Optimizing Wiring Harness Minimization through Integration of Internet of Vehicles (IOV) and Internet of Things (IoT) with ESP-32 Module: A Schematic Circuit Approach

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Abstract: The advancement of hybrid and electric vehicle technologies in response to the demand for reduced environmental effect has led to a rise in automotive engineering complexity. Engineers are entrusted with creating automobiles that not only save fuel and emit less pollution, but also meet demanding safety criteria and customer expectations. To accomplish this, they must have a thorough understanding of hybrid technology, risk assessments, and regulatory compliance. The proposed work, the Wi-Fi connectivity is used as a strong wireless communication technology within the car in the suggested system. The use of Wi-Fi considerably reduces the requirement for physical wiring, allowing for seamless data transfer between car components and the central control unit via ESP-32 now wireless Communications. This method simplifies the internal architecture of the vehicle, resulting in a cleaner and lighter design that improves energy efficiency and reduces manufacturing complexity. This paper presents the conceptualized schematic circuits designed for minimize wiring harness using the Internet of Vehicles (IOV) concept combined with Internet of Things (IoT) principles, all facilitated by the Espressif Systems’ ESP-32 Module.

Keywords: Wi-Fi connectivity, Internet of Vehicles (IoV), Real-time communication, Internet of Things (IoT), Electric Vehicle technologies.

1. Introduction

The development of the Internet of Vehicles (IoV) as a subset of the Internet of Things (IoT) is inextricably linked to the advancement of advanced communication technologies such as 5G and the potential future impact of 6G [1]. The IoV concept entails integrating vehicles, infrastructure, and other road users into a linked ecosystem, enabling real-time communication, data sharing, and intelligent decision-making. However, as you indicated, this integration is fraught with difficulties, particularly when it comes to the requirements of electric cars (EVs).

The Internet of Vehicles (IoV) is an Internet of Things (IoT)-based solution aimed at meeting the road safety and traffic management goals of intelligent transportation systems (ITS) for vehicular clients, which has gained traction as a result of the increased reliability of wireless communication and sensor technologies [2, 3]. The IoV solution consists of a wireless sensor network (WSN) with a central server that processes the received data in real-time to generate contextual measures, vehicular client nodes, and roadside units (RSU) that serve as waypoints for collecting the required sensory data and disseminating safety and traffic related alerts [2].

1.1 Internet of Vehicles (IoV) network connection protocols

The Internet of Vehicles (IoV) signifies a paradigm shift in the automobile industry, allowing cars to be more than just routes of transportation. Manufacturers may improve client experiences while generating new revenue streams by utilizing modern connectivity, software upgrades, data-driven insights, and enhanced services. However, as the automotive market evolves, addressing security, privacy, and ethical data use becomes critical to establishing and sustaining customer trust [4, 5].
The Internet of Vehicles supports five network connection protocols. Using communication protocols like IEEE802.11p, IoV makes it easier for vehicles, road infrastructures, drivers, passengers, and sensors to exchange information. Utilizing a variety of V2X connection protocols, IoV’s communication flexibility is established. A clear understanding of IoV-related operations is crucial to ensuring the security of the IoV ecosystem. With support for elements like traffic distribution along routes, local gas stations, roadside services, and a variety of other features, these protocols enable devices to engage in wireless communication inside the IoV framework. According to the operational layer they affect, IoV protocols are divided into three groups. Since many protocols are created for broader networking contexts rather than being IoV-specific, the OSI-ISO seven-layer network model is used due to its universality in networking paradigms.

**MAC layer:** The primary goal of the WAVE IEEE 802.11p protocol is to integrate the MAC layer and physical to enable communication between automobiles and roadside devices positioned at various on-road distances.

**Routing protocols (RPs):** In the IoV’s 7-layer model, the network layer, or the communication layer, is where these protocols operate. An RP’s main job is to choose the best route between two nodes, taking into account aspects like latency, distance, number of intermediary nodes, and security. By using techniques like geo-cast routing or broadcast, RPs also make it possible for all network nodes within a specific area to communicate widely with one another.

- **Intra-Vehicle systems** that use On Board Units (OBUs) to monitor the internal performance of the vehicle.
- **Vehicle-to-Vehicle (V2V) systems** allow for the wireless exchange of information on the speed and location of cars in the vicinity.
- **V2I systems** enable the wireless transmission of data between a vehicle and supporting roadside units (RSUs).
- **V2C systems** enable the car to get more information via the internet via application program interfaces (APIs).
- **Vulnerable Road Users (VRUs)** such as walkers and cyclists benefit from Vehicle to Pedestrian (V2P) systems.

### 1.3 Objective of this work

- The key idea of proposed work is inventing a feature that reduces energy use by only activating vehicle components when needed is a good step toward improving vehicle energy efficiency. Connecting dashboard switches to a server module and integrating various car components with a client module can certainly help.
- To develop the advance EV system for minimization of wiring Harness Using Internet of Vehicles.

In rest of work as following: In section 2 explore the existing work related to EV, section 3 explain the ideal Working of Internet of Vehicles (IoV) System, in section 4, discussed the used Software and hardware parts for analysis of proposed work, Section 5 result analysis and discussion and last section 7 conclusion and future work.

### 2. Literature Review

**A. Thakur, A., Malekian, R. (2019).** The communication channel and an IoT-based system for road safety and traffic management applications are researched in this study. A comparison of simulation frameworks for building and testing road safety and traffic management related applications for IoT solutions is investigated. Multiple wireless communication technologies are used to simulate communication channels. Communication channel requirements such as transmission speeds and message size are identified. The performance of wireless communication technologies is used to select the best wireless communication technologies for IoV system communication channels [7].

**B. Ahmad, F., Kerrache, C, Kurugollu, F, Hussain, R. (2019).** In this paper, we suggested a new tier-based architecture called "Blockchain in NDN-enabled Internet-of-vehicles (BINDN)," which can allow BC in NDN-enabled IoV. BINDN can be used as a reference architecture for designing security solutions in NDN-enabled IoVs that use BC. Furthermore, it offers a wide range of applications such as IoV security, trust management, and privacy upgrades [8].

**C. Kezia, M., Anusuya K.V. (2022).** This study provides an overview of vehicular mobility models, focusing on the realistic character of vehicular motions and the associated issues. To realize the goal of linked, smart cars with mobility as a major
component, the Internet of Vehicles framework heavily relies on Vehicular Ad-hoc Network (VANET). Because implementing and testing a VANET in real-time is costly, simulations are an important tool in vehicular communication research [9].

D. Wang, Q., Liu, X., Du J. Kong, F. (2016). This survey focuses on algorithmically intelligent interactions. Three alternative perspectives—smart grid-oriented, aggregator-oriented, and client-centered—are used to study key determining factors for coordinated billing. Starting with the formulas provided for load flattening, frequency management, and voltage regulation, we explore their nature and major similarities for EV charging that is focused on the smart grid. Second, we categorize the algorithmic approaches presented in research publications that reflect this viewpoint for aggregator-oriented EV charging as direct and indirect coordinated control, and we thoroughly examine these approaches [10].

E. Luo, W., Chen, W., Feng, Y. et al. (2020). In this study, a brand-new multiband shark-fin car antenna that can operate in the LTE, 5G, WLAN, and DSRC bands (690-944 MHz and 1.46-6 GHz) for IoT vehicle communication is examined. In light of the expansion of the Internet of Things, the Internet of Vehicles (IoV) is a crucial component of mobile communication systems. The long-term evolution (LTE), fifth generation (5G), wireless local area network (WLAN), and dedicated short-range communication (from 690 to 944 MHz and from 1.46 to 6 GHz) frequency bands are all covered by the unique multiband car antenna that is presented. The antenna is based on a monopole antenna, and by loading a toothed capacitor and an impedance matching disk, it performs better at impedance matching [11].

F. Bhaskar P. Rimal and et al. (2022). The next major advancement in smart grids and city sectors for a sustainable society is the Internet of Vehicles (IoV), where people, electric vehicle (EV) fleets, utility, power grids, distributed renewable energy, and communications and computer infrastructures are connected. Decentralized and complicated grid edges, meanwhile, present numerous difficulties in terms of managing, operating, and planning electricity systems. Thus, establishing a trustworthy communications infrastructure is essential. The fourth industrial revolution, which includes a cyber-physical system, the Internet of Things (IoT), and the coexistence of edge (fog) and cloud computing, offers new solutions for overcoming these difficulties and enhances the advantages of power grids [12].

3. Ideal Working of Internet of Vehicles (IoV) System

It is challenging to satisfy the auto market nowadays. A modern car today has approximately 100 million lines of software code. This necessitates advanced coding approaches as well as administration. By giving updates on embedded codes, the Internet of Vehicles can improve consumer satisfaction. These can provide new services, which helps to increase aftermarket service revenue. As previously stated, the IoV creates a social network with smart objects as players by utilizing various forms of interconnection. As a result, the Social Internet of Vehicles (SIoV) was born. That is the vehicle manifestation of the Social IoT (SIoT).

While gathering data, all sensors deployed in vehicles, smart terminals, and platforms dispersed across modern urban infrastructure connect securely. Vehicles are steered in real time based on this data. Furthermore, IoV connectivity enables manufacturers to discover and improve the reliability of their devices. This proactive maintenance reduces the likelihood of breakdowns or emergencies. The IoV also allows manufacturers to sell upgraded software versions with new features. The Internet of automobiles (IoV) is a complex and interconnected system that intends to build a network of automobiles, infrastructure, and digital services that is seamless. Its optimum operation entails the integration of multiple technologies and components to allow for real-time communication, data exchange, and intelligent decision-making. Here's a high-level overview of how an IoV system should work: Vehicle Connectivity, Communication Infrastructure, Data Exchange, Centralized Cloud Services, Intelligent Decision-Making, Enhanced Safety and Efficiency, Customized Services, Predictive Maintenance, Environmental Impact, Continuous Improvement, Data Privacy and Security.

3.1 Layered Architecture of IoV functional system

Perception, coordination, Artificial Intelligence (AI), application, and business layers are all part of a five-layered architecture. A summary perspective is provided in Figure 2 [23-26], and the representations and functions of each layer are detailed in depth below.

![Fig. 2: The five layered architecture of IoT functional system [23-26]](image-url)
Layer 1: Perception [23-26]
The various types of sensors and actuators attached to vehicles, RSUs, cell-phones, and other personal devices that are taken into consideration in the framework make up the first layer of the architecture [23-26].

Layer 2 of coordination
The perceived data from the lower layer is securely transferred to the artificial intelligence layer for processing through a virtual universal network coordination module for heterogeneous networks including WAVE, Wi-Fi, 4G/LTE, and satellite networks that makes up the second layer of the architecture [23-26].

Layer 3: Artificial Intelligence
The virtual cloud infrastructure stands in for the third layer of the design. It serves as the brain of the IoV and is in charge of processing, storing, and analysing information received from lower layers as well as making decisions based on that analysis [23-26].

Layer 4: Applications Layer [23-26]
Smart apps, which include infotainment systems with multimedia content and web-based utility applications, as well as ones that improve traffic efficiency and safety, are represented by the fourth layer of the design. The layer's duty is to offer end users intelligent services that are founded on a perceptive and critical evaluation of data that the AI layer has processed [23-26].

Layer 5: Business Layer [23-26]
The operational management module of IoV stands in for the architecture's fifth layer. The layer's primary duty is to construct business models using foresight tactics based on statistical analyses of the data and information about how users interact with the application [23-26].

3.2 Overview of the important points in related to Wiring Harness Minimization

Complexity of Hybrid and Electric Vehicle Technologies: The integration of both electric and internal combustion engine components in hybrid vehicles, as well as electric vehicles' reliance on high-voltage electrical systems, provides major technical obstacles. Engineers must create systems that seamlessly blend the two modes of propulsion and assure their efficient coordination.

Customer happiness and Safety: Ensuring customer happiness entails not only producing vehicles with lower environmental effect, but also exceeding consumer expectations for performance, comfort, and dependability. Given the complicated interplay between electrical and mechanical systems, safety remains crucial. To avoid possible risks connected with hybrid and electric vehicle technology, engineers must incorporate robust safety systems.

Environmental Impact and Sustainability: Hybrid and electric vehicles are being developed to lower the transportation sector's carbon footprint. Engineers are working to improve energy efficiency, reduce emissions, and employ sustainable materials in vehicle building.

Standards Set by Governments and Regulatory Agencies: Governments and regulatory agencies set tight standards to assure the safety and compliance of cars on the road. Engineers must be familiar with these regulations, which frequently change to accommodate new technologies. This involves meeting emission, crashworthiness, electromagnetic compatibility, and other criteria.

Risk Assessment and Management: Developing hybrid and electric vehicles entails assessing and managing different risks connected with the technologies, such as electrical system failures, battery management, thermal management, and others. Engineers use advanced risk analysis techniques to identify potential risks, quantify their likelihood, and develop mitigation or prevention measures.

Interdisciplinary Approach: Because hybrid and electric car technologies are multidisciplinary, engineers frequently interact with experts in fields such as electrical engineering, materials science, and computer science to create and develop cutting-edge solutions.

Continuous Learning and Adaptation: As hybrid and electric car technologies improve, engineers must keep up with new innovations. Continuous learning, attending industry conferences, and interacting with experts are all part of being on the cutting edge of innovation.

4. Detailed Analytical Model for calculation of (pdf)

Our traditional traffic flow approach, which will be more accurate, was applied in our estimating model to characterize the vehicular environment. Vehicles are assumed to follow Poisson distributed arrivals in order to calculate the probability density function (pdf).

Area for Next Hop: Area that needs to be calculated is also known as the area of intersection of the circles with the radius of \( R_s \) and \( R_a \) respectively, the area of the region we have the following formulas in Eq. 1 [27].

\[
A_{Total} = A_{Int1} + A_{Int2}
\]

However

\[
A_{Int1} \approx \frac{(\bar{a} - \sin(\beta) \cdot \bar{a}^2)}{2} \tag{2}
\]
And

\[ A_{int2} \approx \frac{(\alpha - \sin(\alpha))R_s^2}{2} \]  

(3)

The expected area for selecting the next hop node.

\[ A_{Total} = \left[ \frac{(\beta - \sin(\beta))R_d^2}{2} \right] + \left[ \frac{(\alpha - \sin(\alpha))R_s^2}{2} \right] \]  

(4)

Thus, \( A_{Total} \) shows the expected area for the selection of neighbor node.

**Node Relative Velocity:** Relative velocity between the vehicles, with velocity \( v_1 \) and \( v_2 \) respectively, can be calculated using the following law in Eq. 5 [27].

\[ \vec{V}_r = \sqrt{V_1^2 + V_2^2 - 2v_1v_2\cos\theta} \]  

(5)

**Probability Density Function of Relative Velocity:** Probability density function (pdf), we can find it is expected relative velocity function as Eq. 6 [27].

\[ E(V_r) = \int_{-\infty}^{\infty} v_r f(v_r) \, dv_r \]  

(6)

**Average Number of Neighbor Nodes:** Accordingly, the distance to first next-hop (\( N_H \)) can be calculated as [27].

\[ N_H = \frac{L}{D_L} \]  

(7)

In Eq. (7), \( D_L \) represents the distance between two nodes.

5. **Used Software and hardware parts for analysis of proposed work**

5.1 **Software**

**Eagle for PCB Design:** Eagle is a popular software program for creating printed circuit boards (PCBs), commonly known as Autodesk EAGLE. It enables the creation of schematics, PCB layouts, and production files for electronic projects by engineers, designers, and enthusiasts. A variety of tools and functionalities are offered by Eagle to help the complete PCB design process.

**ThingSpeak:** MathWorks, the organization that created MATLAB, developed the IoT (Internet of Things) platform known as ThingSpeak. It offers a method for gathering, analysing, and visualizing data from different IoT devices or sensors. With ThingSpeak, users can build IoT projects and applications without having to have a deep understanding of programming.

**Arduino Integrated Development Environment (IDE):** To program and write code for Arduino microcontroller boards, one uses the open-source Arduino IDE software application. It offers an intuitive environment for writing, assembling, and uploading code to Arduino boards, making it simple enough for beginners to use while simultaneously providing sophisticated functionality for seasoned programmers.

5.2 **Hardware components**

These components can be used to build a variety of electronic circuits and applications. The list of electronic components used in these projects as listed in following.

- **ESP32:** The ESP32 is a flexible microcontroller with built-in Wi-Fi and Bluetooth capabilities. It can be used as a server or client in IoT applications, facilitating communication between devices over the internet.

**Features and Technical Specs for Espressif Systems (ESP-32) Module**

ESP32 is an embedded module that supports both WiFi and BT(dual-mode) connectivity and is thus used in cloud-based IoT projects. ESP32 is the upgraded model of the ESP8266 module and is designed by Espressif Systems in China. The following table 1 [13] shows the main features and technical specifications of the ESP32 module.

<p>| Table 1: Technical specifications of the ESP32 module [13] |</p>
<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Parameter Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Operating Frequency</td>
<td>240MHz</td>
</tr>
<tr>
<td>Microprocessor</td>
<td>Tensilica Xtensa LX6</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>3.3V</td>
</tr>
<tr>
<td>DAC Pins</td>
<td>8-bit, 2 Channel</td>
</tr>
<tr>
<td>Analog Input Pins</td>
<td>12-bit, 18-channel</td>
</tr>
<tr>
<td>DC Current on I/O Pins</td>
<td>40 mA</td>
</tr>
<tr>
<td>Digital I/O Pins</td>
<td>39 (34 are normal GPIO pins)</td>
</tr>
<tr>
<td>DC Current on 3.3V Pin</td>
<td>50 mA</td>
</tr>
<tr>
<td>Communication</td>
<td>SPI(4), I2C(2), I2S(2), CAN, UART(3)</td>
</tr>
<tr>
<td>SRAM</td>
<td>520 KB</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>V4.2 – Supports BLE and Classic Bluetooth</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>802.11 b/g/n</td>
</tr>
</tbody>
</table>

- **Diode**: A diode is a device that allows current to flow in only one way. They are used for rectification, voltage regulation, and reverse voltage protection [14-17].
- **Buzzer**: When an electrical signal is supplied to a buzzer, it produces sound. Alarms, notifications, and audible indicators are frequent uses for them [15-20].
- **LED**: When electricity travels through Light Emitting Diodes (LEDs), they emit light. They are utilized in a variety of technological projects as visual indicators, displays, and illumination [21-22].
- **Power supply**: A bridge rectifier converts alternating current (AC) to direct current (DC) by rectifying the waveform. It’s widely utilized in power supply circuits to convert AC power to DC power [14-16].
- **Capacitor**: Capacitors store and release electrical energy. They serve a variety of functions in electrical circuits, including voltage smoothing, signal filtering, and coupling components.

6. **Block Diagram and working**

In this work, a smart control system will be installed inside a car that is divided into three unique zones: the electric vehicle zone, the driver zone, and the back zone. The ESP32 module, which has access to both Wi-Fi and Bluetooth, is at the heart of this system. Four switches are located in the front zone of the car, and one of them is used to interface with the ESP32 module. The ESP32 module receives wireless commands from outside sources to start the system working. This communication-ready module plays a crucial role as both a transmitter and a receiver of instructions. The module starts a continuous loop check after getting a command to see if any additional data has been received. The block diagram of driver-zone for transmitter and receiver circuits as shown in figure 2.

![Block diagram of Driver-Zone for transmitter and receiver circuits](image)

**Fig. 2**: Block diagram of Driver-Zone for transmitter and receiver circuits

An LCD screen connected to the ESP32 module is a crucial component of the user interface for the system. As soon as the command has been processed, the module moves on to display the action that has been decoded on this display, giving users or drivers a crystal-clear visual depiction of the upcoming procedure. The system goes beyond simple presentation. It communicates with the
physical world through a relay, an adaptable electromechanical switch. The relay replies to the processed command by turning on an appropriate indication to indicate the type of imminent action.

The activation of the relay causes a series of events to occur within the associated circuit, which highlights the full significance of this functionality. The activation of the relay causes a series of events to occur within the associated circuit, which highlights the full significance of this functionality. The relay system efficiently spans the gap between the ESP32's low-power sector and the more potent parts of the vehicle, whether it's lighting up particular vehicle zones, activating motors, or regulating other important components.

An intelligent and responsive system is the result of the complex interaction of wireless communication [14,16], microcontroller processing, and relay-based control. The combination of these components enables the vehicle's many zones to work together seamlessly and carry out predetermined tasks. The relay system is a monument to contemporary developments in the field of automotive automation, and the project's success ultimately rests on its capacity to harness technology for improving vehicle functioning and user experience.

7. Result analysis

The Advanced Electric Vehicle System for IoV-enabled Wiring Harness Minimization, a ground-breaking innovation that transforms the construction, operation, and management of vehicles has been introduced in this paper. This ground-breaking approach enables the automobile industry to quickly adapt innovation, improve user experiences, and advance toward a future of effective and environmentally responsible transportation. The proposed design for Vehicle Zone schematic configuration circuits is shown in Figure 3, which cleverly combines bridge rectifier circuits using diodes with necessary parts including IC-7805, resistors, LEDs, and capacitors. In table 2 listed the used Component in these projects.

<table>
<thead>
<tr>
<th>Component</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP (Espressif Systems)</td>
<td>32- Module single-/dual-core 32-bit LX6 microprocessor(s) 12-bit SAR ADC up to 18 channels 2 x 8-bit DAC</td>
</tr>
<tr>
<td>Liquid Crystal Display (16x2)</td>
<td>Display 16 characters per line and there are 2 such lines.</td>
</tr>
<tr>
<td>Relay</td>
<td>12V DC</td>
</tr>
<tr>
<td>BC-547 Transistor</td>
<td>NPN Transistor</td>
</tr>
<tr>
<td>Power supply (PS)</td>
<td>AC-DC &amp; DC-AC</td>
</tr>
<tr>
<td>Capacitor</td>
<td>1000µf-25V</td>
</tr>
<tr>
<td>Integrated Circuit (IC)</td>
<td>IC-7805</td>
</tr>
<tr>
<td>LED</td>
<td>5mm three lights</td>
</tr>
<tr>
<td>Other Component</td>
<td>Ultrasonic, Buzzer, LDR sensor, Switches, Solar panel</td>
</tr>
<tr>
<td>Software</td>
<td>Eagle for PCB Design, ThingSpeak, Arduino IDE</td>
</tr>
</tbody>
</table>

The goal of IoV is to connect numerous users, cars, things, and networks in order to constantly deliver the best connected communication capability that is manageable, controllable, operational, and credible. It makes up a highly intricate system. Furthermore, IoV applications are significantly different from those of other networks, and as a result, various particular requirements develop. Both of these factors introduce new technical obstacles to IoV research and development. Because of its complexity and dynamic nature, the Internet of Vehicles (IoV) poses numerous key issues. These issues cover technical, sociological, and regulatory dimensions, and overcoming them is critical for the effective implementation and widespread adoption of IoV technology. Here are some of IoV's significant challenges.

- Heterogeneity and Interoperability
- Security and Privacy
- Real-time Communication and Low Latency
- Scalability and Network Congestion
- Vehicular Mobility and Dynamic Scenarios
- Energy Efficiency
- Edge Computing and Cloud Integration
- Societal Impact and Equity
8. Conclusion

Internal combustion engine (ICE) vehicles continue to rule the automotive landscape in virtually everywhere else in the world, despite the tremendous growth of electric cars. The conversion of ICE vehicles into electric vehicles (EVs) appears as a potential option as a technique to quicken the transition to sustainable transportation while conserving resources. In this regard, a thorough Internet of Things (IoT) paradigm that combines non-contact fluid sensing devices with a variety of electrical features is investigated. In this paper we have proposed the schematic circuits and its module for reduction of Wiring Harness using IOV with IoT. This combination makes it easier to monitor and evaluate intravenous (IV) drip infusion systems and their controllers in real-time. A robust, economical, and dependable system is successfully built, expertly supervising drip infusions across various environments by employing cloud storage linked with GSM service and a potent sensing component. In further proposed model well be helping for design of EV for minimization of wiring Harness as well as reduction power losses. Future aspects should help in clear envisioning of IoV in terms of the benefits over VANETs.

References