Application of Blockchain Technology in Smart City Infrastructure

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***Abstract*—With the rapid growth of urbanization, smart city needs efficient and sustainable intelligent solutions in the transportation, environment, energy, government affairs. The smart city infrastructure, which combines the IoT, Big Data and Energy Internet, is one of the most effective solutions. It's facing many problems such as poor security of IoT, equipment maintenance and upgrade difficulty, high operating costs of large data center construction, poor resistance to damage, the difficulty of establishing the energy Internet users trust , user privacy is easy to leak, market model is not applicable and so on. The Blockchain is a kind of distributed P2P network common intelligence accounting technology based on cryptography. The features of open, transparent, interconnection and peer-to-peer, storage and sharing in the Blockchain are relevant to the openness, interconnection, peer-to-peer and Shared characteristics of the energy Internet. Its features of redundant storage and distribution also make up for the disadvantages of large data center's high operation cost, poor recovery ability and the difficulties for the maintenance of IoT equipment.**

This paper, first introduces the role of the big data, IoT, and the energy Internet in the construction of smart city and Blockchain technology. By analyzing their respective characteristics and comparing their similarities, corresponding solutions are put forward to aim at the problems such as poor security of IoT, upgrading of equipment maintenance and upgrading, construction and operation cost of large data center, poor flexibility in anti-attack, difficulty in establishing trust in energy Internet users, user privacy leakage and inapplicability of trading market mode. A kind of architecture of P2P light-heavy backup is put forward to overcome the high cost of Blockchain data storage.

***Index Terms*—Smart City, Blockchain , Energy Internet, Big Data , Internet of Things**

I. INTRODUCTION

WITH the increasing urbanization rate in China, the urban population, the traffic pressure and the energy consumption demand are all increasing, new requirements for medical ,education, health and other aspects have been put forward, which poses a greater challenge to the construction of smart City. How to integrate new technologies and concepts such as Internet of things, big data and energy interconnection, so that to let emerging technologies help smart city construction become the main direction of development.

Large data technology ic the foundation to support the construction of smart City, and it is an important guarantee for the correct formulation and implementation of the planning scheme and management strategy. Smart city is an organic integration of smart government, smart transportation, smart energy, smart healthcare and other services under the premise of clear data and decentralization, which puts forward high requirements for big data service platform. It is a great cost to develop or maintain the big data platform which has high reliability and performance, multiple purpose, anti-attack and disaster recovery capability. Moreover, all the questions of the centralization database such as low openness and poor flexibility can all be solved by blockchain technologies.

The energy Internet is proposed to realize the widespread interconnection of distributed renewable energy, improve the efficiency and flexibility of the energy system. But the energy system still has some technology defects when solving the difficulties of establishing the users' credit and the maintenance of the centralization data, and the problem of divulging the users' privacy .The energy Internet has not fundamentally changed the market mechanism and business model inherent in the energy sector, especially in the power industry.

Internet of things technology is not only a direct source of a large number of data, but also an essential terminal tentacle in the Energy Internet. With the popularization and deepening of the Internet of things technology in all walks of life, the human society is entering a new era of "all things interconnected". Hundreds of billions of new equipment such as smart phones, wearable devices, smart homes, smart public facilities and so on will be connected to the network, which not only brings opportunities to the development of IoT, but also has a lot of

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problems such as the difficulties to identify the identity, the leak of data privacy, the great cost of the development and the maintenance of the database, the difficulties to maintain and upgrade the equipment.

Blockchain technology is the underlying technology of bitcoin. It is a kind of co - trust smart book technology based on the principle of cryptography. At the beginning, Blockchain was used in bitcoin, and for the first time it was concerned by the financial sector, then the script was extended to smart contracts technology, which let the Blockchian be applied to more areas, the application of block chain technology has also gained wide attention in addition to the financial field. The characteristics of distribution, transparency, fairness and sharing of block chains may have an important impact on technological innovation and industrial transformation in the future, and have potential to become one of the important technical solutions to the new ecological challenges of the future energy Internet.

This paper starts with the integration of the Blockchain and the smart city construction composed of Internet of things, large data, and the energy Internet. First, it introduces the important role of the Internet of things, big data and energy Internet in the smart city and the basic concepts, the key technologies and the domestic status of the Blockchain, then it summarizes some technical bottlenecks of the IoT, big data and energy Internet, and compares the similarities and differences of block chain with them. Through the analysis of the characteristics and advantages of the Blockchain, demonstrates that the technical characteristics of the Blockchain is suitable for the energy Internet naturally, and also can solve the problem of networking and big data center such as the high cost for centralized database maintenance, the leak of user privacy, the difficulties of upgrading the terminal equipment and so on. A preliminary solution is provided to provide some help for the potential application of block chains to the future of smart cities.

II. THE INFRASTRUCTURE TECHNOLOGY OF SMART CITY

The infrastructure of smart city is based on the integration of Internet of things and cloud computing technology on the basis of digital city. Under the premise of energy Internet guarantee energy supply, we use big data to analyze and decide urban construction. The following focuses on the big data, the energy Internet and the IoT technology in the infrastructure.

Big data is the technical foundation of a smart city. Through the analysis of urban data, it is possible to make a scientific plan for the city and develop a development strategy. The supporting role of energy Internet in smart cities is mainly to promote the green development of cities and to ensure the safe and reliable electricity utilization of cities. IoT technology brings a lot of convenience to urban life and management, while the Internet of things sensors are the main sources of data acquisition, and the smart grid also uses Internet of things technology in large quantities.

A. Role of Big Data

A city is a wide variety of data types, according to the structure of the division are: a structured, semi-structured, and unstructured, according to the specific content is divided into: the map with the point of interest data, GPS data, traffic data, traffic data, mobile phones, LBS location data, video monitoring, environmental and meteorological data, such as social activity data is relatively commonly used.

Big data is in urban intelligent traffic system, political wisdom, wisdom, health, intelligence community, the wisdom tourism is widely used in such aspects, the city's infrastructure, dynamic data accumulated the massive cities and how to use so much of the data, make the data make the city more wisdom, big data analysis play an important role in it.

B. Role of Energy Internet

Due to the development of urbanization, energy consumption increases.

The purpose of the development of the energy Internet is to build a smart energy system that is energy-efficient, low-carbon, economical, environmentally friendly and sustainable.

Can realize the interconnection of distributed renewable energy, improve energy utilization ratio, which greatly reduce the pressure of the non-renewable energy, on the premise of meet the demand of urban environmental sustainable goal.

Firstly, energy Internet construction can effectively support energy consumption and supply dilemma through efficient use of distributed energy and energy scheduling through information sharing.

Let the coordinated development of traditional energy and renewable energy achieve energy point-to-point trade freely, solve the problem of distributed renewable energy given, so as to promote the development of renewable energy, increase in the proportion of the energy structure.

Second, building energy on the Internet, for energy transmission, distribution, conversion and utilization to provide technical support, for different types of distributed energy unit load, energy storage, electric vehicles and related equipment to provide interconnection interface, the participation of market main body to create a based on the energy development and consumption of open, flexible information interactive platform for the innovation, traditional top-down to shift the energy industry structure, forming flattened new pattern of industry.

C. Role of Internet of Things

Internet of Things (IoT), interconnecting objects and objects and using information sensing devices to interact with them, greatly saves man's time, increases the utilization of resources, and improves the accuracy and coverage of information collection.

IoT is a key enabler of smart cities, and IoT sensing devices in cities are an important component of connecting communication and networking devices. Sensing devices are used to detect and monitor real-time operation of various scenes in the city.

It is predicted that in the near future, industries, individuals, offices, home appliances, machines, and articles will be able to feel, communicate and process information anytime, anywhere. However, it will face the great challenge of how to design a smart city framework that combines different technologies and

fully optimizes them. In addition, smart city solutions must conserve energy both from the user and the environment.

III. BLOCKCHAIN TECHNOLOGY

Blockchain is a chain based on the principles of cryptography, all things can record any valuable things, including accounting books, voting, copyright, property and any other things that can be expressed in code. In the era of all things connected, everything needs its own account, and the blockchain fits this need well. The traditional Internet can only transmit information, while blockchain is constructed to convey value to the network, is considered as the next generation of global credit certification and value of the Internet, one of the basic agreement. It reduces the cost of credit and allows two untrustworthy people to trust without third-party credit endorsement. With high transparency, high security, high efficiency, openness, traceability.

Melanie Swan of the United States divides the blockchain into: blockchain 1.0, blockchain 2.0, blockchain 3.0, while blockchain 1.0 refers to cryptographic currency, such as the most famous bitcoin. Blockchain 2.0, on the other hand, is a contract that can cover economic, marketing and financial applications and can be extended to more areas such as equities, debt, insurance, title, smart assets and contracts only. Blockchain 3.0, on the other hand, transcends the fields of money, finance and markets, especially in the areas of government, health, science, culture and the arts, and builds a decentralized and cooperative society.

Blockchain is an integrated technology, which includes Hash, asymmetric encryption, workload proof, Merkel tree, timestamp, P2P and other technologies are not new technologies, but with new ideas to combine them cleverly . Unique system architecture and operating mechanism, the blockchain not only can record all the transaction information, and the recorded information cannot be tampered with by anyone. Trust the system by believing in the system. Here are some of the key technologies covered by the blockchain.

A. Hash

Hashing functions, which convert any length of input into a fixed-length input through a hash algorithm, is the hash value. Hash algorithm to achieve cryptographic security must have three characteristics: collision-resistance, hiding, puzzle-friendliness. Hash algorithm is used in the timestamp, Merkel tree, Asymmetric encryption and so on.

B. Asymmetric encryption

Asymmetric encryption requires two keys to encrypt and decrypt. The pair of keys are public key and private key. The data encrypted with the public key can only be decrypted with the corresponding private key, and vice versa. It ensures that the blockchain satisfies security requirements and ownership verification. Common algorithms include RSA, Elgamal, Rabin, Elgamal, ECC (Elliptic Curve Cryptography) and so on.

C. Timestamp server

The timestamp server can prove that certain data exists at a specific time. The timestamp will be included in its random hash along with other pieces of information in the block, which will become part of the next block and so on to form a chain.

D. The consensus mechanism

The consensus mechanism is a set of mechanisms designed by distributed ledgers to keep the books of different nodes consistent within a certain period of time. Common mechanisms are PoW, PoS, DPoS and kinds of Byzantine fault tolerance algorithms, which are mainly used by business and The performance needs of the decision. PoW mechanism can attract many users to participate, and the more people involved, the greater the power, the more secure the system, but it is too power-hungry and likely to cause the concentration of power. PoS (Proof of Stake) is based on the amount of money held by users and time (currency age), a system of interest payments. This mechanism is relatively energy-efficient and more centralized, but the blockchain product credit foundation of pure PoS mechanism is not solid enough. DPoS (Delegated Proof of Stake) is to vote for each person holding a bit of shares, resulting in 101 representatives, we can understand it as 101 super nodes or pools, and the 101 super nodes of each other's rights It is exactly the same.

Consensus mechanisms allow all nodes in the entire system to exchange data credible in an environment without any third-party trust endorsement, so that trust in "people" and institutions becomes a trust in machine and mathematical algorithms, and anyone Can not interfere with the correct operation of the system. Reflects the autonomy of blockchain.

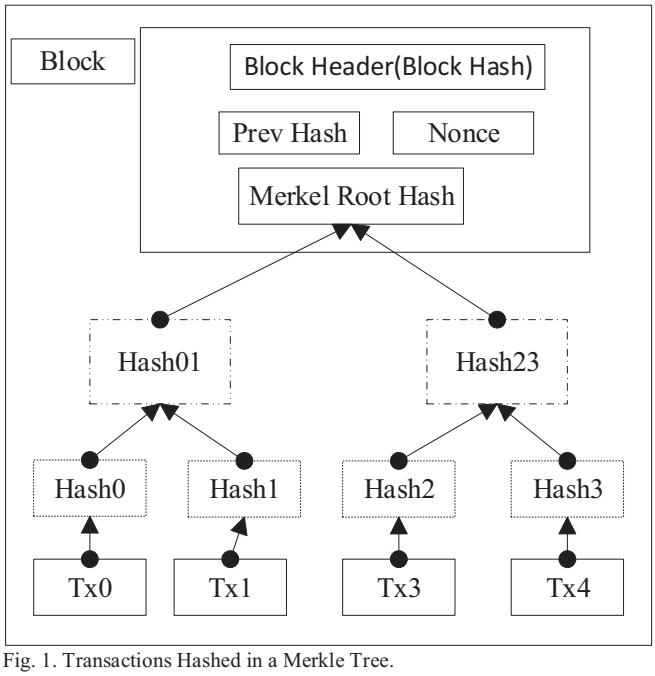

Fig. 1. Transactions Hashed in a Merkle Tree.

E. Chain structure and Merkle tree

The chained structure of the block and the Merkle tree make it hard to tamper because the transactions in the block interlock with each other within the block through the Merkle tree, and the block-to-block hash value is stored by storing the hash value

of the previous block as shown in Figure 1.The chain structure of a chain deduction, making the blockchain transaction tampering can be easily found.

F. Scripting and Smart Contract

The scripting mechanism is similar to an extension interface provided by the blockchain, and anyone can develop a blockchain-based application based on this interface, making blockchain technology an underlying technology. Each output of each transaction, strictly speaking, does not point to a person's address but to a script. Programmable blockchains, such as Ethereum, that evolve based on the principle of scripting, not just simple OP instructions, but scripting languages.

G.P2P Network

The blockchain is built on top of the P2P network, and its propagation is through flood algorithms. The node always treats the longest chain as correct. If divergence occurs, another chain is reserved, waiting for the next block to be found. Does not require all nodes to confirm to confirm, as long as the transaction information is enough nodes to record. The missing node can be downloaded later.

TABLE I
CONCEPT CONTRAST OF BLOCKCHAIN AND ENERGY INTERNET

Feature	The connotation of energy Internet	The connotation of Blockchain
Open	The network structure is open to all kinds of subjects and provides a platform for exchanging physical information.	Provides a wide range of network interfaces, the main body to join and synthesis of distributed databases
Peer	Each subject in the network can manage its own energy production consumption and transaction independently, and participate in the system decision.	With the characteristics of decentralization and collective maintenance, the operation of the system does not exist in the control center, but it is the decentralized decision-making of each node.Rights and obligations are equal.
Sharing	Each system module can achieve the full interconnection of energy and information with high security and economy.	Blockchain is a flattened distributed network with real-time interconnection of nodes and redundant data storage and sharing.
Interconnection	Sharing information on system operations and market transactions between nodes can further enhance the ability to optimize the allocation of resources.	The essence of blockchain is a distributed database. All nodes in P2P network share the information of all the blocks at the same time to ensure the security and transparency of system operation.

Blockchain is hard to attack, and 51% is a high cost attacker. As long as it has powerful calculation support or a reasonable proof of workload, the blockchain can be regarded as very safe. What the attacker can only try is changing one's own deal and trying to get the money back from the recent spend. The point of their own benefit is only to complete the transaction on their own double flower problems, fraudulent transactions recipient's interests. Due to the huge gap between inputs and outputs, the data in the blockchain is theoretically not tampered with.

IV. RELATED WORK

Based on the big data, energy Internet, the main role of Internet of Things technology and the characteristics of blockchain technology in the smart city construction introduced in the previous two chapters, this chapter mainly discusses how to combine the blockchain to solve the energy Internet in smart city, Internet of Things Some problems facing big data.

A. Blockchain to solve some problems of energy Internet

Some problems in the energy Internet:

1) The user's credit to establish.

How to prove yourself as a "Legitimate" user when users access large Energy Internet. Before the password mechanism there is a big security issue.

2) The credibility of the data

As the relevant data will be collected and stored in the central database, once the data in the central database is damaged and tampered with, the data in the entire system will be unreliable.

3) User data privacy protection

Once the system user data is stolen by lawless elements and the data is sold to a third party, the third party can analyze the user data and even control the user's equipment to steal the electricity, which seriously endangers the rights and interests of users.

4) Trading model changes

Once the system user data is stolen by lawless elements and the data is sold to a third party, the third party can analyze the user data and even control the user's equipment to steal the electricity, which seriously endangers the rights and interests of users.

The characteristics of the distribution, transparency, fairness and sharing of the blockchain are in good agreement with the features of the openness, equivalence, sharing and interconnection of the energy Internet *(see Table I)*

Therefore blockchain can solve some problems in energy internet:

1) For the user's credit to establish.

Users can dynamically create their own device interaction rules that allow a large number of devices on the energy Internet to authenticate who is their legitimate user. When a device's alert mechanism detects a hacker's entry, its rules are triggered and a 51% consensus blockchain mechanism ensures that only legitimate users can control devices on the energy Internet, thereby creating a real credit to the user.

2) For the credibility of the data

It can use the blockchain distributed technology and information cannot be tampered with characteristics of the data open and transparent, distributed in different nodes, once the information is recognized by a sufficient number of nodes, it will form an irreversible record storage. It ensures that even if one or more nodes are compromised, the overall network data is still reliable and secure.

3) For user data privacy protection

Users of data on a central database there are many problems, the maintenance center database security costs are high, and the effect is not satisfactory, even if Google such technology has also appeared in the user massive mailbox password leak events. And for users, the data is only the most reliable

in their own hands, and the blockchain will be able to solve these shortcomings. Public chains provide only anonymity, transactional information is still public, but the energy Internet can consider deploying regional federation chains and using double-stranded technology to separate user chains from transactional data chains, which contain user's own personal data and only Limit my key to view, and the implementation of the transaction chain hidden technology funds, a combination of multiple methods, you can well protect the user's data privacy.

4) For trading model changes

Blockchain distributed computing uses point-to-point computing to process transactions generated in the system, turning traditional centralized transactions into point-to-point distributed transactions that localize energy supply and demand. It can make full use of the computing power, storage capacity and transmission capacity of a large number of idle devices distributed in unused locations, greatly reducing the calculation and storage cost and long-distance transmission loss, and changing the previous transaction modes.

Under the influence of the blockchain, the energy industry has shifted from a centralized centralized power grid to a decentralized distributed power grid. In the actual operation of the system, you can localize electricity supply and demand as shown in Figure 2. The smart meter can record the electricity that the user uses and emits within a certain period of time, and records the transaction on the blockchain, as shown in Figure 3. When the transaction time arrives, according to the rules previously defined on the smart contract, the consumer will

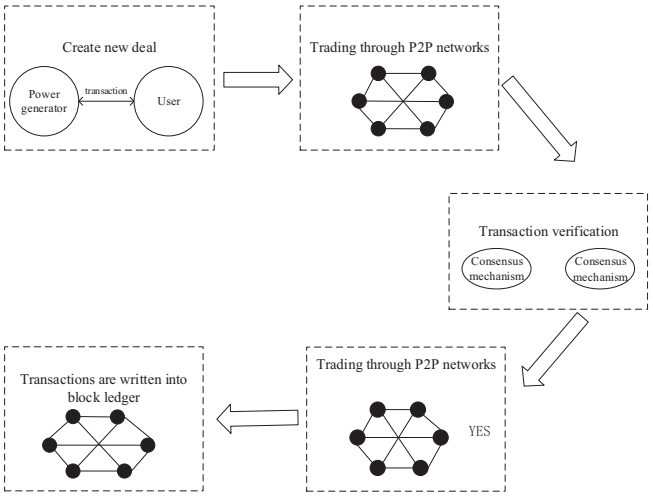

Fig. 3. Magnetization as a function of applied field.

transfer the corresponding digital currency to the generator if the generator sent the corresponding power within the specified time. This better matches supply and demand, while also saving on expensive power delivery costs.

However, this new type of energy development is faced with the small size and scattered distribution of distributed generation elements, resulting in the difficulty of actually participating in the economic dispatch of the power system and even the competition in the energy market. Need to establish and improve a transparent and notarized, efficient and

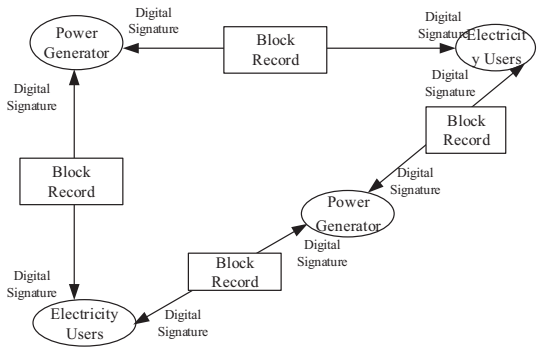

Fig. 2. Local supply and demand map. Such as the residents of Henan Yucheng use of solar power

standardized trading mechanism, such as a pilot small-scale pilot electricity retail market.

B. Blockchain to solve some problems of Internet of Things

1) IoT node legal identity certification.

The risk of counterfeiting is high due to the limited computing and storage capacity of the sensor device, which makes it difficult for the sensing device to use the more complex security measures. The blockchain verification and consensus mechanisms help to identify legitimate IoT nodes and avoid the access of malicious or malicious node active devices.

2) IoT data privacy and security issues

Because the data of human life and work will be collected and stored in the central database. Once the data in the central database is attacked and stolen, or some back doors opened up to the government and the manufacturers can allow these institutions to collect information without authorization from the users Analyze user data and even control user equipment. Once the manufacturer due to profit-driven, without user authorization to sell user data to third parties, which potentially jeopardize the rights and interests of consumers. The blockchain is a distributed, non-centralized structure, with each node being equal and all data encrypted and effectively mitigating these potential risks.

3) Centralized databases are expensive and have limited computing and storage capabilities.

If something goes wrong, finding the problem node in hundreds of millions of nodes is a time-consuming task. Most of the existing IoT are centralized networking. Hundreds of millions of nodes are connected to a large server or a centralized cloud, which brings bottlenecks to the cost and computing storage capacity. Blockchain distributed technology, which can ensure that one or more nodes in a timely manner to be compromised, the overall network data is still reliable and secure. And distributed computing uses point-to-point computing to deal with hundreds of billions of transactions that occur in the Internet of Things to take full advantage of the computing power and storage capacity of a large number of idle devices deployed

in unused locations, thereby greatly reducing the computing and storage costs.

4) IoT equipment maintenance and upgrading issues

B With the popularity of the Internet of Things, the daily maintenance of hundreds of millions of devices has become a headache for IoT device manufacturers and service providers. The introduction of a blockchain allows manufacturers and service providers to move their day-to-day maintenance of equipment to a self-service center made up of blockchains, reducing equipment maintenance costs and improving maintenance services.

For example, the traffic information of car networking is currently required to transit through the data center, thus reducing the timeliness and accuracy of information. The blockchain system is built point to point, end to end, each car will have its own unique identifier, the vehicle will join the system will report their position in real time, through the vehicle networking equipment to capture nearby vehicle data, through the terminal comes with miniature Analysis system, you can plan the current best route. And the vehicle information is anonymous, thus avoiding the disclosure of personal privacy.

C. Blockchain to solve some problems of Big Data

In the smart city, the Internet of Things (IoT), which consists of mass sensors, continuously collects data that needs to be stored, preprocessed, queried and analyzed before being applied to various places to provide intelligence services to digital cities and to analyze the real-time performance of data analysis The demands are getting higher and higher, which brings with it a number of issues and challenges.

1) Privacy and information security in big data.

Because of the privacy of many users involved in big data, new protection measures need to be introduced to improve the protection level of secure transmission and secure storage. Blockchain proved to be safe and reliable, while publicchains provide only anonymity and transactional information is still open, but energy internet can consider the deployment of regional affiliatechain, federation chain with admittance mechanism and can use Double-stranded technology, the user chain and transaction data chain separate user chain stored in the user's own personal information, only my key to view, and the implementation of the transaction chain hidden funds technology, a combination of multiple methods, can be well protected User's data privacy.

2) Data center anti-attack pressure, disaster recovery capacity is weak

Due to the high cost of setting up a data center and data storage, the disaster recovery mechanism cannot be improved. Therefore, how to reduce the storage cost and improve the capability of disaster recovery is a major problem currently facing. The blockchain to centralized services to distributed services, can effectively prevent the attack on the key network infrastructure.*User data privacy protection*

3) Data storage costs are too high and data center development and maintenance overhead is too high

The storage cost of storage technology cannot keep pace with the data growth rate of decline. Blockchain technology distributed decentralized features. The original large number of servers together, mass storage distributed in the participating nodes, can greatly reduce the big data platform deployment and operation and maintenance costs.

However, the traditional blockchain accounting node needs to back up the complete data, in which case, nodes still need to store huge amounts of data, even more than before. In order to avoid this situation, this paper provides a P2P light-weight backup federation chain architecture. The backup of this architecture refers to the complete information of each block (including the specific information of each transaction), while the light backup only backs up the information of the node header of each node (including the merkel root generated by all node transaction information, similar to light client). The coalition chain refers to participate in the competence of each node are completely equal, we do not need full mutual trust can be achieved under the conditions of credible exchange of data, R3 formed by the bank block chain alliance to build a typical coalition chain .

This architecture blockchain using DPoS consensus mechanism, selected by a coalition vote accountants, each accountant in order to generate two seconds of privileged time block, if the accountants in a given time cannot generate the area Block, block generation permissions to the next time slice corresponding billing. The holding node can vote to replace these accountants. Accountants need to back up the data. Ordinary nodes only need to back up the entire blockchain lightly, and can also download the complete data for verification at any time. Such an ordinary node can be supervised, and the revenue that can be earned by accounting also motivates powerful nodes willing to pay for the storage of complete data to gain accounting rights.

The big data platform, with the government as the main investor, often cannot create the social benefits of investment due to the lack of competitive incentives. After the introduction of blockchain technology, the government is only responsible for setting standards and regulation, avoiding the ambiguous position of referee and athlete. But also further liberate the creativity of the big data open platform. All the participants are free to use the open big data to provide external services, and urban residents are free to choose various services. Smart cities are dominated by the past government. Government promotion has become government regulation, social promotion and participation by the whole people. This not only reduces costs, reduces government workload, improves service efficiency, promotes organic integration of data and services, and promotes wisdom Urban health and sustainable development.

V. CONCLUSION

This paper analyzes the concepts, features and functions of the Internet of things, large data and energy Internet in the infrastructure of a smart city. Discuss the concept and characteristics of block chain technology, find the existing problems from the energy Internet, Internet of things, big data platform of the smart city infrastructure. Study the compatibility and complementarity of their key technology by comparing their similarities in concept. Aiming at the

problems such as the poor security of the Internet of things, the difficulty in upgrading the equipment, the high cost of building and operating the big data center, the poor flexibility in anti-attack, the difficulty in establishing trust in the energy Internet users, the user privacy leakage and the inapplicability of the trading market mode, the corresponding solutions are put forward. It also presents a solution to the problem of increasing storage pressure in the late blockchain. The solution proposed a P2P light - heavy backup architecture, hoping to be able to provide practical help for the future.

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