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Cloud based EV-ECU Monitoring using IoT

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Abstract: ***The EV Market is burgeoning in India. As the government is shifting its focus toward the EV industry to reduce its carbon footprint. As automobile industry is shifting from traditional combustion engine to EVs there are some somber concerns about user safety due to vehicle catching fire incidents, EV Motor failure. This is due to unmonitored critical components like battery voltages and temperatures, motor temperature and current and crash alerts. This design aims to solve the problem of unmonitored systems in e-bikes for EV manufacturers and e-bike riders. By providing real-time data and remote diagnosis capabilities, the system can enhance the safety and efficiency of e-bikes while reducing the risk of accidents. The cloud-based ECU monitoring device can benefit manufacturers by improving the competence, consistency, and safety of their products, while e-bike riders can benefit from enhanced safety features, such as real-time crash alerts.***

Keywords: IoT, Firebase, BMS, RTDB.

1. Introduction

Over the past decade, World has been grappling with many environmental issues like rise in global warming, acid rain and damage to ozone layer. Recognizing the urgency of these challenges, countries worldwide have made concerted efforts to reduce their carbon footprint, which serves as the fundamental driver behind these adverse events. Especially, the burning of fossil fuels emerges as the primary contributor to carbon pollution, and unfortunately, our transportation industry heavily relies on these petroleum-based products. To mitigate this ecological impact, governments are shifting its attention from IC Engine to Electric Vehicle with the aim of curbing carbon emissions.

However, as we transition to a more sustainable mode of transportation, ensuring the safety of bike riders becomes an utmost priority. Recent reports have shed light on several e-bike accidents caused by battery fires, Motor failure. Various critical components within electric vehicles, such as battery voltage and temperature, motor temperature and current, and crash detection, remain inadequately monitored, leaving room for potential hazards to go unnoticed. Consequently, there is a necessity to develop an advanced Electronic Control Unit (ECU) monitoring device that can comprehensively oversee these vital aspects of EV operation, thereby ensuring vehicle safety. By promptly detecting anomalies in data, proactive actions can be taken to avert safety risks and safeguard the well-being of riders.

The advancements in IoT and cloud technology have given rise to Real-time monitoring platforms like Google Firebase, AWS Cloud, ThingSpeak, Blynk, etc. This have transformed the way we monitor IoT devices in real time and store their data on cloud-based Real-Time Database (RTDB) systems in a secure and accessible manner. Further this data can be accessed by the android application.

Key Services provided by Cloud Based ECU Monitoring for EV using IOT:

- Realtime monitoring of EV Parameters
- Analysis of EV Paramenters and Remote Diagnosis
- Cloud based data accessibility.
- Secure data transfer over firebase.
- Accident detection with emergency Notification.

2. Literature Review

a) Dr. Bhargava Ramu T, Sai Ram Koganti, Narender Mangali proposed a monitoring system to monitor various aspects of BLDC motor and BMS temperature and Humidity along with vehicle location using open source hardware.
b) Miss. Sayali A. Patil, Prof. Atul R. Nigavekar proposed a device for monitoring BMS data like battery voltage and voltage across per cell and temperature of battery using cloud using arduino uno and ESP8266 wi-fi module as a hardware interface.
c) Yu Yu Mon Win, Moe Myint Aung, Thin Thin proposed an accident detection system using ADXL335 and Arduino Uno with emergency alerts during accident.
d) Lucian Andrei perisoara, Elena Madalina Stamati, Luciana Raluca chitu proposed a pilot platform for monitoring an EV using GSM, GPS and Arduino Mega 2526

3. Proposed System

The method that we implemented will mainly be elaborated in this section. The hardware plan is illustrated in Figure 1, depicting the integration of various components. The design incorporates the Atmega328P MCU along with the Node MCU, NTC temperature sensors, voltage sensor, ACS712 current sensor, Neo-6M GPS module, ADXL335 accelerometer. These components collectively contribute to the functionality of the system. The main benefit of using Atmega328P it has built-in multichannel 10-bit ADC, which is used for ADXL335, Voltage sensor, current sensor and Temperature sensor. Data Acquisition (DAQ) will be carried by Atmega328P, data will be transferred to Node MCU via Serial Communication. Which will be later uploaded onto google firebase server using MQTT protocol. Further this data can be accessed via Android APP.

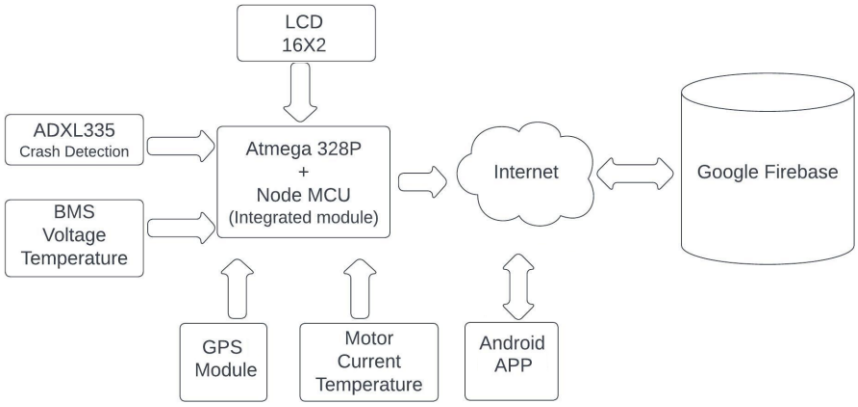

Figure 1: Block Diagram of Hardware.

a) Integrated Module

The Atmega 328P MCU with Node MCU ESP8266 module incorporates this module of terminal gadget. The data acquisition by ADXL335, GPS, Voltage, and current Sensor and Temperature Sensors can be obtained by the integrated module. The communication between Atmega328P and Node MCU is achieved UART communication with baud rate of 115200bps. Node MCU is development board based on ESP8266 MCU which has inbuilt Wi-Fi. Fig 2 shows the connection between Atmega328P and Node MCU Board.

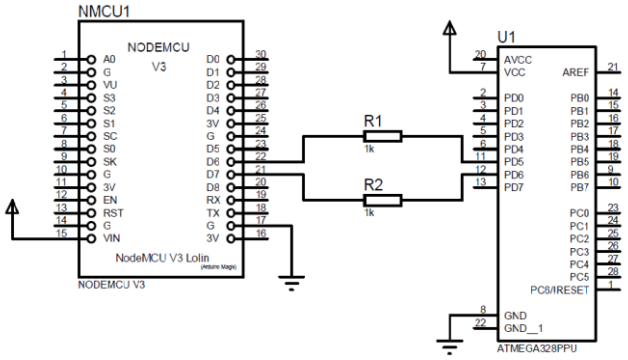

Figure 2: Atmega328P and Node MCU Connection

b) GPS Module

Neo-6M GPS module is a satellite-based module that uses navigation satellites to find its location [6],[11]. It uses UART to communicate with Atmega328P.

c) ADXL335 Sensor

It is Low Power, three axis Micro-electromechanical systems (MEMS) accelerometer. Operating at supply voltage -1.8V to 3.6V. It is used to detect sudden changes in any axis with the accuracy of ±3g. ADXL335 is used to detect crash by measuring the tilt of a vehicle along its X, Y, and Z axis. By setting a threshold for each axis, if the tilt exceeds that threshold, it indicates a significant change in orientation, potentially indicating a crash [4].

d) Battery Management Sysytem(BMS)

Currently, Li-ion and Li-Ferro batteries are the most commonly used battery type in EVs. These Cells have a Nominal cell voltage of 3.7V and a typical EV bike requires 48V, 60V, 72V or 81V. So to fulfill this requirement of EVs they are arranged in Series to obtain the required potential difference. These batteries use a Battery Management System(BMS) chip which is responsible for charging, discharging batteries, short circuit protection (SCP), over charge protection (OCP), etc. [7]. During charging or discharging battery temperature of batteries varies it effects on efficiency of battery so it is necessary to monitor its temperature along with State-of-charge (SOC). The charge in battery is dependent on temperature. If temperature is maintained at 15 to 35°C the efficiency of battery increases [9]. The voltage can be measured using voltage divider circuit by mapping input voltage to 0V-5V range because Atmega328P has an ADC reference voltage of 5V [2],[6],[1]. This means that the ADC pins on the Atmega328P can tolerate a maximum voltage of 5V. For getting the temperature of the battery surface Flex type NTC temperature sensor is used in this proposed work.

e) Motor Parameters

There are two types of Motor used in e-bike, Mid-drive motor and Hub Motor. Hub motor, Motor is integrated into hub of a wheel. To protect motor from overheating motor protection sensors such as NTC/PTC temperature Sensor, Current sensor can be implemented to monitor motor parameters during driving [6]. Current sensor (ACS712) is a Hall effect sensor which is analog so it is interfaced with 10-bit ADC of Atmega328P and NTC temperature sensor is used to detect motor winding temperature which is connected to ADC Pin of Atmega328P.

f) LCD Display

LCD (16x2) is used to Display ECU parameters on vehicle which is interfaced with Atmega328P.

g) Google Firebase

Firebase is cloud service provided by google for various applications which includes IoT service. Real time Database (RTDB) is important feature which is useful for real-time monitoring applications in IoT. It utilizes JSON-based data structure for storing data. It uses MQTT protocol for IoT applications. Data collected from several sensors will be uploaded onto this RTDB. This data can be retrieved from anywhere from globe. An android application is built to retrieve this data from Android phone.

Feature offered by firebase for IoT:

1) Realtime Database- It uses a non-relational database that provides real-time synchronization. Enabling IoT devices to easily send and receive data, allowing real-time monitoring.

2) 2)Security and Authentication- It offers robust authentication mechanism. Also provide secure storage for sensitive data.
3) 3)Firebase cloud messaging (FCM)- It support bidirectional communication between firebase and IoT device. Enabling to send push messages and notifications to IoT devices.
4) Monitoring and Analytics- It provides Monitoring and analytics tools to get insights into data.

h) Android APP

An Android application is developed using android studio to fetch data from google firebase RTDB onto Android phone. Fig 3 Shows the UI of Application. There are four section 1) BMS Data – which shows Battery parameters like voltage and Temperature. 2) Motor Data – this section displays motor current and Temperature. 3) Tracking – This section displays GPS data. 4) Crash info – This displays crash status based on ADXL335 readings and if crash is detected then user will get notification on their phone as well as status will be changed to crash detected from No crash Detected as shown in Fig 4 and Fig3.

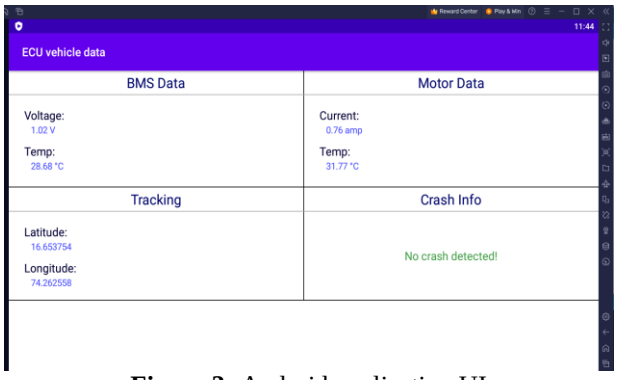

Figure 3: Android application UI

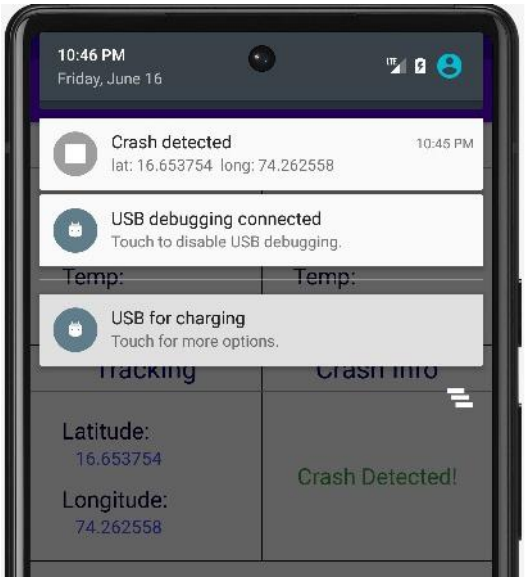

Figure 4: "Crash Detected" Notification

i) System Operation

- First step is to Power ON system, Then LCD displays Project name and Node MCU will get connected to Configured Wi-Fi Hotspot so it can transfer data to google firebase.
- GPS Data received from GPS module will be read from UART Pins.
- Voltage sensor will be connected across battery whose value will be read by Analog Pin.
- NTC Temperature Sensor value will be read by Analog Pin and the further temperature will be calculated programmatically.
- ACS712 Current sensor is connected in series across battery and motor to get discharge current which will be fed to Analog Pin.
- The ADXL335 accelerometer is connected to the ADC pins and provides readings for all three axes. By analyzing the values from each axis, the system can programmatically detect crash events [4].
- All the Sensor values will be read by ADC Pin on Atmega328P calculated further programmatically for required metrices.
- These calculated values will be sent to Node MCU via UART every 2 Secs.
- Received data from Atmega328P will be divided into substring to assign values variables.
- These values are further uploaded to google firebase RTDB.

4. Implementation

1) Step 1- Install Google Firebase Library on PC.
2) Step 2- Goto Google Firebase website and login with your existing gmail account or created new as shown in Fig 5.

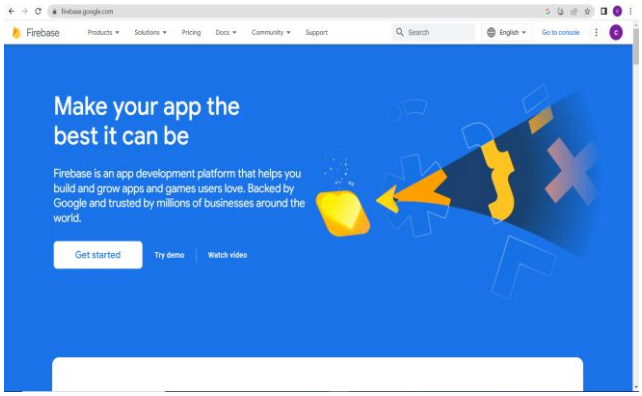

Figure 5: Sign up on Firebase

3) Step 3 – Now next step is to create Firebase project as shown in Fig 6.

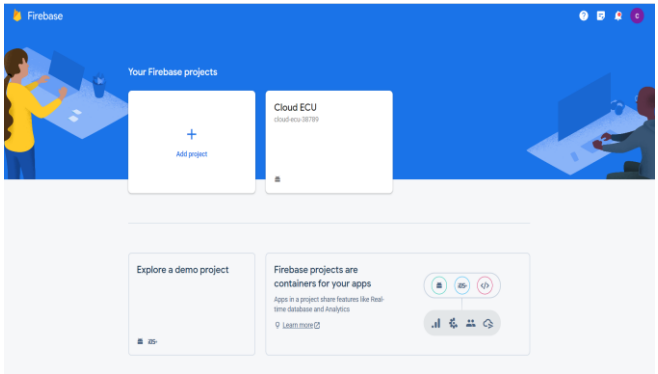

Figure 6: Creating New Project

4) Step 4 - Now click on Project Setting to get Web API key which will be used in Node MCU code so that data can be uploaded to specific RTDB and Project as shown in Fig 7.

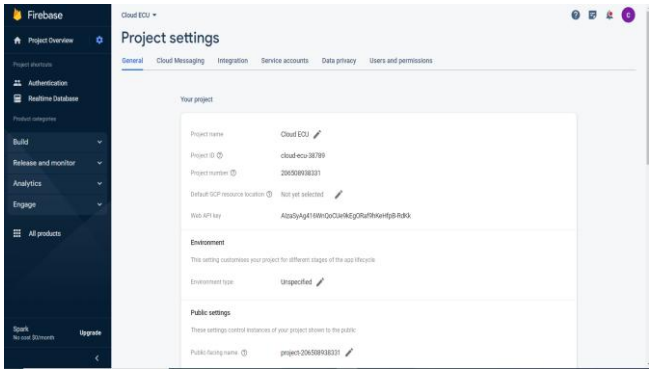

Figure 7: Get API Key

5) Step 5- Now you can access uploaded data from Node MCU to RTDB from Google Firebase.

a) MQTT Protocol

There are two protocols that Cloud IoT Core supports MQTT and HTTP for connecting to and communicating with devices. A "bridge"—either the MQTT bridge or the HTTP bridge—is used by devices to connect to Cloud Core.

- Device connection is maintained
- Device connection status is reported
- Full-duplex TCP connection
- Telemetry events are pushed to Cloud Pub/Sub
- Device configurations are propagated via subscriptions
- Most recent configuration is always received by devices on subscription
- Device configurations are acknowledged when using QoS 1
- Last device heartbeat time is retained

5. Testing Result

1) ECU Parameters on Google Firebase

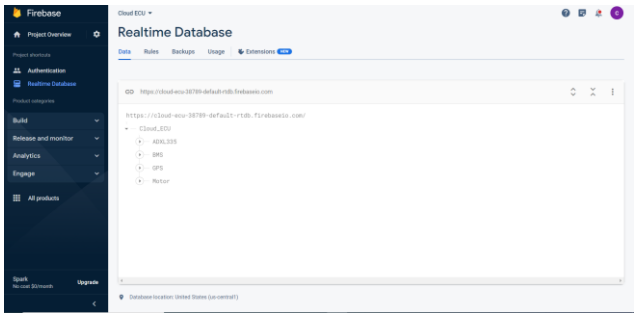

Figure 8: Firebase RTDB

Fig 8 displays RTDB, Data from system is stored in this cloud platform. It uses tree structure to store data in RTDB unlike other databases using Rows and column's structure to store Data. In above Fig Cloud_ECU is a Root Node and ADXL335, GPS, BMS, Motor are Parent nodes where data corresponding to sensor is stored in a pre-determined format by combining two sensor data at a time.

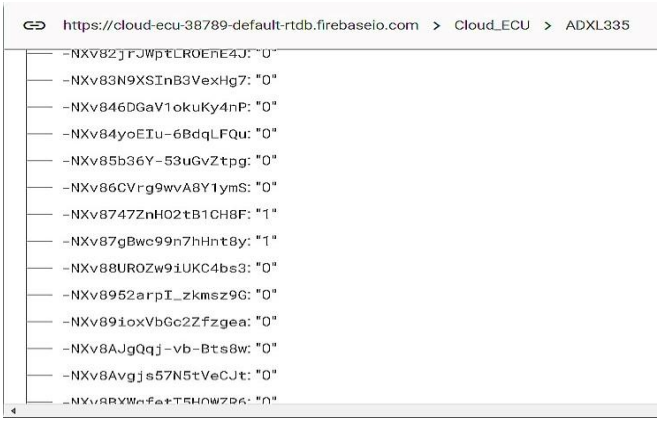

Figure 9 A: ADXL335 Data

Above image show ADXL335 data, [9] If No crash is detected then this bit will be set to "0" and if Crash is detected bit will be set to "1" giving a notification-on-Notification panel with EV Location as in Fig 4.

Figure 9 B: BMS Data

Fig 9B Shows BMS data, here two values from different sensors are clubbed together and stored. E.g.- "9.86" is Voltage across battery and e.g.- "29.04" is a surface Temperature of Li-ion cell.

Figure 9 C: Motor Data

Fig 9C Displays Motor Parameters Data, first value is Motor winding Temperature e.g.- "32.27" and value followed by it is Current drawn by Motor e.g.- "0.76".

Figure 9 D: GPS Data

Fig 9D displays GPS Data, here Latitude is followed by longitude and stored.

2) ECU Monitoring Hardware

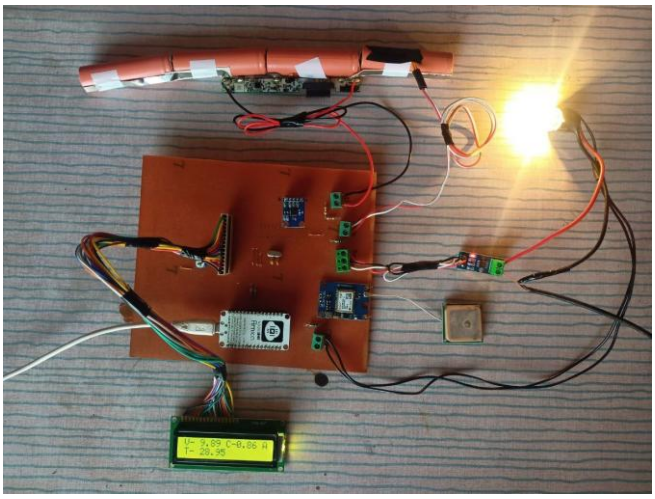

Figure 10: Hardware proposed system

Figure 11: LCD Showing Project Name

Figure 12: LCD Showing ECU Parameters

Figure 13: LCD status during Accident

Fig. 10 contains main Hardware implementation of proposed system. Motor is simulated by using a Bulb and NTC Temperature sensor senses its Temperature. EV battery pack is simulated using laptop battery with BMS, Four Li-ion cells are in Series and a NTC temperature sensor is mounted on its surface to sense surface temperature. Fig 11 Shows Project name when system is powered ON. Fig 12 Displays important EV parameters like BMS voltage, Temperature and Motor Current and if accident is occurred it shows "Accident detected" on Screen as shown in Fig 13.

6. Advantages

1) It provides Real-time monitoring of EV parameters.
2) Convenient data accessibility on Firebase and Android App.
3) Accident Detection with Emergency Notification
4) Secure data transfer over Firebase.
5) Easy analysis of EV parameters.

7. Conclusion

The objective of this system is to enable cloud-based Electronic Control Units (ECU) monitoring through IoT integration. By incorporating an integrated module, real-time data is continuously sensed and seamlessly updated to Google Firebase Real-Time Database (RTDB). The system implemented should prove instrumental in enhancing vehicle safety for both EV owners and manufacturers.

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