over a network without external assistance. Thus, the main objective of IoT is to make it possible for objects to be interconnected using designated paths that deliver countless goals. With added sensors, these devices can not only collect data but deliver value added services like food movement in and out on a date from a smart refrigerator, info on its power consumption, temperature, average time of the door spent open and much more. This helps the manufacturer to analyze data trends to improve the features of the device. As well as tracking data for a company to use, it also greatly benefits the user. Savings in costs are the drivers for such uses. For e.g., if the lights automatically switch off the moment one leaves the room, a lot of money can be saved on electricity bills.

The IoT ecosystem comprises the following:

1) ***IoT devices***: Physical devices that interact with the environment are of two types i.e. Sensors and Actuators.
2) ***Network***: It is responsible for the communication within an IoT ecosystem between smart things, gateway, and the cloud.
3) ***Security Component***: It is used for access control to the IoT network, the security of data transfers, data leakage prevention, and scanning for malicious software. The security component is presented by firmware and software from security providers, such as Azure Sphere.
4) ***Gateway***: It is a physical device that passes through data streams from sensors to the cloud and in the opposite direction. It also performs data preprocessing before the information is transferred to the cloud but not a necessary element since IoT devices can set connections to the Internet by themselves without a gateway as an intermediary.
5) ***Cloud***: It is a computer resource responsible for management of data storage and deep analysis. The cloud is enhanced by powerful analytic and visualization tools, Big Data algorithms, and Machine learning technology.
6) ***Application***: It is the graphical user interface that provides remote control and management devices connected to the 'Internet of Things' ecosystem.

III. BOLT IoT MODULE

It is an IoT platform that gives the ability to manage and control devices securely. By deploying machine learning algorithms with sensors anomalies can be predicted and detected. The Bolt motherboard is a carrier for ESP8266 that breaks out pins to simple headers. The principal task is executed by the software using the interface created in the temperature monitoring system.

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Bolt Wi-Fi module-ESP8266

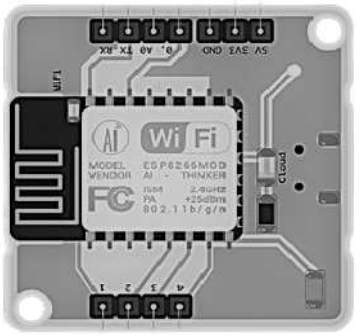

Figure 1: Bolt Wifi Module

It is a multi-tasking platform that comprises:

1) ***Network Connectivity***: A bare Arduino board does not possess any sort of network connectivity; it can only be achieved with the help of a Wifi shield or an Ethernet shield. Although compatibility issues are common with shields, drawing up extra libraries makes them work. While Raspberry Pi has an on-board WiFi chip (802.11 b/g/n) and Ethernet port that enables seamless connectivity among the sensors and web servers the Bolt IoT offers Wi-Fi or GSM variant for developers or enterprise package.

2) ***Cost factor***: Arduino is available at a price of INR 2500 (Mega variant), while Raspberry Pi 3 is available at a price point of INR 2900 in India and Bolt IoT platform is available for the price of INR 1750 in the developer's package.

3) ***Storage***: Arduino offers no on-board storage capacity except for the ROM space, since it relies on the SD-Card modules for storage operations. Raspberry Pi has got the option for on board storage and can support up to 64 GB SD cards.

4) ***Cloud platform***: Both the Arduino and the Raspberry Pi depend on third

5) party cloud architecture to process the data for meaningful applications whereas one of the best features of Bolt is its Cloud platform.

IV. REQUIREMENTS

The project contains both hardware and software requirements. While developing this temperature control device the focus was primarily on cold storage industry which is growing very fast. IoT systems can be integrated into almost every object being used in cold storage facilities to limit energy wastage and power outages.

A. Circuitry Design

By using LM35 analog sensor the circuitry becomes rather simple. Since LM35 sensor has short pins, female to male jump wires were used in connections. Bolt module sports a type-A USB port that can be powered by an auxiliary power source.

Circuitry of Bolt Wi-Fi module

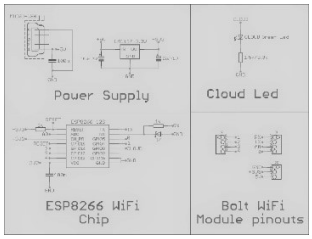

Figure 2: Circuitry of Bolt Wi-Fi

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TABLE 1. Specifications of Temperature sensor

LM35 Pin	Corresponding Bolt WiFi Module Pin	Comments
Vs Supply Voltage	5V	LM35 sensor operates at 5 Volt.
Vout - Output	AO	Since the output is analog and A0 is the only pin on Bolt Wi-Fi module that can read an analog input.
GND Ground	GND	The ground pin of the LM35 to be connected to the ground pin of Bolt Wi-Fi module.

Source: compiled by authors

B. Minimizing Industry loss

In their research on cost effective low energy hybrid storage Beldar M. et al (2021) have identified the need to reduce post-harvest losses of edible commodities by enhancing their storability and shelf-life. Indian cold chain industry is growing leaps and bounds and to reduce food insecurity post-harvest management of fruits and vegetables needs to be encouraged. To reduce post-harvest losses cold storage capacity must be managed scientifically. [5] discussed about an eye blinking sensor. Nowadays heart attack patients are increasing day by day."Though it is tough to save the heart attack patients, we can increase the statistics of saving the life of patients & the life of others whom they are responsible for. The main design of this project is to track the heart attack of patients who are suffering from any attacks during driving and send them a medical need & thereby to stop the vehicle to ensure that the persons along them are safe from accident. Here, an eye blinking sensor is used to sense the blinking of the eye. spO2 sensor checks the pulse rate of the patient. Both are connected to micro controller.If eye blinking gets stopped then the signal is sent to the controller to make an alarm through the buffer. If spO2 sensor senses a variation in pulse or low oxygen content in blood, it may results in heart failure and therefore the controller stops the motor of the vehicle. Then Tarang F4 transmitter is used to send the vehicle number & the mobile number of the patient to a nearest medical station within 25 km for medical aid. The pulse rate monitored via LCD . The Tarang F4 receiver receives the signal and passes through controller and the number gets displayed in the LCD screen and an alarm is produced through a buzzer as soon the signal is received.

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C Software

The proposed temperature control device uses the following software:

a) Bolt IoT module serves to deploy the configurations of the hardware to the cloud server.

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b) Ubuntu server is used for hosting a private server.
c) Mailgun for sending fluctuation message to the subscribed client via email.

e) Twilio for sending fluctuation message to the subscribed client via SMS.

f) Bot-Father bot service to send the fluctuation message to the subscribed client via Telegram/TelegramX messenger.

g) VmWare is used to image the Ubuntu server for updation and maintenance purposes.

h) TinkerCAD is used to design the casing and source it in .stl format to the 3D printer.

A detailed description of each software and its role in the system is provided below:

a) ***Ubuntu***: Ubuntu is a Linux distribution based on Debian and composed mostly of free and open-source software. Ubuntu linux was used to setup and maintain the virtual private server (VPS). It is important for the cloud as it is used to setup relevant libraries and handle files in the virtual server.

b) ***Twilio***: It provides programmable communication tools for making and

d) receiving phone calls, sending, and receiving text messages, and

performing other communication functions using its web service APIs.

c) ***Mailgun***: It is an email automation service. It has a powerful set of inbuilt functions for sending emails.

d) ***Bot Father***: In this device it was used to send alerts to telegram accounts if the system requires attention.

e) ***VmWare***: VMware Workstation is the first product ever released by the software company. It enables users to create and run VMs directly on a single Windows or Linux desktop or laptop. Those VMs run simultaneously with the physical machine. Each VM runs its own OS such as Windows or Linux.

In our case we used VmWare to run Ubuntu linux to create and maintain the device.

V. METHODOLOGY

In this proposed prototype we intended:

a) Gathering temperature data from sensors and sending it to a cloud for monitoring.
b) Monitoring the temperature in a cold storage and sending warning alert through mobile application.
c) Sending alerts to authorities in case of potential fire hazard arising from temperature fluctuation.

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The software development for this device was executed in five phases:

a) ***Planning*:** For effective and intricate measuring of the temperature LM-35 sensor was procured as it can measure temperature ranging from -55°C to 155°C. For getting the output a virtual private server was employed to host and deploy the configurations of the Bolt IoT module. Two major factors while working on casing were ergonomics and utility.

b) ***Development*:** Coding comes into play when creating and handling data in the private cloud server. i.e, to work on files that are used to group data. Python programming language was used to create and edit file configurations such as the API key, authorized token, etc.

During development the code was divided in relation to its function. To carry out each function we created its own unique file in the virtual cloud space with the help of Linux, the instructions for which are coded in python. In case of minor temperature fluctuation, it sent an alert via SMS, email or via Telegram.

c) ***Testing*:** Since the LM-35 sensor has an impressive measuring range (-55°C to 155°C) the uses of this system are numerous. With just a few tweaks in the database the device is well equipped for any relevant task and almost any condition.

d) ***3D device***: The device is powered by an ESP8266 module which runs at peak condition of -55ºC to +125ºC; Accuracy +/-0.5 ºC. This makes the device an industrial grade system that is durable and robust. As for the casing we tested the utility and ergonomics by placing and handling it carefully. Polyethylene terephthalate glycol (PETG), an industrial grade heat resistant material was used as raw material. Not only it is unaffected by heat dissipation of the system but also sturdy enough to protect the elements from minor breakage.

Proposed model of device

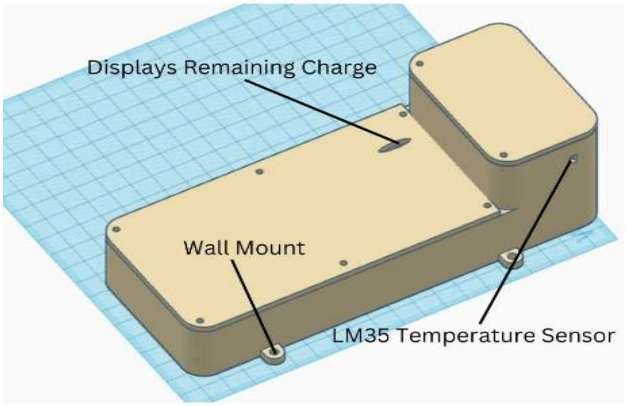

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Figure 3: Proposed model

e) ***Deployment:*** In this stage the response time and connection between the server and communication clients was tested. The temperature dropped and spiked in frequent intervals to check the nature and frequency of the responses achieved over each communication channel.

TABLE 2. Specifications of Bolt Wi-Fi module

Parameters	**Details**
Connectivity and Processing Module	ESP8266 with custom firmware
MCU	32-bit RISC CPU: Tensilica Xtensa LX106
Power	5V/1A DC via Micro-USB port or 5V and GND pins
Operating Voltage	3.3V
CPU Clock Frequency	80 MHz
MCU Internal Memory	64 KB of instruction RAM; 96KB of data RAM
GPIO pins	5 Digital pins [3.3V logic]
ADC	1 pin 10 bit ADC [0-1V input]
PWM	All 5 Digital pins capable of PWM [Software PWM]

Source: compiled by authors

After we complete the project, then we will look more into how to improve the connectivity as well as interface to provide more user-friendly platform. We will also work on the 3D model to make the project

look more polished and work on circuitry to better on the mechanics and keep on working to make it more efficient and accurate with each day passes via the inventory.

VI. DISCUSSION AND ANALYSIS

This project provided a valuable and immense learning experience for us. We got to know how to use the Bolt IoT modules, made use of VM's, designing, and working to model our IoT casing with a 3D printer. During work various challenges arose which were tackled through hard work and perseverance.

The learning curve included observing changes that can be made to the circuitry and elements connected to make the appliance even more compact. One of the most satisfactory results we obtained was on the heat dissipation that affects the temperature

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being monitored. With such a sensitive performance we plan on adding higher grade protection from moisture. In future an even more agronomical design for the device can be worked out. An updated version would be even more compact in structure and ensure a relatively greater power backup.

VII. CONCLUSION

To conclude, IoT can be best described as a CAS (Complex Adaptive System) that is at an evolving stage and therefore requires an innovative approach in software development and emerging technologies. Although countless research papers continue to be published on the topic, the food industry must finance the R&D of the type of temperature controlling device developed by us. This will help businesses, organisations, and governments to achieve long term objectives. IoT issues demand acceptance, cost, connectivity, security, and other concerns, and standards that are still being established due to the influx of new players. Despite these obstacles, the IoT's long-term ambitions hold much potential.

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