IoT Based Battery Management System for Electric Vehicles Using LoRaWAN: A Review

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Abstract– **In electric vehicles, battery is one of the key and most cost-intensive component. The accurate monitoring and estimation of State of Charge (SOC), State of Health (SOH) and detection of in-time failures of the rechargeable batteries of electric vehicles are still a challenge for researchers to provide safety to vehicles and users. Battery Monitoring means keeping a check on the key operational parameters during charging and discharging such as voltage, current, battery internal resistance and ambient temperature. Presently, the adoption of Internet of Things (IoT) related technologies in wireless battery management systems rapidly emerging. Battery management is critical for enhancing the safety, reliability and performance of the battery systems. With the help of the Internet of Things, all battery relevant data can be measured and transmitted to the cloud seamlessly for gathering the real time information about the battery. Smart software in the cloud can calculate an individual charge curve for each recharging process, this ensures the battery is recharged to the optimum level, which help in the conservation of the life of the battery cells. For this LoRaWAN technology which is having long range and low power consumption can play an important role for the designing and implementation of a smart IOT based battery management system.**

Keywords: ***IoT, Battery management system, electric vehicles, LoRaWAN, cloud computing.***

I. Introduction

Battery Management System (BMS) is required in order to monitor the operational system, performance and battery life such as charge and discharge process. It consists of measuring devices to measure parameters such as battery voltage, current, and temperature. These parameters can be processed to estimate the state of charge (SOC) and state of health (SOH) of the battery [1]. Online monitoring and state estimation of the lithium-ion batteries of electric vehicles is necessary for safe and reliable operation of batteries.With a battery monitoring system, it becomes very convenient for every vehicle owner and service providers to monitor the status of the batteries of their vehicles anytime and anywhere, and a falling battery can be quickly diagnosed and replaced before it may drains the remaining good batteries of the string. Battery management system (BMS) monitors and controls each cell in the battery pack by measuring its parameters. The capacity of the battery pack differs from one cell to another and this increases with number of charging/discharging cycles.

The Li-ion batteries which are mostly used in modern electric vehicles are fully charged at typical cell voltage between 4.16V to 4.20 V. Due to the different capacity this voltage is not reached at the same time for all cells in the pack. The lower the capacity the sooner this voltage is reached. When charging series connected batteries with single charger, the voltage on some cells might be higher than maximum allowed charging voltage at the end of charging. Overcharging the cells additionally lowers its capacity and number of charging cycles of the battery.

In recent years, Internet of Things (IoT) plays a major role in monitoring and control, also it enables the remote data logging facility for battery parameters, conditions, etc. The Internet of Things describes the network of physical objects (things) that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. According to world's well known research and advisory firm Gartner at the end of 2020, 25 billion devices are connected to the internet [2].

The devices used for Internet-of-Things (IoT) for the era of green energy, we need low power consumption and wide area coverage. The smaller bandwidth, the lower capacity of channel. Wi-Fi has a high bandwidth, 20-40 MHz, but only a low range at 40 -100 m, with high power consumption. Mobile internet has range within kilometers and the power is medium, but this is depending on internet service provider availability in that particular area. Bluetooth on every device has not only low bandwidth than Wi-Fi but also the lower range. LoRa technology as one of Low Power Wide Area Networks (LPWAN) technology gaining high space for IOT applications.

Because of power limitation, LoRa works in extremely low bandwidth, which is in Sub-GHz industrial, scientific, and medical radio band (ISM band) with different frequency depend on the country, range is 430 to 915 MHz and its range may be up to 15 kilometer

in rural areas [3]. This good sensitivity, high range, low path loss, and good obstacle penetration makes LoRa as a appropriate technology for cloud based smart battery management system for electric vehicles. Another reason for using LoRaWAN for connecting the electric vehicles to the cloud is that it can be very effective, especially in the region like remote rural areas and highways where no proper cellular network connectivity is available.

II. LoRaWAN for IOT based Battery Management System

A. IoT Based Battery Management System (BMS)

In the IOT based battery management system all battery-relevant data such as voltage, current, temperature during both charging and discharging is first transmitted in real-time to the cloud, where the system uses algorithms based on machine learning and artificial Intelligence to evaluate the data. The driver or service provider can be notified whenever a battery fault or defect is identified. This increases the chances that a battery can be repaired or changed before it stops working or permanently damaged.

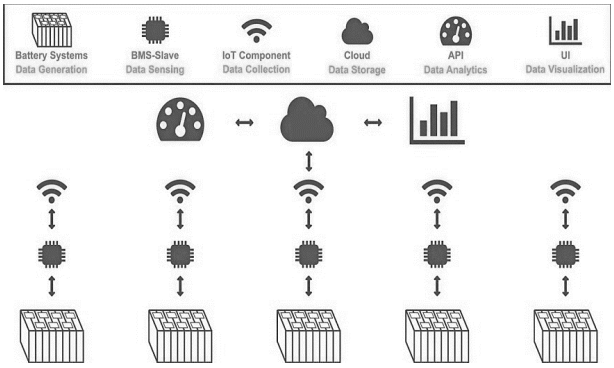

Fig. 1: IoT based Battery Management System (Source: W.Li, *et al*. Journal of Energy Storage 30 (2020) 101557 p. 3)

The Schematic of the IoT based battery management system is shown in figure1. The whole system is divided in to six subsystems which are:the battery systems for data generation, the BMS-Slave for data sensing, IoT component for data collection, cloud for data storage, application programming interface (API) for data analysis and user interface (UI) for data visualization.

B. Role of LoRa and LoRaWAN

LoRa is a low power technology developed by Semtech which defines the physical layer of the system whereas LoRaWAN is Low Power Wide Area Network (LPWAN) media access control (MAC) layer protocol and system architecture developed by LoRa Alliance which built on top of the LoRa physical layer. It defines the network architecture which operates in a non licensed band below 1000 MHz. There are three frequency bands that are used which are 915 MHz for north America, 868 MHz for Europe and 433 MHz for Asia. Lora Technology use adaptive data rate algorithm and maximize the battery life and network capacity of the nodes [4].

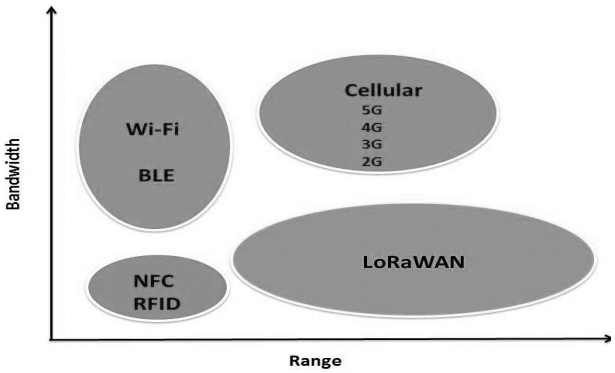

Fig. 2: Comparison of Different Wireless Communication Protocols

The access control mechanism to environment offered by LoRa's allows for multiple final devices to communicate with a gateway using LoRa modulation. The Low-Power Wide-Area network ensures the connectivity of low power devices distributed on large geographical areas. These networks represents a new model of communication, successfully competing with already existing wireless communication technologies such as: Bluetooth, Zig-Bee, LTE, GSM and Wi-Fi.

Due to its low power requirements and low costs of manufacturing and operating, LoRaWAN is one of the most used Low-Power Wide-Area network technology. Moreover, the security of the LoRa system can be guaranteed as the transmission is spread in a pseudo-random way which presents like a noise, hence the modulation technique had provided the basic security for the LoRa system [4].

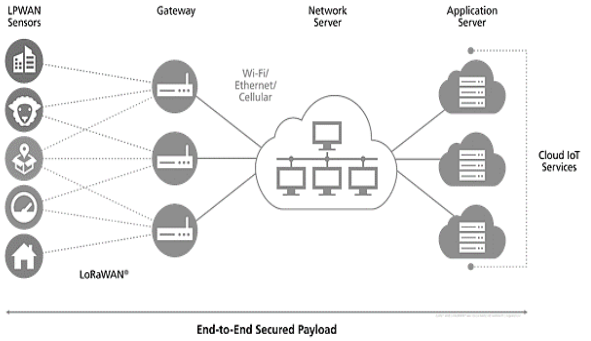

Fig. 3: LoRaWAN Architecture
(Source: https://tech-journal.semtech.com)

The main targeted deployment of LoRa technology is the smart devices which have limited energy and does not require establishing frequent communication all the time.

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All these features makes LoRa an interesting candidate for the current Internet of Thing (IoT) market and make it able to compete with other IoT technology such as Wi-Fi and Bluetooth.

The main advantages of LoRaWAN technology are [5] :

- Use the unlicensed ISM frequency band.
- It is a flexible solution that can be easily adapted. - It is scalable.
- It supports bi-directional communication.
- Provides a high level of security due to encryption algorithms.
- Provides energy efficiency.

III. Study and Findings

At present there are so many wireless technologies such as Cellular, ZigBee, Wi-Fi and Bluetooth communication are used for IOT based battery management systems, but these technologies facing issues like range and power consumption. In this scenario, the ISM band LoRa(WAN) technology, may be a suitable option. A study is done on the research, design and implementations carried out in the IOT applications and the role of LoRaWAN in the field of cloud based Battery Management system for electric vehicles. The whole study is summarized in table 1.

IV. Conclusion

This study gives a brief outline of different type of battery management systems and the role of the technologies like Internet of Things, cloud computing, LoRaWAN for designing smart battery management systems especially for modern electric vehicles. The key findings of the review done here is summarized in table 1. It is revealed from the literature reviewed here that Battery Management System and use of internet of things, cloud computing and technologies like LoRa are still in a premature and experimental stage. It is also clear from the review that due to long range, low power consumption, unlicensed frequency band and high level of security LoRaWAN may be a premier communication protocol for IoT based Battery Management System.

Wireless technologies are updating day-by day so it will be the future of Battery Management System in electric vehicles. In future artificial intelligence and machine learning based algorithms may be applied on the data collected on the cloud from the battery systems for precise analysis and applying it for prediction and system optimization purposes. The gap between the laboratory tests and the real applications are still the topics for future research.

Table 1. Summary of Various Studies on IoT Based Battery Management Systems

S. N.	Research/Study	Citation	Year	Findings
1.	Development of Battery Monitoring System in Smart Microgrid Based on Internet of Things	[1]	2017	A battery monitoring system based on internet of things (IoT) for a smart micro grid system has been developed. Average execution time for overall data acquisition is 19.54 ± 18.00 seconds. The availability of monitored data is 92.92 ± 6.00 percent
2.	Battery Monitoring System with LoRa Technology	[3]	2018	A prototype has been developed for monitoring lead acid battery in far distance area using LoRa SX1278 module. High succes rate up to 98,67%. Low error in measurement 0.023% Low cost, low power consuption, easy installation. Additional digital filter could be used to smoothing the voltage sensing
3.	LoRa based renewable energy monitoring system with open IoT platform	[6]	2018	In this paper, a renewable energy monitoring system using open IoT platform such as Arduino, Raspberry Pi and LoRa network has been ıntroduced. Low-cost, low-powered, and efficient. LoRa network without base station is used. Collection and analysis of energy status data from solar and wind power generation systems with web based protocols.
4.	Various Types of Wireless Battery Management System in Ev.	[7]	2020	This paper explain various types of Wireless Battery Management Systems implemented so far along with its working and key findings. Bluetooth and Zigbee having low power consumption and become more popular in automotive industry instead of CAN communication. Cloud and IoT based technologies will be the future of Battery Management System in electric vehicles.

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5.	Battery Management System Using State of Charge Estimation: An IOT Based Approach	[8]	2020	This paper described the design and development of an IOT based wireless battery monitoring system for battery operated vehicles. Battery degradation can be monitored using middleware application server. Developed a Hardware for the battery monitoring device and a web-based battery monitoring user interface. The system is capable of showing information such as battery SoC condition with deep discharge level indication, battery terminal voltage and estimated kilometer run by incorporating MQTT server based system to notify the user on real time basis.
6.	Digital twin for battery systems: Cloud battery management system with online state-of-charge and state-of-health estimation	[9]	2020	A cloud battery management system was developed based on the concept of the Internet of Things and cloud computing. The functionalities and stability of both hardware and software of the cloud battery management system are validated with prototypes. SOC and SOH estimation algorithms were developed based on an extended Thevenin model. Under field operation and experimental validation for both stationary and mobile applications

V. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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