Lecture Notes in Electrical Engineering 808

Qi Liu · Xiaodong Liu · Bo Chen ·
Yiming Zhang · Jiansheng Peng *Editors*

Proceedings of the 11th International Conference on Computer Engineering and Networks

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Preface

This conference proceeding is a collection of the papers accepted by the CENet 2021—the 11th International Conference on Computer Engineering and Networks held on October 21–25, 2021, in Hechi, China.

This proceeding contains the five parts: Part I Internet of Things and Smart Systems (5 papers); Part II Artificial Intelligence and Applications (41 papers); Part III Medical Engineering and Information Systems (23 papers); Part IV Security and Communication Networks (26 papers); and Part V Communication system detection, analysis, and application (87 papers).

Each part can be used as an excellent reference by industry practitioners, university faculties, research fellows, graduate students, and undergraduates who need to build a knowledge base of the most current advances and state of practice in the topics covered by this conference proceedings. This will enable them to produce, maintain, and manage systems with high levels of trustworthiness and complexity.

Thanks to the authors for their prestigious work and dedication as well as the reviewers for ensuring the selection of the high-quality papers; their efforts made the proceedings possible.

Contents

IOTS Internet of Things and Smart Systems

A Double Incentive Trading Mechanism for IoT and Blockchain Based Electricity Trading in Local Energy Market

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Abstract. In local energy market, double auction is the most frequently used trading mechanism in blockchain based electricity power trading. In the general form of double auction, the transaction orders and prices only depend on the sellers bid and buyers offer prices, regardless of the energy production efficiency of producers and electricity consumption efficiency of consumers. As a consequence, the competitiveness of renewable energy is undermined and the amount of wasted electricity is increased. With the rapid development of IoT technologies and smart grid, it becomes much easier to obtain information and status of producers and consumers. Therefore, we consider combining IoT technologies with blockchain and proposing a double incentive trading mechanism which considers the external costs of producers and the efficiency of consumers in blockchain based electricity power trading. More specifically, we put forward a metric called priority value (PV) which quantifies the external costs or the efficiency of the consumers to optimize the electricity transactions. The case study shows that our method provides more trading preference for producers and consumers which produce/consume electricity more efficiently and environmentally friendly compared with the traditional trading method. The results also indicate that our method will incent the consumption of renewable energy and stimulate electricity producers to improve the utilization efficiency of fossil fuels, which helps to reduce carbon emissions, and coal consumption, and will also encourage users to improve electricity consumption behavior and save electricity.

Keywords: Blockchain · Decentralization · Local energy market · Double auction · IoT technologies · Smart meter

1 Introduction

Local energy market is comprised of numerous electricity producers and residential consumers in a local community to trade electricity. The general centralized electricity trade mechanism depending on a third party is inappropriate for local electricity market due to risk of information disclosure and additional transaction cost. However, blockchain can assure producers and consumers trade automatically, fairly, securely and cost effectively in local electricity market.

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Recently, blockchain has received widespread attention in local energy market, and literatures focus on researches in this area. Esther proposed a blockchain-based decentralized local energy market transaction model and mechanism [1]. A blockchain-based carbon emission trading mechanism is proposed in [2]. Claudia validates the feasibility of blockchain based distributed demand side management [3]. In [4–6] demand side management modes base on blockchain in microgrids have been proposed.

Existing literatures have also introduced the pilot application projects of blockchain in local energy market. The most representative two applications are Brooklyn Microgrid [7] in the United States and Quartierstrom [8] in Switzerland, both of them established blockchain based trading platform successfully.

At present, blockchain-based local energy transactions mainly use double auction [4], which only relies on the price order of producers bid prices and consumers offer prices to make a deal. This method does not take into account consumer's energy consumption efficiency, external cost of electricity generation, and electricity production efficiency. In fact, the efficiency of electricity consumption varies among different consumers. Consumers who are aware of saving energy tend to use electricity in a more efficient way than others, and they should be awarded during transaction procedures. In addition, there are many forms of producers in local energy market, such as thermal power plants, photovoltaic power stations, wind power stations etc., which have different electricity generation efficiency and external costs. For example, thermal power plants emit greenhouse gases, harmful gases, dust and other pollutants when burning fossil fuels to generate electricity, which not only pollutes the environment but also brings harm to people's health. Consequently, all human beings have to spend more efforts to control pollution and treat disease, while such external costs are not included in power production cost.

Nowadays, with the widespread deployment of IoT devices and the rapid development of smart grid, it becomes much easier than before to obtain data of producers and consumers mentioned above. So, why not adopting IoT technologies to blockchain-based local energy transactions, which seemingly will solve the above problems? In this situation, we consider combining IoT technologies with blockchain and proposing a transaction method that considers the priority values of both producers and consumers in blockchain-based decentralized power transactions. By considering consumption efficiency, producers' external costs and production efficiency, our method allows renewable energy generators and high efficiency producers get higher priority to sell electricity, and consumers with high consumption efficiency to buy electricity with higher priority, which directly promote the consumption of clean energy and incent consumers to take measures to save energy.

2 Blockchain-Based Local Energy Market

As shown in Fig. 1, local energy market is composed of electricity generators and consumers in a community [1]. Among them, generators use various forms of energy to generate and sell electricity, such as thermal power plants, hydropower plants, photovoltaic power stations, and residents who use photovoltaic roof or wind turbines to generate electricity. Consumers purchase and consume electricity for producing and living, such as residential users, factories, shopping malls, etc. Producers and consumers trade electricity in local energy market as they need.

In a blockchain-based local energy market, all producers/consumers need to deploy a computing device that runs a blockchain virtual environment as a blockchain node. Each node has a complete backup of the blockchain, so they have equal status in the network, forming a P2P (Peer to Peer) network. Transactions are conducted automatically through smart contracts running on the blockchain. All nodes broadcast the results obtained by smart contract to other nodes. The nodes verify and finally reach an agreement about the data through a consensus mechanism, then encapsulate the transaction data into a new block and store it into blockchain. The characteristics of blockchain, i.e., decentralization, temper proof, and traceability, assure transactions to be secure and transparent.

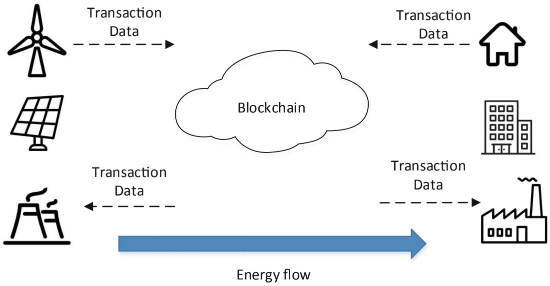

Fig. 1. An illustration of blockchain-based local energy market.

3 Methodology

3.1 System Architecture

We consider the local energy market is consisted of n generators and m consumers forming a P2P network based on blockchain, and transactions are automatically executed by smart contracts running on blockchain. The network architecture is shown in Fig. 2.

As shown in Fig. 3, each generator and consumer include a computing device, a smart meter, and a set of IoT terminals besides its own power generation or consumption equipment. The computing device is embedded with blockchain virtual machine to become a blockchain node, and smart contracts run on the blockchain virtual machine. The whole transaction process is automatically executed through smart contracts. An interface which send and receive data of smart meters and IoT terminals to blockchain also runs in the computing device. Quotation information is provided by the generators and consumers themselves. Based on the history data of electricity production or consumption information, the smart meter predicts the amount of electricity to be generated or consumed in the next trading period, and sends the data to blockchain through the interface. The IoT terminal collects the amount of generation electricity W kw·h per unit time and the fuel C kg to be consumed per unit time to produce W kw·h electricity, and the information is sent to blockchain through the interface.

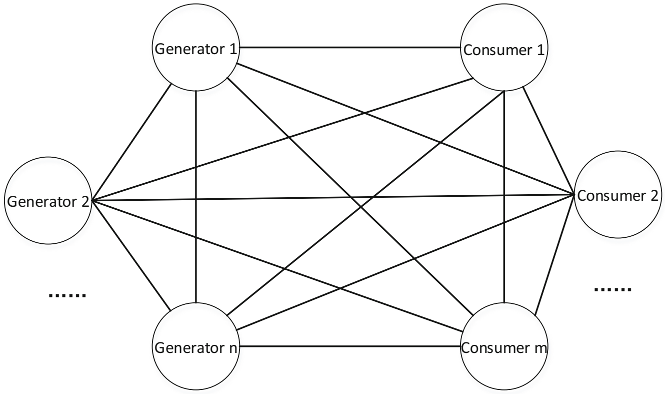

Fig. 2. An illustration of local energy market P2P network based on blockchain.

For a consumer, when a transaction finished, the amount of purchased electricity will be written into the consumer's smart meter, and the remaining amount electricity recorded in the smart meter will add the purchased electricity. When a consumer consumes 1 kw·h electricity, smart meter minus 1 from the remaining amount of electricity. The IoT terminals send operation data of electrical devices to blockchain, such as operating time t, consumption efficiency η, and power of electrical devices P.

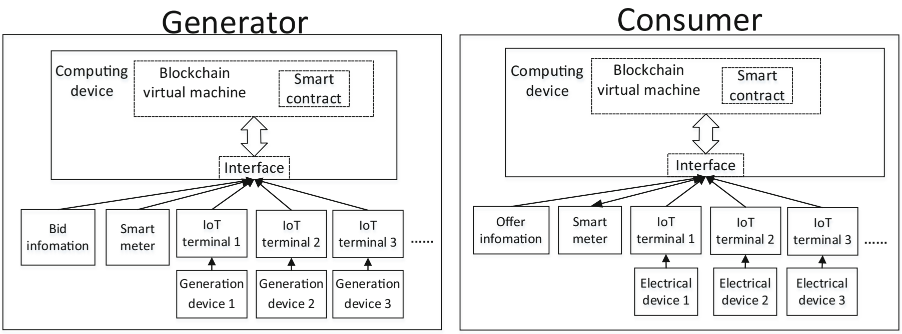

Fig. 3. The structure of a generator and a consumer

3.2 Transaction Mechanism

Transaction Priority Value. In this paper we propose a new transaction mechanism based on blockchain, taking three factors into account, that is, the electricity consumption efficiency of consumers, the external cost of generators, and the power generation efficiency of generators. We obtain a priority value (PV) of the transaction by combining these three factors with bid and offer prices.

For a generator, its PV equals

$$PV_g = p_g + C_e \times \eta_g \tag{1}$$

$$\eta_g = \frac{\sum_i C_i / \sum_i W_i}{\eta_s} \tag{2}$$

Where p_g is the bid price of the generator, C_e is the external cost. For renewable energy C_e equals 0, and for fossil fuel energy, it is provided by statistical academies or associations. η_g is the production efficiency of the generator, W_i is the amount of electricity generated by the i-th power generation equipment per unit time, C_i is the fuel consumed by the i-th power generation equipment to generate W_i per unit time, and η_s is the average fuel consumption for this kind of power plant.

For a consumer, its PV equals

$$PV_c = p_c \times \frac{\eta_c}{\eta_{c\max}} \tag{3}$$

$$\eta_c = \frac{\sum_i \eta_i P_i t_i}{\sum_i P_i t_i} \tag{4}$$

Among them, p_c is the consumer's offer price, and η_c is the average electricity consumption efficiency of the consumer. $\eta_{c\max}$ is the highest efficiency value among m consumers. η_i, P_i, and t_i are the electricity efficiency, power, and operation time of the i-th electrical equipment of the consumer.

Transaction Procedure. Transactions start regularly every fixed time period. Smart meters of generators/consumers predict electricity production/consumption data in the next period and send them to blockchain. Generators and consumers send bid prices and offer prices to blockchain through an interface. The IoT terminals collect the data of generation equipment and electrical devices, i.e., W kw·h electricity to be produced per unit time, C kg fuels to be consumed per unit time to generate W kw·h electricity, electrical devices operating time t, consumption efficiency η, and the power of consumption devices P.

During the transaction process, smart contract automatically calculates the PV, sorts the generators by PV ascendingly and consumers descendingly, and match them in pairs to make transactions according to the sequence order. The deal price is the average of the bid price and offer price of the matched pairs.

The transaction process consists of four phases: Data collection, PV calculation, auction and settlement. Transaction process is shown in Fig. 4.

Data Collection. First, all nodes broadcast the message that transactions will begin and wait for a period of time. During this period, blockchain collects data from generators and consumers, i.e., the amount of electricity to be produced by generators, bid price p_g, average electricity production W, average fuel consumption C, consumer electricity demand, offer price p_c, operation time t, electrical efficiency η, devices power P.

PV Calculation. Smart contract calculates PV of generators and consumers respectively according to Eqs. (1)–(4).

Auction. Based on smart contract, Generators are sorted by PV ascendingly, and consumers are sorted descendingly, and they are matched in order to make a transaction. The transaction price is the average of the quotations of the matching parties.

Settlement. Consumers pay money to generators automatically, the consumer's smart meters record the amount of purchased electricity, and generators produce electricity according to transaction data. Then transaction results are recorded in blockchain via consensus mechanism. Finally, the transaction in this period ends and next transaction will begin.

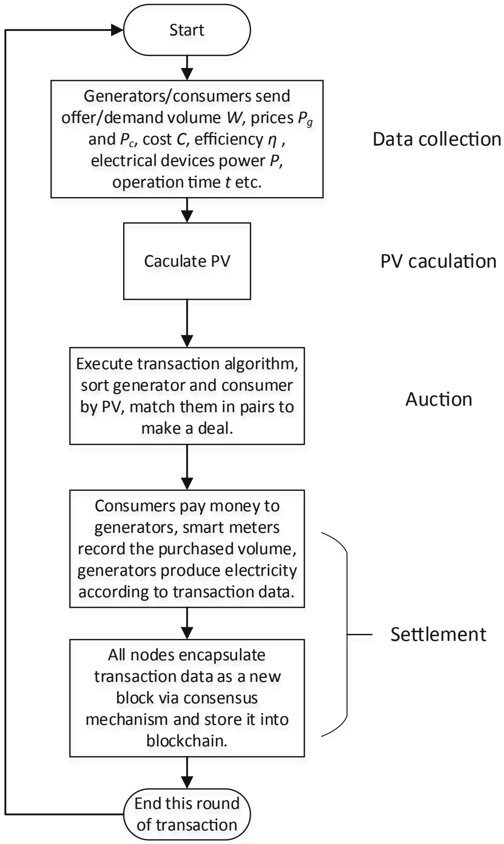

Fig. 4. Transaction process flow chart

The algorithm implementation process of the auction phase is shown in Fig. 5.

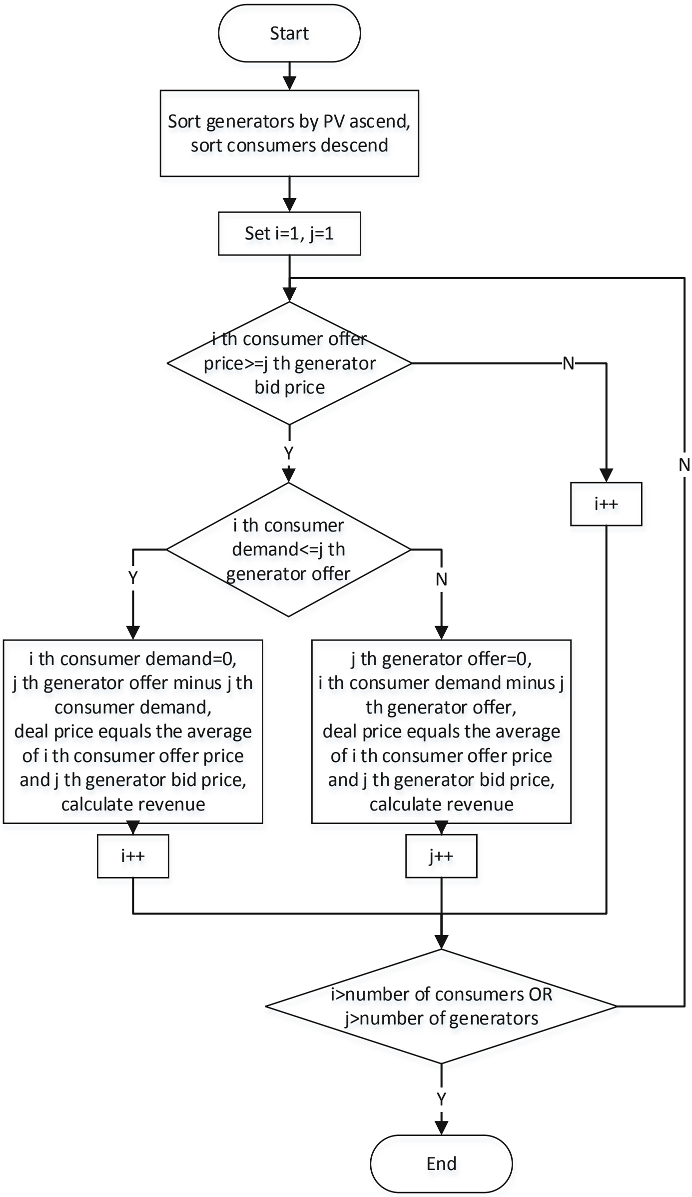

Fig. 5. Process for transaction algorithm