Facilitating Electric Vehicle Charging Across the UAE Using Blockchain

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***Abstract* — Electric Vehicles are becoming popular among car owners now a day with several car manufacturing companies expanding their productivity with different models and sizes. However, there is a lack of proper charging infrastructure to support their wide spread. Blockchain as a technology first was used for money transactions while not relying on any trusted third parties such as central banks to securely approve and validate such exchanges. This paper is focusing on procedures of Blockchains in controlling and sharing charging stations and billing records to permit customers, organizations/authorities, and other power stakeholders to share information among themselves, and increment the ability of systems to exchange and make use of information. Despite the fact that the use of Blockchains may diminish repetition and provide power organizations with constant records about their customers, regardless it accompanies few difficulties which could invade customer's privacy. In this paper, we study different blockchain constructions, discuss the challenges and provide a possible framework to facilitate Electric Vehicles charging across the UAE.**

Keywords— Blockchain, Electric Vehicle (EV), Information Security, Smart Grid.

I. INTRODUCTION

The use of Electric Vehicles (EVs) has been increasing over the years as they are more environmental friendly than fuel based vehicles. Many countries encourage people to replace their vehicles with electric ones and offer them incentives to do so. EVs move from one location to another, their affect on the energy market is dynamic depending on their numbers and whether they are charging simultaneously within a short time window. An appropriate authentication method and power flow control mechanism is required to allow EVs to be appropriately accommodated as part of a smart grid network [1].

Blockchain is a technology that has emerged few years ago with the main application being money transfer and Bitcoin. However, Blockchain as a technology is being utilized now a day to serve many applications that are designed to be executed as transactions over decentralized peer-to-peer distributed systems. One of the main attraction features of Blockchains is its ability to provide strong security features protecting users' privacy. Fig. 1 shows how blockchains works in general. Blockchain is a distributed ledger, which implies that a record is distributed among all participants in the network, and each peer holds a duplicate of that record. On account of the data can't be altered or tampered with during the transaction, it uses cryptography to ensure the security of the data records, and it also allows verification without being dependent on any third-parties [2].

Transfer of information among the individual participants within a Blockchain can be done in a protected manner either on or off the Blockchain based on the execution of what is known as smart contracts to be further explained in section three of the paper. In our EV charging example, using a smart contract permits the exchange of data/information among the EV charging blockchain members in a straightforward transparent manner without the requirement for any brokers. However, smart contracts need to be well thought to be effective enough to carry the functionalities intended.

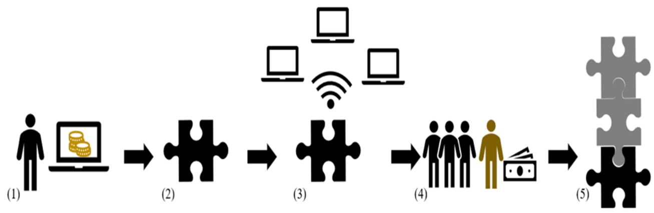

Fig. 1. (1) A transaction is requested. (2) A block that represents the transaction is created. (3) Block is broadcasted to every node in the network. (4) Miners compute the block to validate it, first node to compute the hash receive a reward for the Poof of work. (5) The block is added to the existing blockchain, and the transaction is completed.

In this paper we propose a solution to enable seamless charging for EVs across the UAE where there are different power providers by implementing a Blockchain and discuss the security and privacy challenges related to the use of blockchains in the energy sector. The remainder of the paper is as follows: In section 2, we present related background information, solutions that others provided for EV charging and security and privacy challenges. In section 3, we explain our proposed solution while the paper is concluded in section 4.

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II. BACKGROUND AND CHALLENGES

Blockchain as a technology is based on a decentralized consensus system for increased security and trust among participating entities. This has opened the door for various applications to utilize this technology and provide better services. Blockchains are of two types either public or permissioned with the latter being either private or consortium. Given the problem this paper is trying to address, a consortium blockchain can be considered as a suitable solution for providing seamless charging for electric vehicles across different power providers in the UAE. In a consortium Blockchain every participant needs to be certified to join the consensus process [3]. Transaction data in this kind of Blockchain can be public or restricted as it is partially centralized. Examples of these types of blockchains include Hyperledger and Quorum [4. Although the idea of enabling seamless charging for electric vehicles across different power providers seems simple, its implementation poses a number of challenges. This section introduces the main ones.

A. Security and Privacy Challenges

An EV user could face several security and privacy risks, especially when he or she is charging outside the home network. These users could be charging at any location for example at their home, a friend's home, at work, or at public charging stations. Therefore, these users should be made aware and secure against security vulnerabilities, which may results in serious attacks compromising their private information, their charging equipment, EV or the power network at large. Furthermore, EV users need to follow a remote authentication and a payment transaction method, for the power utility company to be able provide them with electricity based on their requests. In doing so, proper precautions need to be taken to prevent information leakage, replay or other kind of attacks as a result of remote communication with servers. Examples of information leakage can be knowing where the user frequently charges i.e. the exact location and how often charging is done etc.

The authors in [5] proposed an EV charging and payment transaction protocol for EVs using the nested signature approach for proper authentication while keeping separate components of the transaction private. The proposed approach relied on a trusted third party for payment transactions. Another paper [6] introduces several privacy issues in Vehicle to Grid (V2G) networks, including the leakage of privacy-sensitive data. The authors have also proposed various approaches and techniques to achieve privacy preservation. This included anonymous authentication hiding geographical, payment or any private information.

B. Leveling the Energy Load

In an energy system, it is normal for the demand of power from consumers to vary from time to time. However, if this variation in demand is unbalanced, it can cause frequency deviation from nominal values, which may lead to system failures. Power utility companies implemented different methods to lessen peak loads and to retain this balance [7]. One approach would be to utilize the power generated from renewable energy resources such as wind and solar. However, these resources are highly unpredictable because they depend on uncontrollable factors such as weather conditions. Instead, in [7] the authors have come up with better methods of energy scheduling and price optimization algorithms such as: game theoretic based, collaborative based, and incentive based in addition to centrally controlled models. The authors also discussed different topics related to peer to peer energy trading including the four types of demand response optimization approaches. In addition, they looked into two key challenges related to security and privacy and mobility.

C. Location of Charging Stations

For EVs to be successfully deployed at a large scale within a given country or across a continent there need to be enough charging stations properly distributed allowing travelers to charge their EVs easily and without any worries of being out of power on the road. This will avoid what is known as "range anxiety" among EV owners and will result in an increase of EV ownerships. In one of the research papers [8], the authors developed an algorithm that determines the number of charging stations for a specific type of an electric vehicle when traveling between any two points within a given area of interest. Their approach was based on an algorithm, which determines the number of charging stations needed between two points of interest based on the average EV mileage being used. An advantage of this algorithm is that it provides flexibility in the sense that it shows the locations of existing charging stations and proposes new ones for better driving experience.

III. PROPOSED SOLUTION TO FACILITATE EV CHARGING ACROSS THE UAE

We strive to create a developed and collaborative way to facilitate the process of charging electrical vehicles in different locations across the UAE. Our idea is to build a consortium blockchain that would integrate all the participants in the process including power providers, users of the electric vehicles, electric vehicles, charging stations whether private, company owned, or commercial based. To do so, smart contracts (electronic contracts) need to be developed to govern transactions across all involved entities. Fig. 2 presents our proposed detailed architecture of the needed blockchain network. It is composed of three main layers, which are as explained in the next section: power grid network, smart contract network and the mining network.

A. A layered approch

In this section we explain the three layers making up our proposed architecture as shown in Fig. 2. The upper layer, the mining layer, is where memberships and permissions are assigned to users of electric vehicles. It consists of all registered charging stations data, such as location data, permissioned users and available types of charging. Moreover, this layer contains the four main utility power providers in the UAE, as shown in Fig. 3, and their corresponding blockchain data. In the UAE micro grids and small scale energy providers are not yet established, however, there is a noticeable renewable energy effort by at least two of the main utility companies, namely, Dubai Electricity and Water Authority (DEWA) and Abu Dhabi Water and Electricity Authority (ADWEA).

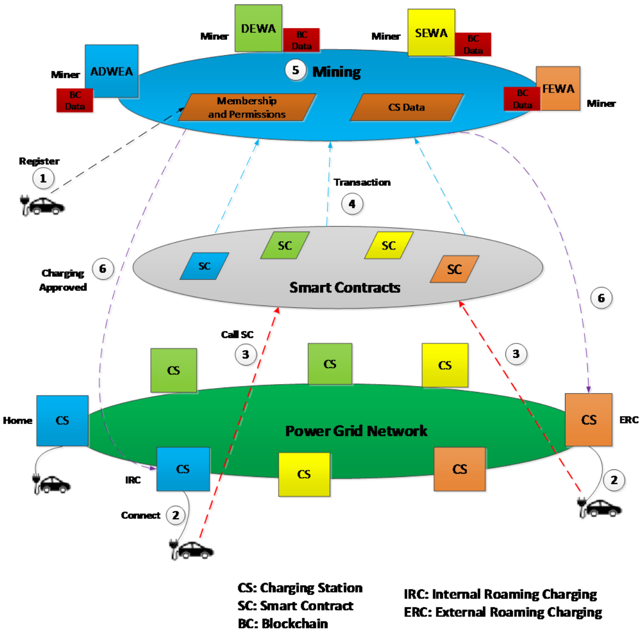

Fig. 2. An Architecture of a blockchain network of charging EVs across the UAE.

Blockchain utilizes what is referred to as smart contracts [9] to facilitate, automate and define how entities on the blockchain network interact and deal with each other. These electronic computer codes are specified using certain syntax based on the hardware and software platform used. Smart contracts compose the middle layer in our proposed architecture as shown in Fig. 2. In our example, smart contracts can include program logics, EV owner contract, contract unique identifier, account balance and private data storage.

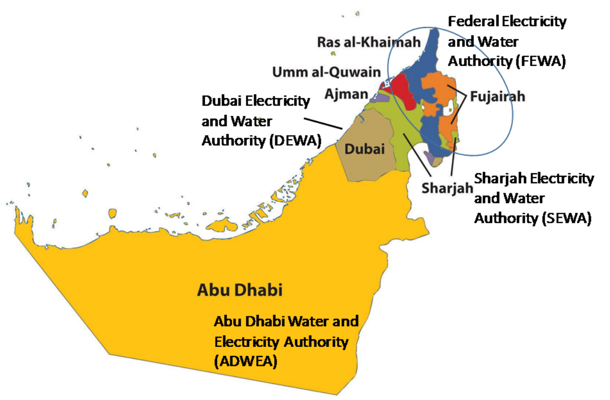

Fig. 3. A map of the UAE showing the different power and water providers per area.

The execution of smart contracts is carried out through a consensus algorithm between the miner nodes which in our case are the four main utility providers mentioned previously. These contracts are created by the mining network of the Blockchain through agreed upon transactions. A new smart contract is added to the Blockchain network after the network of providers authenticate the contract and agree on it through a consensus approach. Once the code of a smart contract is added on the Blockchain network it cannot be changed. This guarantees that the contract terms cannot be modified by any unauthorized party. However, the smart contract layer is nothing, but a set of rules and conditional statements to govern the acceptance or rejection of performed transactions. It acts as an agreement between participants in the form of computer code. For example, you need to have an authenticated identity to access this specific service. In the case of an EV charging example, a smart contract will generate an output based on the input received from the electric vehicle. In a consortium Blockchain which we are pursuing as a solution, a smart contract can be created to include all needed rules and conditions specified by each miner defining its relationships with all other entities.

The power grid network layer shown in Fig. 2 represents the infrastructure layer of the blockchain network. It consists of all charging stations in the UAE coordinated based on their types, and the provider they belong to. For example, DEWA reported in October 2018, the completion of installing more than 100 EV charging stations across Dubai. They built three different types of their electric chargers: wall box charger, public charger, and fast charger each one differs on the power level and time needed to fully charge an EV. These charging stations were placed in different areas of Dubai such as government offices, airports, petrol stations, shopping malls, commercial offices, hospitals, residential complexes and establishments [10].

In order to facilitate payment transactions among participants an Energy coin can be used. This coin can be exchanged instead of actual currency to complete transactions. The idea of an Energy coin has been used in other countries based on a peer-to-peer cryptocurrency technology. Transactions in using an Energy coin run based on the Proof of Stake protocol [11]. Staking is more energy efficient compared to mining, thus this approach is considered better than other protocols. In addition, cryptocurrencies can be simply associated with actual real payment systems while an underlying blockchain network offers more than a simple storage solution. The authors in [11] used it as a platform to host tokens. An untraceable electronic cash method implies a kind of prepaid digital payment system that can protect users' privacy. These systems have lately been given appreciable attention by both theory and development projects. However, in most current schemes, loss of a user device consists of electronic cash entail a loss of money, just as with real cash. In comparison with credit schemes, this is considered a serious shortcoming [12].

B. The overall process

In this section we explain the step-by-step process of EV charging based on the proposed architecture. The circled numbers in Fig. 2 indicate this process. Step one of the process is registration where the user who has an assigned permission to access the blockchain network is registered. This will allow the registered users of an EV to connect their vehicles to charging stations within their provider utility company premises or externally.

There can be several scenarios for EV charging, internal or external. Internal charging consist of two types; the first one is at the registered user's house/local charging station where usually a wall box charger is installed. In this scenario the user directly charges the vehicle and the electricity bill for that is transferred directly from the user's home account to the miner's network (Endorser). In the second case of internal charging the user is charging the EV from within the same home network but from a different place other than his or her home. Such locations can include a workplace, a friend's house, a petrol stations etc. On the other hand, external charging is when the user charges an EV on a power network provider other than the home network he or she is registered with.

Subsequently, in step 2, the EV connection process to a charging station will generate an output from the smart contracts deployed by the energy providers in the blockchain network based on the input data provided by the EV. For each charging scenario, specific rules and conditions are to be activated on the EV in order to invoke the corresponding smart contract, i.e. step 3. For this to happen some kind of a software such as API that will be needed to allow the EV to connect with its corresponding smart contract.

Thence, in step 4, the smart contract layer will develop a transaction that will be sent to the mining layer. Transactions are then verified by the mining layer before being registered on the blockchain, this happens in step 5. The validation process is to verify that the particular EV has needed permissions to withdraw energy from the specified power provider in addition to verifying that the involved EV has the sufficient tokens/account balance to pay. The validation process could also prevent a replay attack by the EV asking to be connected for charging. Once mining is completed, miners order the transactions based on their type and in a chronological order to be added to the corresponding blocks with the blockchain network. In step 6, the power provider sends an approval to the charging station to start releasing the electricity to the EV.

IV. CONCLUSION

In this paper, we presented a layered architecture to enable seamless charging for EV across the UAE. The topics covered include blockchain related to energy and EVs, challenges that the users of EVs may encounter such as security and privacy issues, unbalanced energy load issues and issues related to how to determine ideal locations of charging stations. Moreover, we discussed smart contracts and how they can be used to facilitate our proposed layered approach. The steps of the proposed approach were explained in details to provide the reader with an understanding of the overall layered architecture and its components. Our future work will be to build a proof of concept system to validate the proposed approach.

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