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Research Article

Conceptual Implementation of Artificial Intelligent based E-Mobility Controller in smart city Environment

Jayaraj Jayakumar[1], **Balakrishnan Nagaraj**[2], **Shanty Chacko**[1], **and P. Ajay**[3]

[1]*Department of Electrical and Electronics Engineering, Karunya University, Coimbatore 641114, India*
[2]*Department of Electronics and Communication Engineering, Rathinam Technical Campus, India*
[3]*Department of Electronics and Communication Engineering, Anna University, India*

Correspondence should be addressed to Jayaraj Jayakumar; emailtojayakumar@gmail.com

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Testing and implementation of integrated and intelligent transport systems (IITS) of an electrical vehicle need many high-performance and high-precision subsystems. The existing systems confine themselves with limited features and have driving range anxiety, charging and discharging time issues, and inter- and intravehicle communication problems. The above issues are the critical barriers to the penetration of EVs with a smart grid. This paper proposes the concepts which consist of connected vehicles that exploit vehicular ad hoc network (VANET) communication, embedded system integrated with sensors which acquire the static and dynamic parameter of the electrical vehicle, and cloud integration and dig data analytics tools. Vehicle control information is generated based on machine learning-based control systems. This paper also focuses on improving the overall performance (discharge time and cycle life) of a lithium ion battery, increasing the range of the electric vehicle, enhancing the safety of the battery that acquires the static and dynamic parameter and driving pattern of the electrical vehicle, establishing vehicular ad hoc network (VANET) communication, and handling and analyzing the acquired data with the help of various artificial big data analytics techniques.

1. Introduction

Testing and implementation of integrated and intelligent transport systems (IITS) of an electrical vehicle need many high-performance and high-precision subsystems. The existing systems confine themselves with limited features and have the following shortcomings.

(i) Driving range and associated driver range anxiety

(ii) Longer duration for charging

(iii) Presence or frequent availability of charging stations

(iv) Heterogeneous communication technologies between vehicle to grid (V2G) and grid to vehicle (G2V)

(v) Data flow and cloud integration

(vi) Handling and analysis of big data

The above issues are the critical barriers to the penetration of EVs with a smart grid. This proposed concept consists of an embedded system consisting of sensors which acquire the static and dynamic parameter of the electrical vehicle, cloud integration and big data analytics tools depicted in Figure 1, and connected vehicles that exploit vehicular ad hoc network (VANET) communication which is shown in Figure 2. Vehicle control information is generated based on machine learning-based control systems.

The capacity to organize, advance, and screen the position, steering, and well-being of vehicles is the key when looking to limit long-haul working expenses and increment in range are the important factors to be considered in electrical vehicle industries.

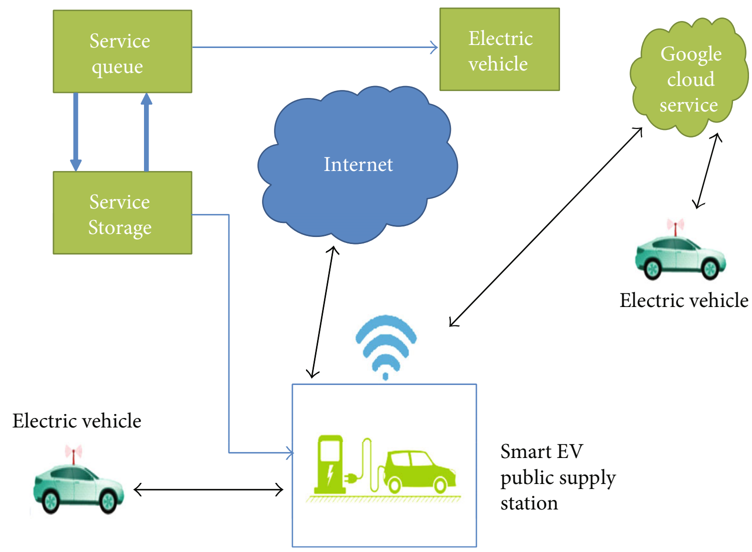

Figure 1: Electric vehicle grid integration.

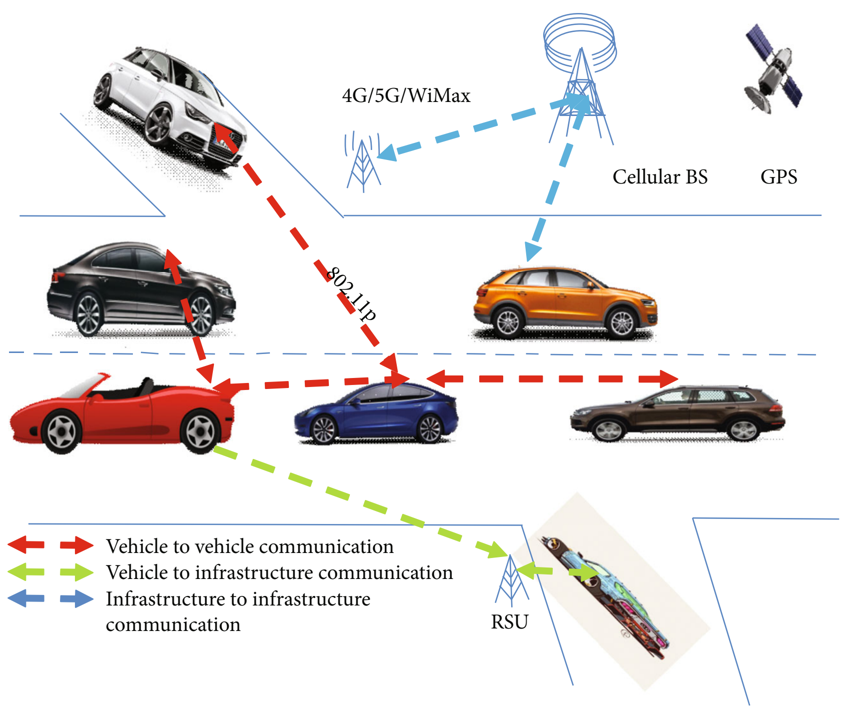

Figure 2: Vehicular ad hoc network.

All the electric vehicles consist of battery units, and every unit has separate estimations of cell voltages and temperatures and state of charge. Acquiring such estimations physically would require obtrusive, enormous, and complex circuits.

In this paper, a machine learning-based embedded controller is proposed. This controller screens distinctive driving procedures, energy utilization versus load conditions, the energy required for existing and important routes for future use, and battery reenergized profiles. This paper also describes the design and implementation of a data acquisition system for vehicles, with special emphasis on EVs.

2. Review of Status of Research and Development in the Smart Electrical Vehicle

The paper by Hannan et al. explains a charge equalization algorithm which gives an equal and balanced charge to all lithium ion cells in a battery pack [1, 2]. Here, a voltage method is used to find the state of the charge of a battery. Here, the voltage is compared at every instant and compared with the reference voltage so as to get voltage versus time curve which is a reference point of the state of charge. The paper by Wang et al. discusses an optimal charging method for improvement of charging efficiency of a lithium ion battery [3, 4]. It is observed that there is no considerable improvement in the charging efficiency of a lithium ion battery.

Lithium ion batteries are not fully safeguarded from the operation problems due to several factors. So, different methods are found out to improve the performance of lithium ion batteries. These methods may be battery management system methods or their chemical constitution and manufacturing process. If we consider high-power rated battery packs, cells must be connected in parallel to improve the current and power rating. But, at that time, there are problems of loose connection and sparking in between which reduce the output and smooth operation. Also, the different cells may not behave in a uniform manner. The paper by Satyavani et al. portrays the displaying and test assessment of equal associated lithium particle cells for an electric vehicle battery framework [5]. The primary outcomes from this examination feature that huge contrasts in the current stream can happen between cells inside an equal stack that will influence how the cells age and the temperature circulation inside the battery assembly [6]. The paper by Zhang et al. clarifies an information-driven-based condition of an energy assessor of lithium particle batteries used to supply electric vehicles [7]. This paper clarifies another strategy utilizing the Kalman channel to gauge the condition of energy of a lithium particle battery. SoE or condition of energy of a lithium particle battery is the limit of a battery as far as kilowatt-hour (kWh) is concerned. The scope of an electric vehicle relies on the condition of energy of a lithium particle battery [7].

The existing intelligent transport system testbed has its own limitation in the area of wireless sensor network (WSN) research [8, 9]. These systems usually give the instructions about the design and implementation of a complex system but failed to integrate the control techniques of ITS. Already existing systems are not economically viable to take up the research for further development [10]. Certain testbeds are available for autonomous vehicles, but the results and findings need more clarity and such test system cannot be used for a wide range of systems [11]. Datta et al. propose a cloud-based service provider for ITS testbeds, but it is restricted with connected vehicles. None of the literature considers the driving range and associated driver range anxiety, longer duration for charging, presence or frequent availability of charging stations, heterogeneous communication technologies between vehicle to grid (V2G) and grid to vehicle (G2V), data flow and cloud integration, and handling and analysis of big data.

In India, lithium ion battery-based electric cars are coming into the scene. The government of India and various state governments are promoting the use of electric vehicles and provide subsidies and tax reductions on electric vehicles. But most of the electric vehicles are using a lead acid battery due to their availability and cheapness. Lithium particle batteries are not being utilized generally because of their significant expense, and furthermore, there are not many lithium particle battery makers in India which produce electric vehicle lithium particle batteries. The paper [12] clarifies the strategies and union of progress of high-rate lithium particle batteries. In this methodology, the essential concern is to improve and redesign the cathode materials. Various strategies and amalgamation such as strong state techniques for $LiFePO_4$ powders, strong state combination, mechano-synthetic initiation, and so forth and ways to deal with work on the electrochemical execution of $LiFePO_4$ are being used.

In developing nations like India, the maximum population suffers from unemployment, poor education access, inferior environmental conditions, and mass death following road crashes. Hence, in this context, queries might increase about the challenges entrenched in peoples' mind, their behaviorism and skepticism regarding AVs' safety issues, and finally whether driverless vehicles would create or displace jobs [13–15]. The novelty of this study lies in exploring people's attitude towards AV and their concerns regarding challenges of AV technology in an Indian scenario with a special focus on a forward section of the society. As per Roger Everett's exemplary model, the "dissemination of innovations," among the five classes of innovators, early adopters, early majority, late majority, and laggards, the early adopters embrace the innovation faster [16, 17]. Since the forward segment of the general public with elevated places and administrative abilities has the novel attribute of innovative familiarity or on the grounds that they harbor positive perspectives towards state-of-the-art AV innovation, we guess that the respondents considered in this review will be inside the early adopters [18]. This study through adoption of an online survey objectively intends to analyze the people's mindset, attitudes, and impressions on smart car technologies and strategies. Owing to lack of adequate literature regarding AV technology emergence in India and its acknowledgement, this study would be of its initial kind to probe into the forward section user perception towards AVs in an Indian scenario [19, 20].

3. Importance of the Proposed Method in the Context of the Current Status

In the future, electric vehicles (EVs) are expected to be widely used by all kinds of people and industries. A traditional vehicle like combustion engines produces pollution into the atmosphere and causes toxic gases like SOX, NOX, and COX. When we migrate from the usage of a traditional vehicle to an electrical vehicle, the fuel consumption will be reduced by 70% which will reduce the pollution. Moreover, the operating cost, drivability, and maintenance cost will be reduced further. The usage of an electrical vehicle with IITS not only gives profit to the users but also gives more comfortable and safer journey to the users with lot of information like speed limit, nearest charging station location and charging time details, and battery parameters.

3.1. Current Issues in Our Intelligent Transport System for the Electric Vehicle. The existing electric vehicle system is facing the following problems:

(i) Decision-making intelligence for the selection of charging stations (CSs)

(ii) Reliable and efficient information exchanges between EVs, meters, charging stations, and the power grid

(iii) Vehicle-to-infrastructure and vehicle-to-vehicle communication network design dynamic speed and no standard network topology

(iv) Difficulty in collecting the vehicle parameters when the number vehicles are more with reduced distance band width limitation with a dense scenario

In order to overcome the above issues, the following suggestion is proposed in this paper. The vehicle parameters can be exchanged between nearby/peer EVs by establishing a secure ad hoc communication between EVs for a necessary action. Establishing an ad hoc communication between vehicles follows the principle of VANETs, i.e., vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The location, speed, travelling distance and direction, stability loss, braking, etc. are communicated in the V2V mode with 5.9 GHz frequency and a bandwidth of 75 MHz. V2I represents a one-way hop communication between the Road Side Unit (RSU) and the vehicles. The RSU may proactively suggest fuel consumption, acceleration, velocities, and the intervehicle distance to be maintained based on the traffic conditions [21, 22]. Information to drivers may be broadcasted through the wireless connections directly. The maximum distance (limit/range) of the vehicles is set as 60 km. Usually, it is 1000 meters in simulations.

4. Proposed Methodology

Execution variety, low cycle life, and temperature affectability of a lithium particle battery stockpiling framework for electric vehicles are subject to changing driving examples. The determination of an energy stockpiling framework is vital on account of electric vehicles. It ought to have great energy thickness and extensive force thickness, and furthermore, it should be lightweight. The low-energy-thickness batteries will expand the weight needed to give the necessary energy and capacity to the vehicle. So, it will add to the complete load of the framework. This will cause the depletion of the battery without any problem. So, a lightweight battery or a battery with impressively high energy thickness should be utilized in electric vehicles. Lithium particle batteries are preferred a lot as electric vehicle batteries. They have high energy thickness, high life cycle, and smooth activity. However, there are issues related to lithium batteries; for example, they have high-temperature affectability, and their activity will be influenced by overcurrent charging and overcurrent releasing past their greatest evaluated values. It might detonate or consume on the off chance that they are fumbled.

So, for the battery, the executives and control framework are extremely fundamental in electric vehicle energy stockpiling battery packs. In these batteries, the board and control framework will control the charging current release and voltage at charging and will remove the activity if boundaries change from the permitted values. Additionally, the battery boundaries including working temperatures should be observed and controlled with the goal that the battery life or cycle life will be improved. This paper is a survey about the need of a plan of a novel battery and the board and control framework for lithium particle batteries for execution improvement in electric vehicles.

The outline is explained in Figure 3. The lithium ion battery is charged by a plug-in source. The charging and discharging according to load, driving patterns, operating temperature, state of charge, state of health, state of safety, current, etc. are monitored, and optimal operation is ensured by the intelligent controller which is represented in Figure 4. The intelligent controller consists of new algorithms which control and optimize the energy storage system for electric vehicles. The supercapacitor will support the battery while starting from rest or after braking, and the solar cell will ensure charging of the battery if the battery state of charge is less than 30%. Thus, the overall performance of the lithium ion battery and in effect the mileage of the electric vehicle are improved. Usually, electric vehicles are using a lead acid battery in India. But we are using a lithium ion battery to ensure a lightweight battery and also reduce the weight of the entire electric vehicle system.

The below objective is very useful in electric vehicles and public transport such as bus, taxi, and auto rickshaw. Based on the above objectives, an intelligent control system will be developed. This intelligent control system will utilize solar energy to charge the battery and the supercapacitor. The supercapacitor will support the vehicle while starting and climbing. The intelligent controller will take decision to power the motor from the solar cell or supercapacitor or from the battery. This decision is based on battery parameters like state of charge (SoC), battery temperature, current, and voltage stability.

The main necessity of this intelligent controller is that it will improve the performance of the battery by reducing the strain caused by different driving conditions, and so it will improve the battery cycle life. So, the operation cost of the electric vehicle will be reduced as the battery replacement frequency will be less. Because of the optimal design of the battery capacity for a particular power, the overall weight of the system can also be reduced.

4.1. Uniqueness of the Embedded Controller. The controllers available in the market are operated under an open loop. No battery parameters are considered for controller design. These kinds of controllers simply act as a switch between on and off. Because of such kind of controllers, the battery life and range of the battery vehicle are reduced. This intelligent controller is overcoming these issues, resulting in reduced processing time while taking decision. Real-time data sampling, acquiring, filtering, and processing are a real challenge. The running time and algorithm complexity are given below which are mentioned in the main manuscript as per the suggestions given by the reviewer.

(i) Decisions cannot be taken instantaneously

(ii) Less stable

(iii) Frequency of changeover in switching is more

(iv) Need a very detailed program to set the control parameters

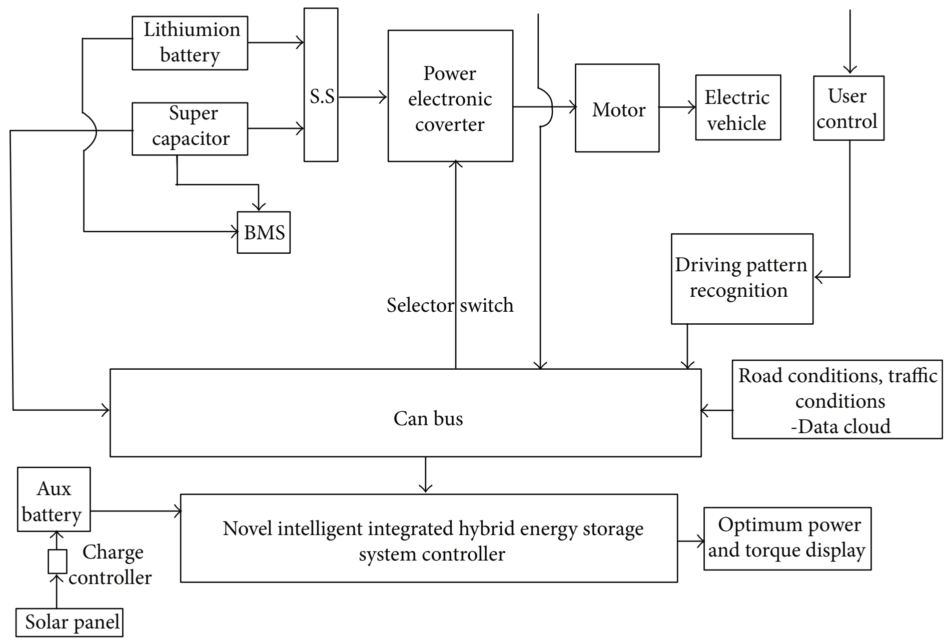

FIGURE 3: Functional block diagram of an intelligent embedded controller.

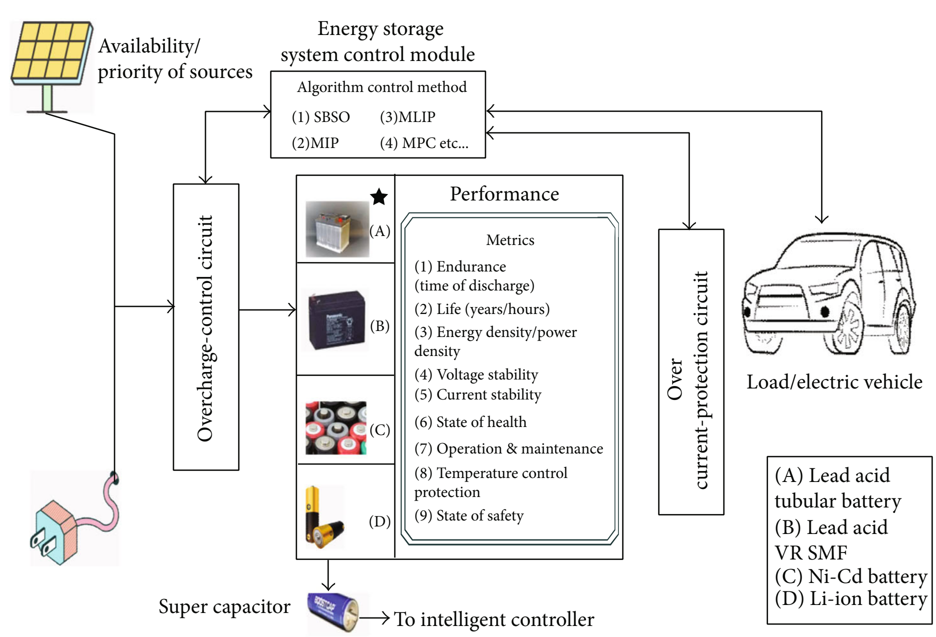

FIGURE 4: Intelligent controller-based hybrid electrical vehicle block diagram.

(v) Predicted results may not be available always

(vi) Error in any part affects the whole functioning of the system

(vii) Misfiring of the system may occur due to any error in its interfacing program

(viii) Switching between the sources causes a time lag

The above complexity has been addressed in the proposed methods. Due to the addition of all these constraints, the run time of the algorithm is increased.

The proposed embedded controller will enhance the following:

(i) It will improve the overall performance of the lithium ion battery

(ii) It will increase the discharge time and cycle life of the lithium ion battery

(iii) It optimizes the battery current according to battery parameters and driving patterns

(iv) It increases the range of the electric vehicle

Table 1: Specifications of the sensors used in the proposed method.

S. no.	Sensor	Features/specifications
1	MSC360 rotary position sensor	Simple & robust magnetic compact design, endless rotation, up to 360° of electrical angle, magnetic shielding, programmable linear transfer characteristics, self-diagnostic features, overvoltage protection, and reverse voltage protection Analog and PWM output
2	Steering sensors	Cast iron material, 20-22 mm diameter, hydraulic type
3	GPS-MEMS Gyroscope—GYPRO3300	(i) Digital angular rate sensor with the SPI interface (ii) Angular rate measurement around the z-axis (yaw) (iii) ±300°/sec input range (iv) Ultralow noise (v) Excellent bias instability (vi) 24-bit angular rate output (vii) Embedded temperature sensor for on-chip or external temperature compensation (viii) Built-in self-test (ix) 5 V single supply voltage (x) Low operating current consumption: 25 mA (xi) CLCC 30 package: 19.6 mm × 11.5 mm × 2.9 mm (xii) Weight: 2 grams
4	Low-g accelerometer LIS2DW12TR	3-axis MEMS accelerometer, ultralow power, configurable single/double-tap recognition, free fall, wakeup, portrait/landscape, 6D/4D orientation detections
5	Personal cloud-WD My Cloud Home WDBVXC0040HWT-BESN 4TB network attached storage	14 × 5.3 × 17.55 cm; 1.05 kilograms, 17.6 ∗ 5.3 centimeters, model WDBVXC0040HWT-BESN, components-personal cloud storage, Ethernet cable, AC adapter and quick install guide
6	Synology DiskStation DS1621+ network attached storage drive	174% performance boost with over 110,000 4 K random read IOPS2, built-in M.2 2280 NVMe SSD slots permit cache acceleration without occupying storage drive bays, flexibly scale up to 16 drives to increase storage capacity as demand grows, back up critical data and reduce your recovery time objective (RTO) with snapshot replication, build an on premises multiuser collaboration environment with fine-grained control, 28.2 × 24.3 × 16.6 cm, 4.29 kg
7	MAX17843 Data acquisition interface	12-channel, high-voltage smart sensor data acquisition interface
8	IoT gateway	UTX-3117N4200 series fanless IoT gateway, supports 2 × COM port, 1 × HDMI, 1 × display port, 2 × USB3.0, TPM, and DCIN 12~24 V Built-in 1 × M.2 expansion slot (i.e., Wi-Fi module), 1 x half size mini-PCIe expansion slot (i.e., Zigbee, module, or mSATA), and 1 × full – size mini – PCI expansion slot (i.e., 3G/LTE module) with 5 antennas Supports 1 × 2.5" HDD or SSD storage Wide operating temperature -20~60°C support (with E3900 series SoC) IoT SW integration: WISE-PaaS IoT software platform, AWS Greengrass, Microsoft IoT edge
9	Battery monitoring sensors	The lithium ion battery banks of an EV are monitored using a MAX17843 programmable smart data acquisition interface. Cell diagnosis, balancing, and voltage level measurements along with safe levels are addressed using this interface
10	Vehicle navigation	GPS is primarily used for tracking. To combat with the existing drawbacks of GPS such as lack of local knowledge and driving path distractions, GPS-MEMS-based gyroscopes and low-g accelerometers are used for tracking the position/path
11	Power steering sensors	The directing point sensor (SAS) figures out where the driver needs to control, coordinating with the controlling wheel with the vehicle's wheels. It is customized to decide the guiding point speed

(v) It enhances the safety of the battery

(vi) It acquires the static and dynamic parameter of the electrical vehicle

4.2. Steps Involved in Implementing the Concept

(1) The static and dynamic parameters are sensed and processed. Specifications of the sensors used in the proposed method are shown in Table 1

(2) The data can be exchanged between nearby/peer EVs by establishing a secure ad hoc communication between EVs for a necessary action. Establishing an ad hoc communication between vehicles follows the principle of VANETs, i.e., vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The location, speed, travelling distance and direction, stability loss, braking, etc. are communicated in the V2V mode with 5.9 GHz frequency and a bandwidth of 75 MHz. V2I represents a one-way hop communication between the Road Side Unit (RSU) and the vehicles. The RSU may proactively suggest fuel consumption, acceleration, velocities, and the intervehicle distance to be maintained based on the traffic conditions. Information to drivers may be broadcasted through the wireless connections directly

(3) The heterogenous data can be moved to the cloud for central processing/storage exploiting the IoT gateway

5. Conclusion

A new concept of monitoring and control of the intelligent transport system has been proposed with the help of the wireless sensor network and artificial intelligence in this paper. Various modules and hardware requirement with technical specifications have also been mentioned. Guidelines to analyze the static and dynamic parameters of the electric vehicle using big data analytics are briefed in this paper. Based on the power and energy density of the battery of the electric vehicle, current and voltage stability, and state of health of the battery, a decision-making algorithm is developed and then it is integrated with AI techniques, and finally, it is implemented using an embedded controller to take intelligent decision to control and monitor the electric vehicle. Based on the proposed method, the discharge time is improved by 20 minutes and the cycle life of the lithium ion battery is increased by 200 cycles. Also, the range of the electric vehicle is increased to 2.3 km, and battery replacement cost is only 4/5 of the total cost.

Data Availability

Two sets of data will be considered to train the mode with the help of an advanced algorithm. These data have been generated during the study: (1) the discharge time extension in percentage for different conditions of driving patterns and (2) the discharge time extension in percentage for different states of charge of the battery. The data sheet is attached in the portal as a supplementary file (available here).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

Supplementary Materials

The data are generated during the study to train the AI model with the help of an advanced algorithm: (i) the discharge time extension in percentage for different conditions of driving patterns. *(Supplementary Materials)*

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