Journal of Ubiquitous Computing and Communication Technologies (UCCT) (2021)
Vol.03/ No.03
Pages: 229-240
https://www.irojournals.com/jucct/
DOI: https://doi.org/10.36548/jucct.2021.3.006

Ethereum and IOTA based Battery Management System with Internet of Vehicles

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Abstract

The era of Electric Vehicles (EVs) has influenced the very make and manufacture of vehicles resulting in low pollution and advanced battery life. On the other hand, the internet of things has also expanded allowing a number of devices to stay connected using the internet. Massive drawbacks faced by EVs today are the limitation in battery swapping and charging stations and limitation in the range of batteries used. This proposed paper aims to efficiently manage the best battery system apart from building the essential infrastructure. In some cases battery swapping option is also provided through other EV drivers or at registered stations. Hence a complete database of the EV network is required so that it is possible to swap and charge batteries successfully. An EV management using two blockchains as a data layer and network of the application is implemented in this work. The first step involves the development of a blockchain framework using Ethereum and the next step entails a direct acyclic graph. When integrated, these two methodologies prove to be an efficient platform that offers a viable solution for battery management in Electric Vehicles.

Keywords: Ethereum, smart contract, estimation of charge, Electric Vehicle, battery management, multiple blockchain methodology

1. Introduction

Electric Vehicles (EVs) have evolved tremendously in recent years and have become a point of high interest and technological development. Automobile manufacturers have leaned

ISSN: 2582-337X
Submitted: 29.08.2021
Revised: 28.09.2021
Accepted: 20.10.2021
Published: 01.11.2021

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towards investing and manufacturing Electric Vehicles with advanced features, integrating Internet of Things. However, the largest concern using Electric Vehicles is the lack of infrastructure for proper use and adaptability of these vehicles in rural areas. Electric Vehicles originate from the invention of electric motors during the 1990s [1]. EVs can be categorized into Battery Electric Vehicles (BEVs), Plug-In Hybrid Vehicles (PHEVs) and Hybrid Electric Vehicles (HEVs) [2]. An internal combustion engine and an electric motor operating together or independently powers the PHEVs and HEVs. On the other hand, the BEV runs on a fuel-cell or battery powered electric motor. In PHEVs external charging of battery is possible whereas HEVs do not have that provision [3]. Multiple drive-train configuration is available for PHEVs and HEVs. Coupled with transmission, EVs that operate in series make use of the electric motor for propulsion [4]. When the charge of the battery is low, an internal combustion engine is available to charge the battery. This is primarily used for driving in the city with requirement of frequent start-stops. Hence both the engines are used for parallel operation to transmit power, thereby increasing the efficiency of the EV [5]. A more complex design is required for vehicles that are built in a series-parallel mode combination with both the modes operating in the same architecture.

Battery power is the primary source of energy in the BEVs and PHEVs which can be charged using an external power source. There are two types of charging mechanisms used:

- Dedicated fast chargers: these are provided in specific locations like the electric charging station.
- On-board chargers: These are low weight and compact battery chargers that are carried on the vehicle to enable charging when required. However, the drawback with this provision is the slow charging of the battery.

Constant power [6], voltage [7], current [8] or a combination of them are the different methods used for charging the EV. Though there is a significant increase in the autonomy of EVs, there are still a number of challenges faced by the EV drivers with respect to availability

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of charging stations, battery charging time and battery life. Since its introduction, a number of works is being carried out to incorporate inductive charging in places such as airport roads, traffic light stops [9], parking areas etc. However, fixed charging stations still prove to be the main source of electric charge supply. A possible solution to tackle this issue would be to build a decentralized network that enables charging stations [10] and users to connect to swap and/or charge batteries [11]. This will also serve as a network that is accessible by self-driving or autonomous vehicles. Ideally, the autonomous vehicles are built to communicate with each other directly to share data on weather, incidents, traffic conditions etc. These autonomous vehicles use machine-to-machine communication which is enabled with the help of sensors [12] to gather data from the surroundings to send, using Internet of Things devices [13].

Incorporating the decentralized Internet of Things (IoT) network of swapping and charging stations, provides the users with certain details like the state of battery (remaining capacity, health, charge cycles, etc.), possibility of swapping the batteries, various types of batteries that suit the vehicle, availability of swapping and charging services and the location of the station. These systems can be incorporated based on observing the various parameters of the battery. When these parameters are not met, the driver is immediately alerted. To strengthen the security of the system [14], IoT applications are incorporated with novel methodologies that ensure higher reliability and security. In 2008, blockchain was introduced for the first time as a novel technology in crypto currency Bitcoin [15] as the underlying network architecture. It paved the way to a more secure environment with decentralized networking, enabling anonymous transactions. The primary goal of this architecture is to build trust between the members connecting to the architecture without being mainstreamed by a central authority. Other than bitcoin, blockchain has been applied in many applications.

2. Related Work

In [16], the authors have introduced a transaction model for microgrids using decentralized electricity transaction which provides a method of double auction between the

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seller and buyer, varying the price based on the changes in the market. Similarly, in [17] the authors have developed a novel methodology for transactions in microgrids [18] by validating the individuals using signatures, according to the attributes. Other customers who also have similar attributes verify the signatures, removing the need for a central authority for regulations. The authors introduced a blockchain technology in sustained energy systems, with a detailed outline of the various blockchain methodologies used. Authors in [19] also introduced the integration of IoT and blockchain technologies in the industrial sector to provide better results for plant asset management, autonomous vehicles and supply chain management. In [20], a blockchain data provider was proposed along with IoT, to develop a decentralized data provider. However, the drawback with such an approach was the security conflicts faced by the IoT in terms of communication between different systems. IOTA, a combination of IoT and the word iota which means extremely small, is a technology with a promising growth. An IOTA-based directed acyclic graph (DAG) [21] was proposed by the authors in [22] to enhance the security level. IOTA in vehicles and IOTA sensor node systems were examined in the works [23], [24] and [25]. In this paper, swapping and charging of batteries in EVs using IOTA public tangle and Ethereum blockchain models is incorporated and the performance of the system is analysed [26].

3. Proposed Methodology

Fig.1. shows the proposed battery charging and swapping system. Here, the information about the available battery as well as battery data is monitored with the help of on-board computers on every EV. However, these computers will not be able to efficiently handle the resources required for POW [27] hashing. Hence the transactions are performed by the stations while blockchain is incorporated by the charging stations. It provides the users the ability to swap requests, create charge, add new batteries and register on the system. A smart contract is used to handle these requests which are then deployed on the system. IOTA tangle [28] and Ethereum blockchains [29] are implemented and analysed in this paper.

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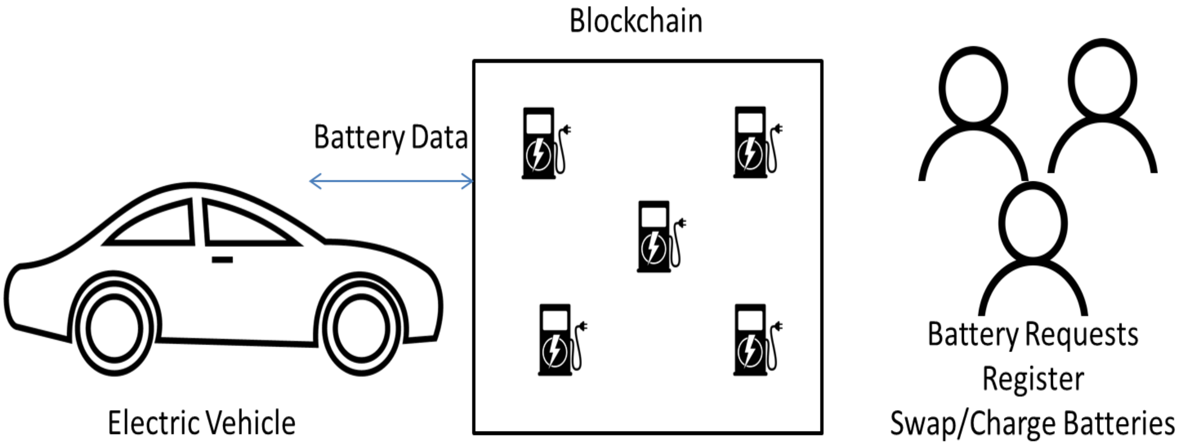

Figure 1. Proposed Blockchain System for Battery Management

3.1 SOC and Battery Monitoring

Lithium-Polymer (Li-Po) [30] is commonly used to test and develop due to their high discharge rates and high current values, establishing them as the apt solution for EV battery packs. The following are the four batteries commonly used:

- Two 3-cell, 30 C discharge rate, 11.1V, 1000 mAh
- Two 2-cell, 90 C discharge rate, 7.4 V, 800 mAh

Open Circuit Voltage (OCV) is used to estimate the SOC in this paper. With the help of Li-Po look-up table, a voltage-SOC table is formulated and used. A linear approximation is established using the relation:

$$SOC = \frac{V - V_{min}}{V_{max} - V_{min}} \tag{1}$$

where V_{max} and V_{min} represent the maximum and minimum voltage values. With the help of 4-parameters logistics function, a symmetric sigmoidal approximation is determined using the equation given below:

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$$SOC = a + \frac{b-a}{1+(\frac{V_{normalized}}{c})^{d\prime}} \quad (2)$$

Where c represents the control of the transition region position, d represents the slope of the response while b and a are used to control the upper and lower asymmetric positions. Here,

$$V_{normailzed} = \frac{V-V_{min}}{V_{max}-V_{min}} \quad (3)$$

3.2 Ethereum and IOTA Model

An Ethereum blockchain is developed to incorporate swapping/charging applications with a smart contract. In order to identify the new blocks, the participating nodes have to execute Proof-of-Work (POW). In order to encourage participation of users, the user is to submit a transaction fee, commonly called as gas. Based on the transaction payload, the gas cost will increase on a public chain. Hence this deems the public Ethereum unsuitable for IoT and other applications that require data transactions. The difficulty of hash function and the cost of gas on a customized chain can be controlled which leads to better facilities to battery management in Electric Vehicles. The flexibility and power of the smart contracts are incorporated in Ethereum to form application logic on blockchain. It ensures that every node uses data immutability and operates on the same code. The major difference between other blockchain platforms and IOTA is the manner in which data is saved onto the memory. Scalability issues are handled using this methodology by connecting the previous transactions with the current transaction, thereby validating it. As a transaction fee is not required for the IOTA network, it requires a public network to function. However, IOTA will not be able to support smart contract which is the biggest disadvantage of this methodology. Hence a master node is required to handle the application logic leading to the development of a semi-decentralized system. The master node is then used to filter and extract the data as extra operations while the Ethereum version will enable direct handling of the smart contracts.

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4. Results and Discussion

Fig.2, Fig.3 and Fig.4 show the voltage and plot with respect to state of charge and time taken for charging in a 2-cell battery. The users can directly view the results using the front-end application. It is possible to improve the estimation of SOC, taking into consideration the users and stations that can offer replacement of batteries and services, environmental factors and age of the battery. Fig.4 shows a plot between voltage and SOC using the proposed algorithm which indicates the dataset measured for 500 transactions based on the battery replacement and availability. When compared with the previously existing Ethereum model, the proposed IOTA based Ethereum model performs better.

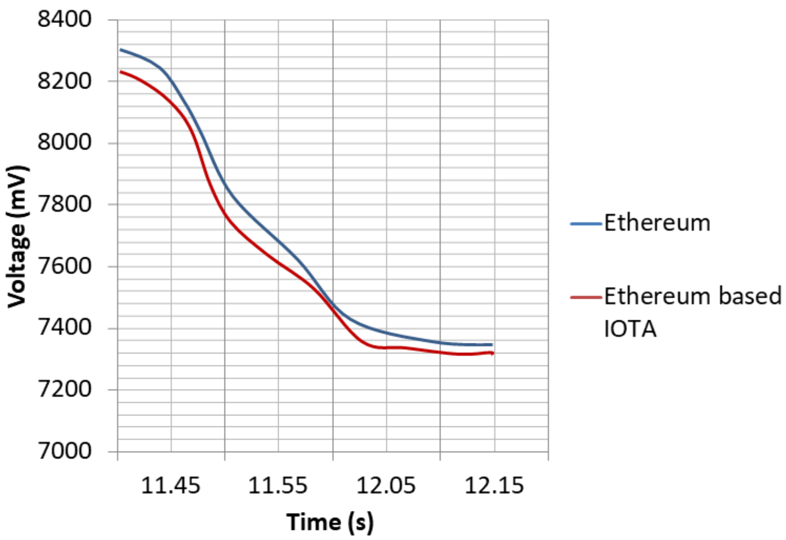

Figure 2. Voltage Vs. Time for 2-cell battery

A comparison is made between the transaction times in IOTA and Ethereum implementation which shows that the transaction time for the former holds maximum and minimum values at 104.14 and 3.8s, transacting at an average of 18 s. In IOTA the POW operations are carried out at the time of new transaction, while in Ethereum, these operations are carried out in a continuous manner by the mining nodes. POW in IOTA is performed locally due to the restriction when using the Raspberry Pi board.

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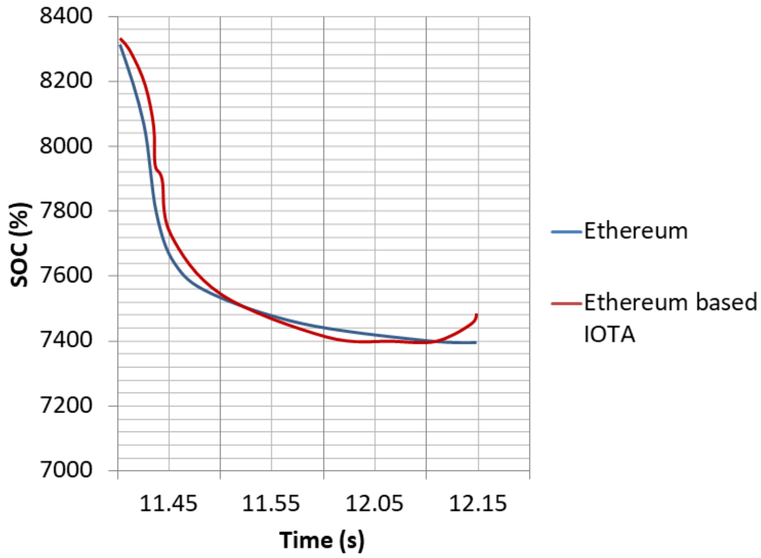

Figure 3. SOC in percentage Vs. Time for 2-cell battery

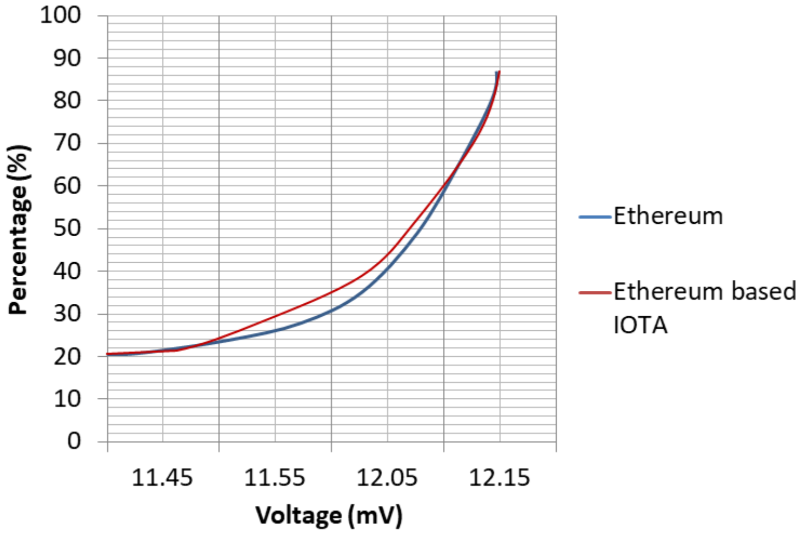

Figure 4. Voltage Vs. SOC in percentage for 2-cell battery

5. Conclusion

A battery management system which efficiently manages the batteries in the Electric Vehicle is proposed in this paper. Here, data is shared between the charging station and the

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Electric Vehicle using a semi-decentralized network on monitoring information in a continuous manner. In recent years, blockchain has played a major role in the development of cryptocurrencies. The general architecture of blockchain makes it the apt choice for data-driven applications. In order to determine the feasibility of the work, IOTA network and Ethereum blockchain are incorporated in this work. The IOTA network is used to implement zero-fee transactions while Ethereum blockchain provides access for sharing and processing data ensuring privacy and immutability of data. The output is observed and recorded to determine the efficiency of the proposed work. It is observed that both the platforms are useful in building IoT applications and have good transaction duration, making it apt for battery monitoring in real-time. The use and development of blockchain platforms for crucial IoT applications make it an ideal system that works well in a real-time environment. However, Ethereum continues to be the major platform for various applications of IoT. Subsequently, as the use of data-driven and IoT application begins to change, other alternative approaches will be required to meet the imposed demands.

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ISSN: 2582-337X
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