Consortium Blockchain-based V2G Energy Trading System Using Tokens

Junho Hong
Department of Bigdata Science
Chungbuk National University
Cheongju, South Korea
2020278011@chungbuk.ac.kr

Eunhwa Oh
Department of Bigdata Science
Chungbuk National University
Cheongju, South Korea
oeh0131@chungbuk.ac.kr

Yeojin Yang
Department of Bigdata Science
Chungbuk National University
Cheongju, South Korea
ty0092@chungbuk.ac.kr

Kyungwoo Roh
Department of Management Information System
Chungbuk Natioanl University
Cheongju, South Korea
roh@chungbuk.ac.kr

Minji Oh
Department of Bigdata Science
Chungbuk National University
Cheongju, South Korea
mj2020@chungbuk.ac.kr

Jaesung Kim
Department of Management Imformation System
Chungbuk National University
Cheongju, South Korea
comkjsb@cbnu.ac.kr

***Abstract*— Recently, under the influence of the Fourth Industrial Revolution, the government is attempting a new field of revitalization of the power energy trading market in the energy industry. With the advent of prosumers that generate and consume electricity by themselves, the need to promote transparent transactions by establishing a safe and reasonable transaction platform for energy transactions has increased. With the development of blockchain technology, the research has been actively conducted, and interest in services incorporating blockchain is increasing in various fields, and various studies incorporating blockchain into the energy transaction field have been actively conducted. Along with the need for a transparent energy trading platform, the need for electric vehicle charging infrastructure and power load management, one of the core technologies of smart grid, is also increasing. Therefore, this study aims to build a V2G energy transaction system based on the consortium blockchain and develop an application for transaction activation. In addition, it intends to incorporate the blockchain system into real life and lay the foundation for commercialization of the blockchain system.**

Keywords— Consortium Blockchain, EV(Electronic Vehicle), Power Load Management, Energy Trading System

I. INTRODUCTION

Under the influence of the Fourth Industrial Revolution, the Korean government is trying new projects in the energy industry. In November 2015, the [2030 New Energy Industry Expansion Strategy][1] was established and suggested energy prosumers and decentralized clean energy diffusion, ICT convergence, and greenhouse gas reduction as key keywords of future energy [2]. The Ministry of Trade, Industry & Energy has conducted a demonstration project of "Power Transaction between Prosumers and Neighbors" since March 2016 to activate a trading market in which prosumers sell the remaining electricity to neighbors with high electricity bills. In addition, as new and renewable energies such as solar power increase, prosumers, which generate and consume electricity by themselves, are expected to become the leading player in the change in the energy paradigm [3].

Currently, the energy trading market is revitalized by the government, and there is a problem in that information on power price setting is not transparently transmitted to consumers. Faced with the problem of information asymmetry between the supplier and the consumer, the direction of information flow is one-way, which is one direction transmitted from the central management authority to the consumer. This problem can be solved by introducing a blockchain-based transaction platform.

Blockchain became known to the public through a cryptocurrency called Bitcoin after Satoshi Nakamoto first mentioned it in his 2008 paper [4]. Blockchain is a distributed data storage technology that transparently records and copies transaction details on a ledger and stores them on multiple computers. The core of this technology is to ensure information transparency by preventing hacking by multiple computers. As blockchain technology develops, blockchain-based energy trading platforms are being actively developed in the US, Europe, and Jung-gu. However, it is difficult to find a case of using blockchain in each industrial field in Korea, and there is insufficient discussion on issues that may arise due to the introduction of blockchain [5].

Therefore, it is expected that the following expected effects can be evoked if an energy trading platform using blockchain is built. First, transparent electricity transactions can be promoted by sharing energy transaction information on a distributed ledger. Second, it is possible to reduce transaction costs by eliminating transaction fees between power providers and consumers. Third, it can contribute to the development of new electric business by promoting the transaction of surplus electricity for electric vehicles.

The purpose of this study is to build a transparent energy transaction system by introducing energy blockchain technology. This study is organized as follows. First, build a consortium blockchain transaction platform based on Hyperledger Fabric. Second, introduce an energy transaction method using tokens. Third, build a user-friendly smartphone application to promote energy transactions.

II. Prior Research On Blockchain

Researches on the transaction system using blockchain and the idea of constructing an energy transaction system incorporating a blockchain into a smart grid have been actively conducted. Ju Min Cha et al. (2019) proposed a service that allows users to trade dogs with the Clayton blockchain platform [6]. The dog transaction service DApp has sufficiently replaced the existing centralized web or app, promoting decentralization and transparency. Young-Gon Kim et al. (2019) proposed a highly reliable power transaction payment system for production and consumption patterns using artificial intelligence prediction techniques by linking the permission-type blockchain network hyperleisure system and energy big data system [7] . Gichan Im et al. (2019) reviewed the domestic smart grid technology trend and analyzed the utilization of smart grid blockchain [8]. In addition, they suggested that if blockchain is used for smart grid, a transparent and easy-to-use energy transaction system will be established in P2P transactions. Chan-Guk Jang et al. (2019) proposed a system that is difficult to forge and change data by introducing a private blockchain to the electric vehicle charging infrastructure, which is the area of the smart grid, and sharing transaction data. In addition, research implications for the development of blockchain and blockchain applications for electric vehicle charging infrastructure were left [8].

This study intends to build a system that promotes information transparency and stability by adopting the consortium block chain among the block chain configuration methods. In addition, when setting electricity prices, we propose a reasonable pricing process that considers the maximum load time period, etc., and promote safe energy transactions through tokens. We propose a system that enables consumers to easily conduct electricity transactions and information inquiry through smartphone applications.

III. Energy Trading System Based On Blockchain

3.1. Blockchain Configuration

Blockchain is divided into public blockchain and consortium blockchain [10]. Most of the blockchains currently traded on the exchange are public blockchains. Since there is no restriction on the targets participating in the blockchain network, anyone can view all details and verify transaction details [10]. The public blockchain is completely decentralized and can be operated by old people, so the operating entity is not unclear. In addition, since this is a structure that is widely applied in cryptocurrency, it is characterized by being relatively free from legal binding power as there are many cases of financial activities through virtual currency [11]. Under the public blockchain structure, peers can participate in the consensus process to verify the validity of transactions, and have the right to create blocks and register them on the chain.

On the other hand, the consortium blockchain has a partially decentralized structure and only a few peers have the authority to validate transactions. Also, unlike a public blockchain, a consensus process between authorized peers is required to register a block on the chain, so reliability can be maintained. Therefore, transaction details are not disclosed to everyone, and there is a characteristic that privileges can be set differently for each node.

The electric vehicle charging infrastructure consists of a power supply system, an infrastructure operation system, a customer information system, and a charging station [12]. Subjects participating in the EV charging infrastructure can be divided into electric vehicles, electric vehicle chargers, electric vehicle charging companies, power companies and prosumers, and consumers. Since there is a possibility that personal information of various subjects may be exposed, under a public blockchain structure in which anyone can participate in the network to search and register information, there is a possibility that problems with personal information may occur. A specific node with authority must be created so that only legally responsible institutions can create transactions, and a blockchain structure that can clarify who is responsible in case of a financial accident during a transaction must be established.

Therefore, the energy transaction system of this study adopts the consortium blockchain structure to establish a transparent and safe energy transaction platform.

3.2. Proposal on a Blockchain-based Energy Trading System

The overall structure diagram of the blockchain-based transaction system proposed in this study is shown in Figure 1. The consortium blockchain was adopted, and the three main entities participating in the power transaction were eco-friendly electricity producers, electric vehicle users, and industrial complexes. Eco-friendly electricity producers can use solar power to produce and sell energy, electric vehicle users can purchase or sell electricity, and industrial complexes can purchase electricity during periods of high power usage. Each representative server of the power transaction entity can be connected to the consortium blockchain network to ensure safe transactions.

In order to promote the stability of the transaction, the trading entities participate in the transaction by converting them to TOKEN, a virtual currency. In addition, by limiting the nodes that can generate transactions to the representative server of each subject, we tried to protect personal information safely. Therefore, eco-friendly electricity producers, electric vehicle users, and industrial complexes connect to the blockchain network through other nodes with smartphone applications. All activities in the smartphone application such as membership registration, login, power transaction, etc. are registered in the

Identify the applicable funding agency here. If none, delete this text box.

blockchain network through SDK, and the record is shared and recorded to create a trusted ledger for peers of three organizations.

Electricity bills at the time of purchase and sale of energy are set at a price that is beneficial to both the buyer and the seller during the light load and peak load period. The pricing process and final price are stored and shared in the consortium blockchain to increase the reliability of power transactions.

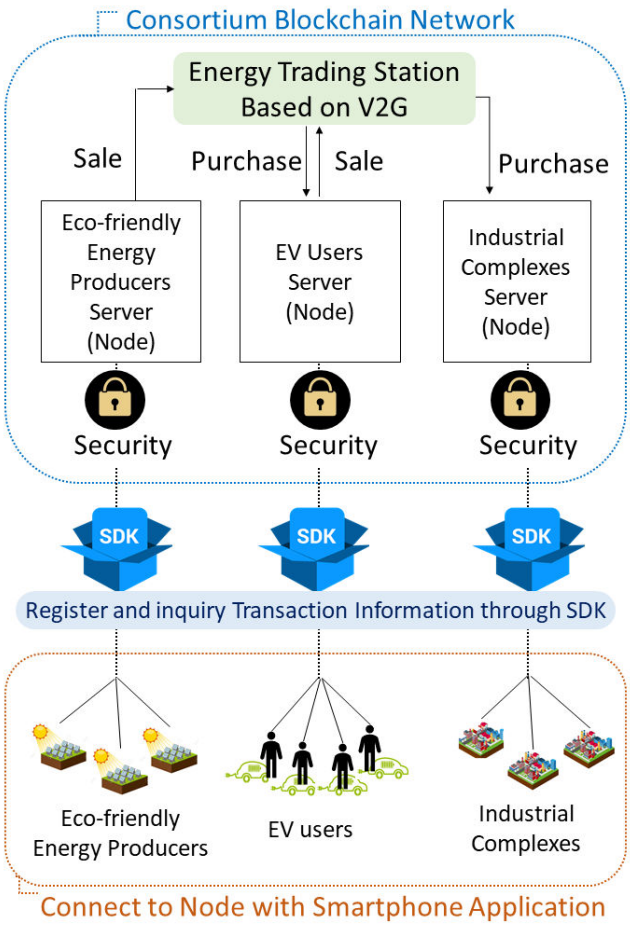


Fig. 1. Vehicular back LED detection and retrieval of data.

Since the consortium blockchain method limits network participants, general users who trade energy can participate in the transaction through the 'membership registration' process at the lower level among the authorized representative groups as shown in Figure 2. After authentication, it is a structure to search for transaction information and participate in the transaction, and the transaction information of general participants is securely protected by the consortium blockchain. In addition, each individual can check his or her transaction information and personal information through the representative node server.

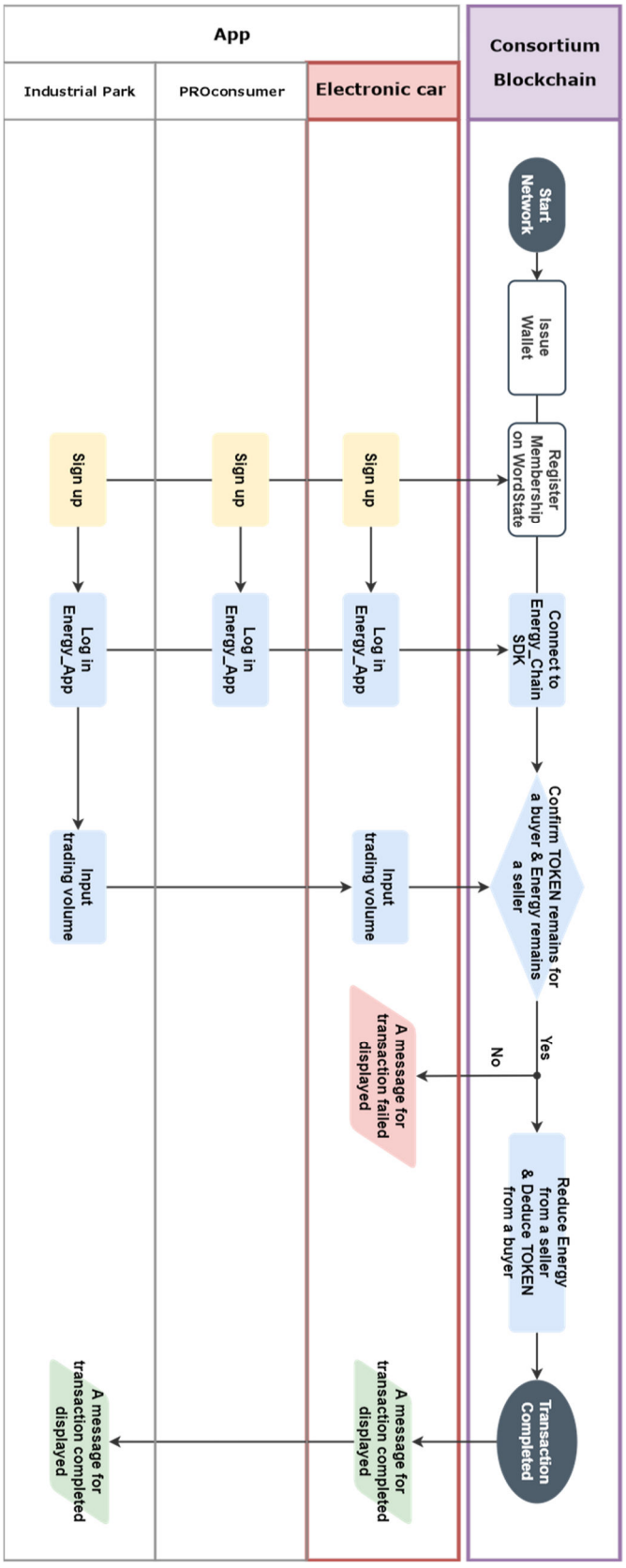


Fig. 2. Workflow of Consortium Energy Blockchain and Application

3.3. Back-End Structure of Blockchain Network

An example block chain network configuration code is shown in Figure 3. In the blockchain-based V2G energy transaction system application using tokens, 3 organizations and 6 peers establish a network. In each organization, clients belonging to the organization can participate in the blockchain network through the SDK, and membership registration is required to use the SDK.

Ethereum's proof-of-work (Pow) method has limitations in real-time token transactions due to the slow transaction speed. Proof-of-work is a method of verifying credentials in Bitcoin by allocating blocks to nodes that have solved the problem in a faster time. In Bitcoin, it takes more than 10 minutes for a block to be created, so it takes a long time to meet the finality. Ethereum has also devised a new structure because it is risky to proceed with transactions in real time. In order to solve the problem of finality, Ethereum was applied to the network of Hyperledger Fabric, and transactions by adopting a method in which clients of three organizations access the blockchain through nodes of the representative organization without directly participating in the transaction. The improved network was built by increasing the speed.

```
// ERC20Metadata is the definition of the chaincode structure.
type ERC20Metadata struct {
    Name string `json:"name"`

    Symbol string `json:"symbol"`

    Owner string `json:"owner"`

    TotalSupply uint64 `json:"totalSupply"`
}

// TransferEvent is the event definition of Transfer
type TransferEvent struct {
    Sender string `json:"sender"`

    Recipent string `json:"recipient"`

    Amount int `json:"amount"`
}
```

Fig. 3. An Example Configuration codes of Blockchain Network

The internal chain code of the consortium blockchain is shown in Figure 4. When registering as a member, check the duplicates, confirm that they are not duplicates, and then register the member information in the block. Member information registered in the block is used when logging in. In addition, the purchaser's token holding amount is checked during the transaction, and if it is confirmed that the token holding amount is zero, no energy purchase occurs. After checking the amount of tokens held by the buyer, check the energy holding amount of the seller, an energy provider. If the amount of energy reserves is less than the amount requested by the purchaser, no energy is sold. If there is no token as requested in the transaction or the energy reserve is insufficient, the energy sale and transaction will not proceed, and this will not be stored in the block.

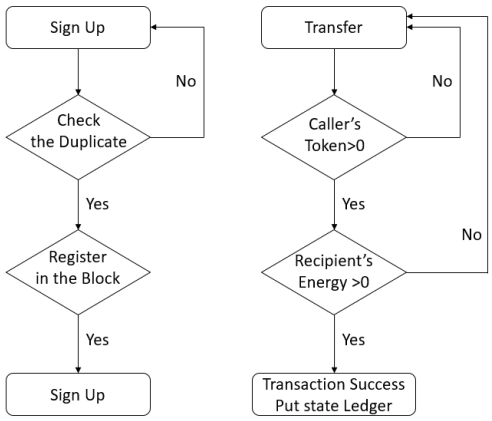


Fig. 4. Structure of Energy Blockchain

IV. Implementation and Results

The blockchain network proposed in this paper is composed of five blocks. The KEY block stores the unique identification ID, and the Value block stores the transaction details and the transaction price represented by tokens per KW. The Timestamp block stores the block registration time, the Prev_Hash block stores the hash value of the previous block, and the Proof block stores the error and forgery verification process.

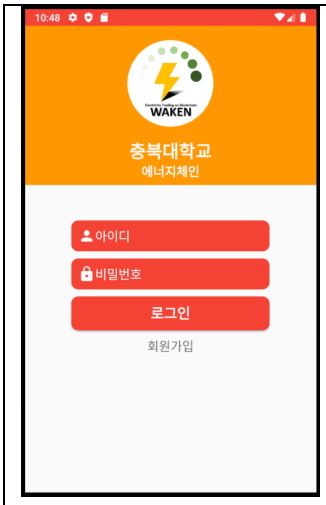
In the case of Chaincode inside the blockchain, the application calls the chaincode to interact with the blockchain, manages the state of the ledger, and stores transaction records in the ledger. Chaincode was installed on each peer node running in Docker container, and Hyperledger Fabric chaincode was programmed through Go, Node.js, and Java. The main functions used in the chaincode are shown in Table 1.

main Functions	The role of the main function
case “totalSupply”	Total amount of TOEKNs issued
case “balanceOf”	Current Key Value Status
case “SignUp”	Sign Up for the Trading System
case “Update”	Membership Information Modification
case “transfer”	Energy Trading
case “historyAPI”	Transaction History
case “DetermineCose”	TOKEN per 1KW

Table 1. Main Functions in the chaincode

The energy transaction system based on the consortium blockchain is linked with a smartphone application so that general users can easily participate in transactions. The DApp built in this study consists of login, membership registration,

purchase, sales, personal information modification, currency exchange, transaction history inquiry, and charging station search, and each screen is shown in Table 2. The user can register personal information on the login screen. After logging in, you can check the current electricity transaction price and your own tokens on the main screen. In order to buy and sell electricity, the user can proceed with the transaction by visiting the purchase page and the sale page, respectively. On My Page, you can edit personal information, check notices, and go to the currency exchange page to change the amount of tokens held. In addition, by accessing transaction information registered in the blockchain network through SDK, you can check all transaction activity and transaction information details on My Page. By linking the location-based service to the smartphone application, you can check the location of the nearest power charging station from your location.

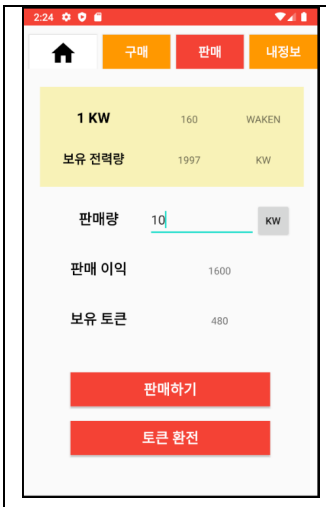


(1) Log-in page

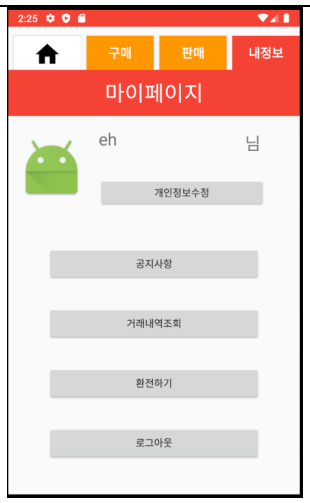
(2) Sign Up page1K

(3) Main page

(4) Purchase page



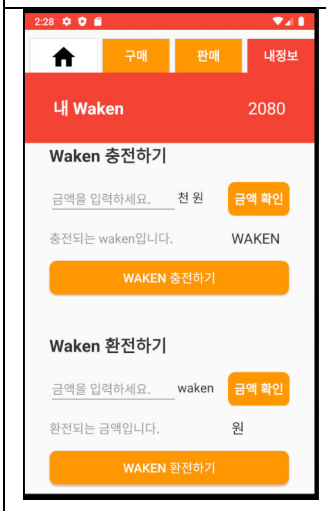
(5) Sale page



(6) Mypage - Main

(7) Modify information

(8) Notification



(9) Charge Token page

(10) Check Transaction page

(11) Nearby Stations page

Table 2.

Smartphone application screens of Blockchain based Energy Trading System

V. CONCLUSION

It is an important value of blockchain to enable secure and transparent transactions between parties without the need for intermediate traders or third parties. One of the key ways to utilize a blockchain-based business model is to technically replace the role of an intermediary. By simplifying the mediation stage, the business of the two-sided market platform will be able to achieve great development by connecting suppliers and consumers, which are participants of the two mainstreams.

The consortium blockchain power transaction system proposed in this study can bring the following effects. First, it enables independent power transactions for the power grid infrastructure through electric vehicles. Second, since power is charged and discharged at the energy trading station, spatial limitations can be overcome by securing mobility in power trading. Third, there is an effect of overcoming the temporal limit of power trading through energy trading stations. Fourth, there is an effect of contributing to peak management by appropriately allocating power use time. Fifth, there is an effect of distributing electricity transactions to the consortium blockchain ledger. Sixth, there is an effect of improving accessibility to power transaction information with a smartphone application.

However, since the electric vehicle (EV) charging infrastructure is installed in a limited place, it is expected that it will take time for the blockchain-based V2G energy transaction system service to become practical. In the future, when technology develops and an infrastructure for system construction is formed, in order to support this, a consortium blockchain-based V2G energy transaction system was designed and built in this study.

ACKNOWLEDGMENT

This research was supported by the MSIT(Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support program(IITP-2020-2018-0-01396) supervised by the IITP(Institute for Information & Communications Technology Planning & Evaluation)

REFERENCES

[1] Ministry of Trade, Industry and Energy, "Comprehensive measures for performance diffusion and regulatory reform in new energy industry", 2016

[2] Hyoseok Lee, Taekyu Lee, Seungwon Jung, Jeonguk Kim, "Comparision of Profitability according to the Type of Electric Power Transaction in a Solar Powered House Considering Energy Prosumer System", New & Renewable Energy 15(4), pp.55-65, 2019

[3] Ministry of Trade, Industry & Energy, "Prosumer Neighborhood Electricity Transaction – Demonstration Project″ , http://eiec.kdi.re.kr/policy/materialView.do?num=151929, 2016

[4] Nakamoto, S., & Bitcoin, A., "A peer-to-peer electronic cash system. Bitcoin", URL: https://bitcoin. org/bitcoin. pdf. , 2008

[5] Taeu Bahk, DongHyun Ko, Seonjin Hwang, Yoon-Ho Choi, "A Review of Blockchain Limitations by Examining Blockchain Use Cases", Proceedings of Symposium of the Korea Institute of communications and Information Sciences, pp.98-99, 2020

[6] Ju Min Cha, Jeong Gyu Kim, Yong Yook Kim, Moo Hyun Lim, Woosaeng Kim, "Blockchain-based Pet Trade Service DApp", Journal of Information Technology Applications & Management, 26(6), pp.79-87, 2019

[7] Young-Gon Kim, Keol Heo, Jung-In Choi, "A Study on the Production and Consumption Authentication Power Trading System based on Big Data Analysis using Blockchain Network", Journal of Energy Engineering, 28(4), pp.76-81, 2019

[8] Gichan Im, Gunhee Jang, Seohyeon Jeong, Nhu-ngoc Dao, Sungrae Cho, Hyounchel Bae, "A Survey on the use of blockchain in smart grid", Proceedings of Symposium of the Korean Institute of Communications and Information Sciences, pp.919-920, 2019

[9] Chan-Guk Jang, Okyeon Yi, "Blockchain Network Configuration for Smart Contract in EV Charging Infrastructure", The Journal of Korean Institute of Communications and Information Sciences, 44(8), pp.1597-1604, 2019

[10] Ki Jin Jang, "Research on Product Management and Transaction System Development based on Blockchain", The e-Business Studies 21(4), pp.57-70, 2020

[11] Lim. H., Lee. M. S., and Goo. W. Y., "Blockchain Service for Things Sharing / Transaction". The Korean Institute of Information Scientists and Engineers, pp.319-321, 2019

[12] H. -G. Lee, "Development status and prospect of electric vehicle charging infrastructure", KIPE Mag., vol.15, no. 6, pp.73-76, 2010