ARTIFICIAL INTELLIGENCE (AI) AND BLOCKCHAIN-BASED ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Abstract

Electric vehicles (EVs) with greater ranges will use a variety of networks, some of which are not necessarily owned or operated by the same utility. As a result, we suggest an infrastructure that can provide a charging service for moving automobiles. In addition, the energy internet allows for the transfer of energy and data, but its centralized design prevents it from facilitating a truly seamless EV roaming service. Electric vehicles (EVs) that travel between jurisdictions with varied electricity regulations could benefit from a trustworthy billing platform made possible by blockchain technology's decentralized architecture. Artificial intelligence (AI) integration also guarantees that all participants receive their just share of the money. The purpose of this article is to create a billing architecture that uses artificial intelligence and blockchain to provide a charging service for "roaming" electric vehicles and to present a consistent, equitable billing system.

Keywords: Artificial Intellegence; Neural network; Electrical Engineering; Power Supply System

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I. INTRODUCTION

The rising popularity of electric Vehicles (EVs) can be attributed to improvements in (a) range, (b) the ability to assist utilities with peak demand shaving, (c) reduced environmental effect, and (d) cost per mile [1]. The typical range of a new electric automobile is over 200 miles.

The Model S, Tesla's most expensive vehicle, has a range of up to 370 miles on a single charge [2]. There has been an increase in the need for flexible power grids as the popularity of long-range EVs has grown. Therefore, a pricing structure that supports roaming is crucial.

When they are not at home, drivers of electric vehicles (EVs) who are "roaming" have the same access to charging stations that are part of both their HUN and a VUN.

For example, as part of the HUN's loyalty program at the Gold, Diamond, or Platinum level, drivers who have been faithful to the same HUN for a long time may be eligible for a lower EV charging charge or improved charging services.

This means that consumers who take their HUN with them on trips outside the service area will not be cut off from their plan's perks. A customer HUN will also be used to guarantee that an EV driver will never receive multiple bills once the necessary infrastructure for roaming has been put in place. Improvements to charging stations; (a) introducing new functional entities; (b) developing new communication interfaces; (c) interconnecting the energy and the information flow; and (d) creating contractual agreements among the participating utilities that would bind them to provide the agreed upon charging services to each other's customers while respecting consumer confidentiality all contribute to the overall cost of providing roaming services. The authors of this study offer a novel approach to mobile charging of EVs using artificial intelligence and blockchain technology.

Bitcoin is the first practical application of blockchain technology, which was designed especially for Bitcoin transactions. Blockchain technology has many more applications outside Bitcoin networks, all of which have the potential to profoundly impact the business world. From the points of view of each of the actors in Figure 1, we'll analyze how blockchain technology could improve the charge ro billing system.

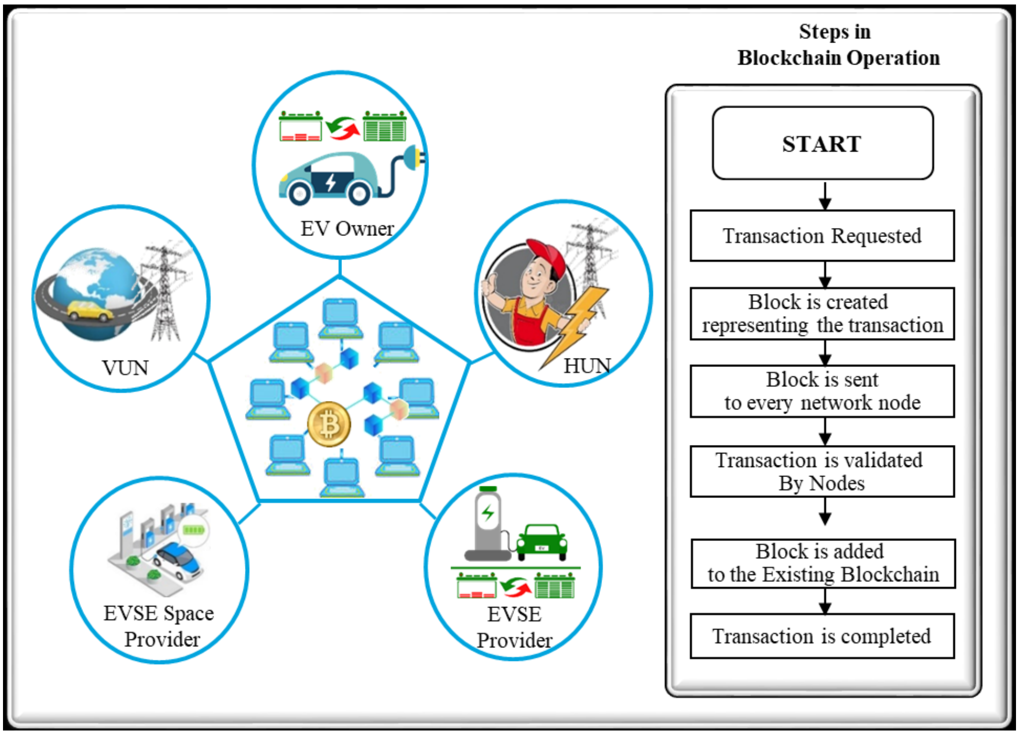

Figure 1: Key participants in the blockchain-integrated, AI-powered billing infrastructure for on-the-go electric vehicles

Electric vehicle (EV) owners can get numerous benefits from blockchain-based roaming. The necessity to carry around several subscriptions, loyalty cards, credit cards, or gift cards for various charging networks is eliminated, for instance, with blockchain-enabled roaming. Since no central authority is needed to process blockchain transactions, transaction fees are decreased [4].

When AI is used with blockchain technology, billing becomes more open, equitable, and secure.

In addition, it provides a unified billing service [5] that can be used regardless of the source of the charge request. In addition, it allows for the provision of premium services, such as priority charging, lower taris, pre-booking of charging facility, etc., to selected consumers.

Second, the utility sector stands to benefit greatly from blockchain-based roaming due to its positive effect on utilities' income, a key performance indicator (KPI) [6]. The flexibility offered by blockchain-enabled roaming allows utilities to pick and select the best roaming partners, which in turn encourages competition and boosts consumer trust and retention. In addition, it provides a decentralized network for exchanging energy and storing data. Because the entire blockchain system is encrypted, it also provides a very secure infrastructure. When combined with AI, it ensures that money is distributed equitably.

Thirdly, Charging Infrastructure Providers can get many benefits from adopting AI-integrated blockchain-based roaming. Property and charging equipment, also known as electric vehicle supply equipment (EVSE), might be considered part of the charging infrastructure.

Correctness, transparency, traceability, and immutability of transactions are made possible, which is not the case with conventional centralized charging stations. Because the network will permanently save operations histories, including information about battery health and life-cycle, and make it visible to all the players, i.e. the EV owner, the charging/swapping stations, and the utilities, an AI-integrated blockchain-based roaming system will increase EV owners' trust in both battery charging and battery swapping.

As shown in Figure 2, our proposed system design is comprehensive and novel. "Functional Entities" are one division of the architecture, while the "Blockchain Overlay Network" is another. The entities that perform functions are as follows: (i) advanced charging stations; (ii) roaming gateway/router; (iii) authentication, authorization, and accounting (AAA) node; (iv)charging rules and policy (CRP) database; and (v) consumer profile database. A communication protocol and consortium blockchain code are both part of the blockchain overlay network.

The concept of a consumer identity number (CIN) is introduced as a starting point for learning about the roaming architecture. All the functional entities in this architecture and the services connected with the CIN are distinguished by the CIN itself, which is a standardized and formatted string of numbers. For instance, the first digit of a CIN is utilized to establish a connection between a charging station and a AAA node located in a HUN. To verify the customer and identify the specific service, the AAA node deciphers the CIN's second portion.

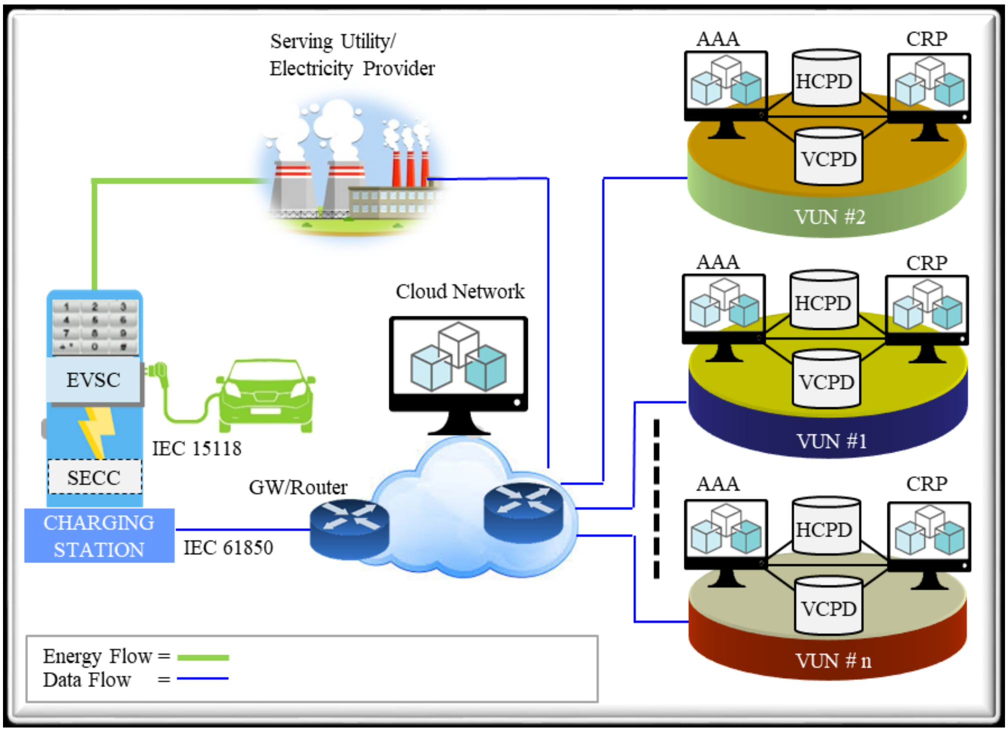

Figure 2: Electric vehicle charging infrastructure proposal

II. ARTIFICIAL INTELLENCE

The field of artificial intelligence is focused on mimicking human intelligence by simulating the actions and reactions that give us that impression. Engineers, in the final analysis, are concerned with constructing a machine that mimics human characteristics [5]. Although bold, this sentence captures the work's central theme. In a chance meeting with me in 1981, MIT professor Marvin Minsky discussed how people typically examine their own limitations and worries through artificial intelligence. He cited real-world instances, such as a colorblind man who studies computer vision or a person with a speech impairment who creates talking machines. He joked off the conversation by wondering what he could possibly say about me, a thinker. Professor Minsky's remark illuminates the hidden motivations of many in the area and reveals the truth about the character of human beings. Problems emerge when people fail to use their brains and learn from their mistakes. Defining the unknown is a challenging task. In this study, we argue that stupor is the polar opposite of intelligent behavior. You can discern the language by comparing examples of intelligent behavior with those of insensitive or lazy behavior.

Finally, you'll see those terms like "life," "spirit," and "sensitivity" are woven into the definition. These things strike to the very heart of the emotional and primitive nature of man. Man's intellectual behavior includes not just inventing and reasoning, but also the forces that drive him, determination, and the will to survive. This perspective must be included in any definition. Understanding how to program robots to mimic human cognitive abilities like reflection, evaluation, and planning is the goal of artificial intelligence research. Every computer of this type needs to be able to evaluate information critically and pick and choose among competing viewpoints. The human ingenuity and labor behind these robot'sdemand that they act like the genuine thing in terms of life, energy, and sensitivity.[2] Time will tell, maybe, whether or not this definition holds true. When we, or our successors, have built the most advanced such machine yet, one that can intelligently respond to environmental stimuli in ways that are competitive with human responses. After that [6], thinking people can specify the actions in the greatest way possible.

III. ARCHITECTURE FOR INTELLEGENCE

The focus of this presentation shifts to an examination of architectural suggestions from an IT point of view. The primary objective is to provide some sense of scale for the numerous suggestions that have been made. This study will evaluate several proposals and provide opinions on some important topics.

As shown in Figure 1, the proposed system design is comprehensive and novel. "Functional Entities" are one division of the architecture, while the computational Network" is another. The charging stations with additional features, the roaming gateway/router (R-GW/R), the authentication, authorization, and accounting (AAA) node, the charging rules and policy database, and the consumer profile database are the five functional entities. The blockchain overlay system is composed of a communication protocol and the blockchain code developed by the consortium.

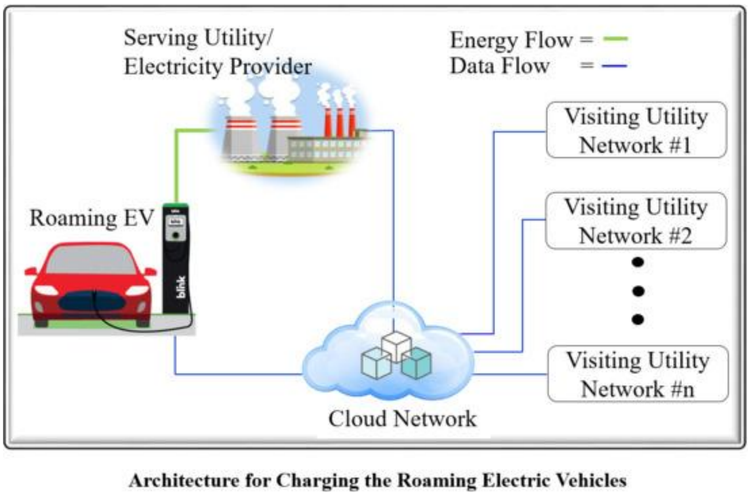

Figure 3: Architecture for Charging System

The concept of a consumer identity number (CIN) is introduced as a starting point for learning about the roaming architecture. All the functional entities in this architecture and the services connected with the CIN are distinguished by the CIN itself, which is a standardized and formatted string of numbers. For instance, a charging station and AAA node in a HUN can create a communication link by using the first portion of a CIN, which uniquely identifies the AAA node. The AAA node uses the CIN's second portion to verify the customer and identify the specific service being used.

1. **Enhanced Charging System:** The upgraded charging stations are located at various spots in the coverage region. Electric vehicles use a charging wire to connect to the charging station. ISO/IEC 15118 protocols are used for all communication between the charging station (i.e., EVSE) and the EV. ISO/IEC 61850 is used for the data transfer between the charging station (SECC) and the roaming-gateway/router (R-GW/R). The EVSE is powered by the supplying utility.

   Enhanced charging stations provide blockchain-based billing and electric vehicle recharging with basic and additional functionality. To facilitate the transfer of both energy and data, each charging station is equipped with a unique identifier and works in tandem with the Energy Internet. While electricity is transferred between the EV and the utility company via the serving charging station, data is transmitted between the serving charging station, the HUN, and the VUN via the cloud. The charging stations provide a graphical user interface for entering personal information like a customer loyalty number or utility-issued consumer identity number (CIN) that can be used to access subscription and service information. A dial pad, scanner, chip reader, radio frequency identification (RFID) reader, or near field communication (NFC) reader might all serve as the graphical user interface; other technologies like optical character recognition (OCR) and voice recognition could also be used. The HUN may include user information on the card provided to EV drivers Possible human and machine readability.

2. **Roaming-Gateway/Router (R-GW/R):** The R-GW/R is a novel entity that has been proposed as an element of the communication infrastructure. It can manage and coordinate the communication details of the charging service for both mobile and stationary EVs. The R-GW/R relays information received from the charging stations to the network, and more especially to the AAA node located in either the HUN or VUN. In a similar vein, it transmits information from the utility network (HUN or VUN) to the intended charging station. It's capable of two-way communication and can process data on both consumer subscriptions and energy usage. For each charging occurrence, these two pieces of data are combined.

3. **Authentication, Authorization, and Accounting (AAA) Node:** The proposed AAA node has three main functions: (a) authentication, which verifies the legitimacy of user credentials; (b) authorization, which checks if the user is authorized to use the service in question; and (c) accounting, which keeps tabs on how much was paid for what. This could be accomplished by any of a number of conventional channels, including debit/real-time card systems, credit card networks, pre-paid systems, and post-paid systems. Because there is no service fee associated with using bitcoin, it is the safest, quickest, and most affordable payment option for customers. Also, unlike using a payment gateway, sending money directly to the business is much easier.

   After the electric vehicle's battery has been properly authenticated and authorized, the R-GW/Router will relay a message from the AAA node to the charging station. To guarantee that the EV receives the requested services and to bill the client accurately, the AAA node and the charging station may exchange many messages while the vehicle is charging.

   The electricity provider can also get data analytics by retrieving information from the AAA node. Auditing, trend analysis, capacity planning, charging service type, charging volume/electricity usage, charging duration, etc. are all examples of uses for accounting data. Also included is data on authentication and authorization attempts, accuracy checks, unlawful service usage, and other uses.

4. **Data Repository for Charging Practices, or CRP Database:** The AAA node coordinates authentication, authorization, and accounting operations with the proposed CRP database. The CRP database resides on the networks of all the utilities that are taking part. Each CRP utility supplier has its own database for storing information about commercial clients, and yet another database for storing information about residential users. Each contract between a utility and its customer specifies the applicable charging regulations and policies.

   The CRP database may interact with its various operational support systems, including a real-time complicated rate and billing management server [1], to apply complex energy rates depending on real-time energy generation, demand, peak load, etc. in the serving area. Since each utility has its own set of charging regulations and procedures, as well as sophisticated tariff rates, customer loyalty membership, and the type of payment method picked, the CRP database makes calculated rate adjustment selections for each subscriber. The CRP database gives the ability to review and update the policies on a regular basis.

5. **Blockchain-based Messaging Protocols, Infrastructure, and Code:** In Figure 3, we show how our blockchain layer would sit atop the TCP/IP protocol stack used by Ethernet networks. In addition, we propose using ISO/IEC-15118 for application-layer communication between the charging station and the EV, and either ISO/IEC-61850 or IEC63110 for communication between the charging station and the utility provider. These methods are described in depth in references [14,15,16].

   All of these protocols are built on top of the blockchain architecture. The blockchain overlay network consists of distributed ledgers (i), consensus mechanisms (ii), enhanced encryption techniques (iii), and smart contracts (iv). We'll take a quick look at their functions below.

   Distributed ledgers are decentralized databases that record the chronological order of all transactions, such as the use of electricity, the cost of goods sold, the timing of their delivery, etc. Decentralization protects against a wide variety of cyber attacks, including distributed denial of service (DDOS), ransomware, and zero-day exploits. [8].

   Protocols include built-in consensus mechanisms to guarantee a "single version of the truth," that no unauthorized changes were made to the data, that all transactions were processed successfully, and that the utility actually owned the commodity it was selling.

   How hash functions, public/private key authentication, and digital signatures function will be covered in the next section. To automate the transfer of funds in response to a specified event set, "smart contracts" can be created within the blockchain architecture and are thus legally enforceable.

   Since artificial intelligence has not yet been incorporated into the official definitions of smart contracts, such agreements are currently static and do not account for the dynamically changing load conditions and time of usage rate of utility grids. It's possible that this issue could result in financial losses for players, utilities, customers, and charging infrastructure providers. We propose using AI [22] technology embedded in smart contracts as a solution to this issue.

   By incorporating AI, we are able to increase the adaptability of smart contracts. To account for the dynamic nature of load situations, peak load, and time-of-use rate of the applicable utilities brought on by AI integration, contracts will be dependent on (i) established, mutually agreed-upon roaming limits and (ii) these factors. In order to execute the smart contracts, our cloud-based AI Client is in continuous two-way contact with the AI Server. Pre-General Availability Terms users can now access the Google Cloud Platform AI server where we ran our proof of concept tests. CVS files containing structured data such as integers, classes, strings, timestamps, lists, and nested fields are exchanged with the AI server in order to facilitate communication. Our AI client uses the Google AI server's AutoML capability for machine learning. AutoML makes use of this data for training MLTables and predicting electric grid loads. The necessary code to accomplish this is included in Appendix B and was generously contributed by Google [23].

To boost efficiency while decreasing expenses, we propose a network hosted in the cloud. The cloud infrastructure consists of virtual devices including routers, firewalls, and management programs. Wireless, cable, and PLC are all viable options for connecting nodes in a cloud network [24]. 4G, 5G, LANs, WANs, and so on are only some of the wireless channels that can be employed. Wired channels include various types of wires like coaxial cables and optical fibers. It is acceptable for a payment network to experience a delay of up to 5 seconds, whereas a communication network can tolerate delays of up to 50 milliseconds in 4G or 5 microseconds per kilometer in optical fibers or coaxial cables.

In response to bitcoin's low adoption rate, some financial institutions are planning to implement blockchain technology for credit card transactions. Shinhan Card has announced [25] that it would begin using blockchain technology for processing credit card transactions. Visa has created a blockchain-based payment system [26] to ease business-to-business transactions.

To operate, we have adopted the "Consortium Blockchain" protocol. A consortium blockchain design requires (i) a functional specification, (ii) a flowchart, (iii) an authentication and authorization code, and (iv) an accounting schema. A brief introduction to these is provided below.

6. **Flowchart:** Figure 4 depicts a billing service that uses blockchain technology as a flowchart. The EV Driver will be prompted by the charging station's graphical user interface to swipe their CIN card. In order to send the CIN to the R-GW/Router, the charging station must read it first. In order to create a one-of-a-kind identifier, the R-GW/Router deciphers the code.

   The HUN must connect the charging station to the AAA hub. In order to authenticate a user and assign permissions for using a service, the HUN's AAA node must perform additional analysis on the CIN. By enrolling in a loyalty program with their HUN, customers can receive discounts and premium services even when they are outside the service jurisdiction of their HUN. For example, a HUN's star customer may be eligible for a discounted EV charging rate based on their long-term dedication to the HUN.

   In order to simplify billing for EV drivers, the HUN's AAA will simply add charges for used services to the customer's existing AAA account. Depending on the day, time, and location of the service, the HUN's AAA may additionally present the EV Driver with an approximate total cost estimate. As soon as the tari is accepted by the EV driver, the charging station will start recharging the battery. The R-GW/router acts as the command center, relaying all communications between the user and the VUN regarding the charging session. The relevant authorities are informed of billing details.

7. **Analysis of a Real-World Example:** As may be seen in the following scenario, which represents EV roaming in the United States, nothing prevents this technology from moving among dierent countries.

Let's pretend for a moment that an electric vehicle owner in Alabama also has an Alabama Power CIN Card. Let's say this same EV driver finds themselves in need of a charging station in North Carolina and chooses to use one operated by Duke Energy, a regional provider. The charging station reads the CIN Card and sends the data to the R-GW/Router. If the R-GW/Router determines that the CIN was really issued by Alabama Power, it will relay the information to the relevant AAA node inside the Alabama Power network.

By accessing the HCP Database, Alabama Power's AAA node verifies (i) the CIN and the service portfolio associated with that CIN are genuine. Duke Energy's AAA receives the CIN Cardholder's eligibility information from the Alabama Power AAA node and sends the "Authorization" and "Service description" to the CIN Cardholder. After obtaining user authentication and service description detail from Alabama Power's AAA node, Duke Energy's AAA temporarily saves the customer profile in its VCP Database. The following time the same customer submits a charging request, Duke Energy can skip the remote authentication/authorization processes and instead perform local authentication.

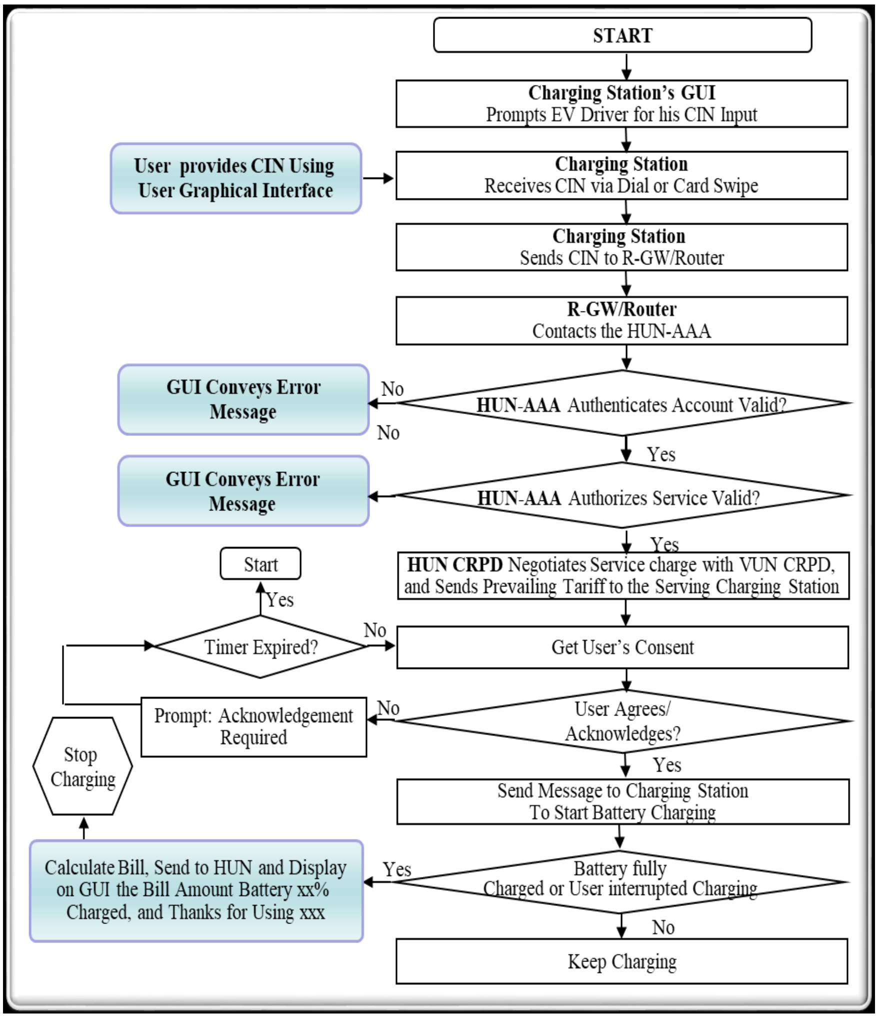

Figure 4: Flow Chart of Charging Analysis

The CRP Database is where Duke Energy stores the policies and charging rules that affect Alabama Power customers, and the AAA server may now access this information. The offering charging station can then use this information in conjunction with the present load circumstances at Duke Energy to provide the service.

After the service is finished, Duke Energy's AAA node will send an invoice to Alabama Power's AAA node. Alabama Power has paid Duke Energy the service fee as required by the service agreement. Only Alabama Power will send a consolidated bill to its customers.

8. **Evaluation of Two Methods:** Equations (1) and (2) are evaluated to compare the performance of no roaming, traditional roaming, and the proposed blockchain-based roaming in terms of income for utility companies.In order to make a fair comparison, we set m1 = 1, m2 = 2, and 2 = 1 in these equations, as done in [25].

Without roaming, the revenue of a utility business (1) serving a region or country grows in line with the purchasing power and propensity to pay of its local clients, as shown in Figure 5. The graph is flipped for the more conventional form of roaming. By allowing customers to seamlessly receive the desired service regardless of where they happen to be located, a utility company's revenue in a certain region/country (1) rises thanks to the contribution (i.e., TCR) from customers in other regions/countries (2, 3, etc.). Alternatively, an increase in region/country (1) has a smaller negative effect on the operator's revenue, and with the proposed roaming, the utility company's revenue rises even more.

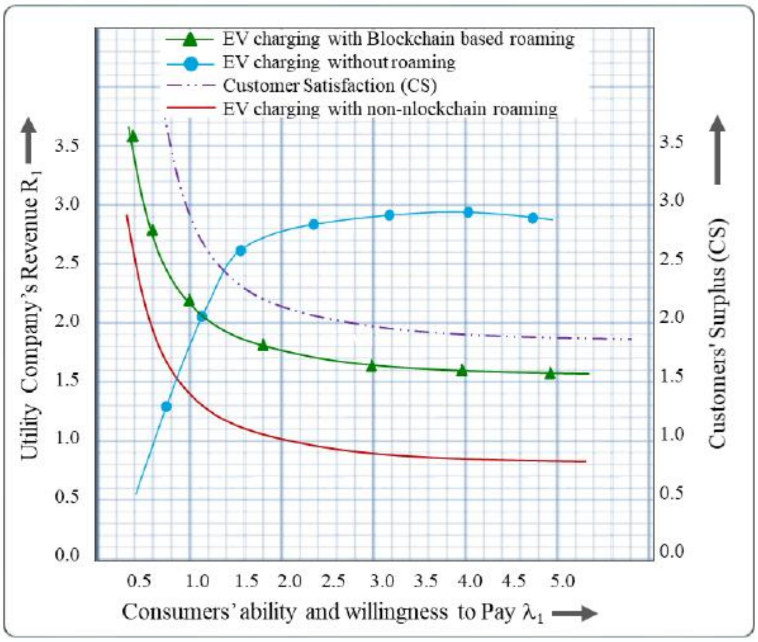

Figure 4

IV. CONCLUSION

Because of their greater range, EV drivers will be more likely to cross into networks serviced by competing utilities. Therefore, we propose an artificial intelligence (AI) and blockchain integrated billing architecture for charging the electric vehicles while they are on the move.

All parties stand to gain from the suggested structure. According to the numbers, it boosts overall customer happiness, which in turn has a good effect on earnings for utilities. The impact of AI on smart contracts is also demonstrated. It is also shown that the efficiency of decision-making performance improves when AI is integrated with smart contracts, guaranteeing that all participants receive their fair share of profits.

In the future, we hope to apply AI to develop a system for remote diagnostics of EVs.

1. **Authentication Code**

```
{
"version": "1.0.0",
"type": "oidc",
"authnConfig": {
"issuer": "<OIDC AAA issuer URI>",
"clientId": "<Client ID from AAA>",
"clientSecret": "<Client secret from AAA>",
"scope": ["<scope1><scope2>"]
},
"appConfig": {
"port": "<OIDC authentication port number used by MATLAB Web App Server>",
"displayName": "<Identity to display on MATLAB Web App Server home page>",
"tokenExpirationMin": "<Token expiration duration in minutes>"
}
}
```

2. **Authorization Code:** The authorization is performed using the following code.

Figure A2. Authorization Code.

```
client_id = 'CLIENT ID HUN';
client_secret = 'CLIENT SECRET FROM HUN';
url = 'https://accounts.HUN.com/o/oauth2/token';
redirect_uri = 'urn:ietf:wg:oauth:2.0:oob';
code = 'YOUR AUTHORIZATION CODE';
data = [...
'redirect_uri=', redirect_uri,...
'&client_id=', client_id,...
'&client_secret=', client_secret,...
'&grant_type=', 'authorization_code',...
'&code=', code];
response = webwrite(url,data);
access_token = response.access_token;
% save access token for future calls
```

```
headerFields = {'Authorization', ['Bearer ', access_token]};
    options = weboptions('HeaderFields', headerFields, 'ContentType','json');
```

3. from google.cloud import automl

```
# TODO(developer): Uncomment and set the following variables
# project_id = "YOUR_PROJECT_ID"
# display_name = "your_datasets_display_name"
client = automl.AutoMlClient()
# A resource that represents Google Cloud Platform location.
project_location = client.location_path(project_id, "us-central1")
# Specify the classification type
# Types:
# MultiLabel: Multiple labels are allowed for one example.
# MultiClass: At most one label is allowed per example.
#
https://cloud.google.com/automl/docs/reference/rpc/google.cloud.automl.v1#classificatio
ntype
metadata = automl.types.ImageClassificationDatasetMetadata(
classification_type=automl.enums.ClassificationType.MULTILABEL
)
dataset = automl.types.Dataset(
display_name=display_name,
image_classification_dataset_metadata=metadata,
)
# Create a dataset with the dataset metadata in the region.
response = client.create_dataset(project_location, dataset)
created_dataset = response.result()
# Display the dataset information
print("Dataset name: {}".format(created_dataset.name))
    print("Dataset id: {}".format(created_dataset.name.split("/")[-1]))
```

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