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Distributed Ledger technologies application in the energy supply sector

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Abstract: This research relates to the field of distributed ledger technologies and their application in the energy industry. Distributed ledger technologies are decentralized technologies for storing, exchanging, and recording information, where synchronization and data exchange is determined by a consensus algorithm, and copies of the data are stored on geographically distributed nodes. Blockchain technology is currently the best known and most researched of them. Meanwhile, blockchain is not the only configuration in which distributed ledger technology can be implemented. Non-blockchain DLTs can be in the form of cryptocurrency or be simply an architecture for storing and exchanging data and have no monetary meaning. Some are seen as being able to replace blockchain because they can process transactions much faster; transactions are added almost instantaneously and processed individually rather than in blocks. The reason alternative types of DLTs are considered useful is that a transaction can be represented by a node, and you can add transactions to the ledger as they arrive. This means that there is no need to wait for a block to be created to validate your transactions. In addition, various types of consensuses developed that reduce latency in the system and increase throughput. However, how reliable and efficient they will be is an open question.

This paper investigates distributed ledger technologies when applied to energy supply sector.

Keywords: blockchain, distributed ledger, energy supply, Industry 4.0

Introduction

With the emergence of blockchain technology and its omnipresent adoption in industries unrelated to financial systems, distributed ledger technology (DLT) has begun to evolve into dramatically new concepts. As each industry is characterized by its characteristics and limitations, both the algorithms for reaching agreement when adding data to the ledger and the data structures are changing. Meanwhile, there is no solid understanding of exactly what kind of DLT would be applicable and useful for solving the problem in a particular industry.

The problem of this study is to answer the question of which of the distributed ledger technologies can be applied to solve a real problem in the energy industry and to give proof of applicability. The question of proving the applicability of the technology in an area can be based on theoretical or practical results. The theoretical result may be the result of simulation of the application of the chosen technology to solve the problem. This paper will describe the theoretical foundations of distributed ledger technology modeling and obtain theoretical results by simulating a distributed ledger.

The relevance of this study is due to several factors. From the point of view of the scope of research is the development of the Internet-of-Energy concept in energy companies, the increase in investment in the field of renewable energy. Renewable energy networks assume localization, small scale, and microgeneration. Distributed ledger technologies have shown themselves well in such cases in other countries, for example, in America. Reforming the industry could potentially improve the situation in sparsely electrified areas of different geographical regions. From the point of the research object, the relevance is due to the special attention to the development of distributed ledger technology in the frame of Industry 4.0 paradigm: the development of this technology is considered important in the context of digital transformation, roadmaps for its development are developed. However, the specific implementation of DLT requires understanding how the system will behave.

1. Distributed Ledger Technology: the main concepts

The distributed ledger technology (DLT) is an approach to storing, distributing, and recording information. Application, the development of these technologies is sharply relevant in the last years, rapidly developing and changing entire industries, but the idea of it originated back in 1982. It is a task of interacting actors, remote from each other, who must work out a winning strategy of action, meantime each of the actors can be an intruder and sabotage the system by broadcasting the wrong information. In the digital world, this technology is needed to transmit property right in peer-to-peer mode over the Internet. Furthermore, it must be ensured that there cannot be a double transfer of ownership, and it must be ensured that the sender originally possessed the object of exchange.

Distributed ledger technology is a censorship-resistant technology of storing, sharing, and recording information where the data synchronization and sharing are defined by a consensus algorithm, and the data copies are stored on geographically distributed nodes.

A DLT system as defined as a system of electronic records that enables a network of independent participants to establish a consensus around the authoritative ordering of cryptographically validated ('signed') transactions. These records are made persistent by replicating the data across multiple nodes, and tamper-evident by linking them by cryptographic hashes. The shared result of the reconciliation/consensus process - the 'ledger' - serves as the authoritative version for these records. Tamper-evident here is close in meaning to "anti-sabotage".

The consensus algorithm is a mechanism to achieve an agreement among multiple agents for a ledger record.

A transaction is considered as any proposed change in the ledger: transactions move the system from one state to another.

A record is the confirmed transaction through a consensus algorithm and then added to the ledger.

A tip is an unconfirmed transaction.

Logs – are sets of tips or transactions stored by nodes for the system methods.

The smart contract is a self-executed code that express terms and conditions of an agreement between two parties that make a transaction.

2. Energy industry and its particularities

The scope of application of distributed ledger technologies in the field of energy is gaining momentum and will soon be as popular and widespread an application of DLT as the financial sector, supply chain, and Industry 4.0. The most expected advantage of energy applications is the guarantee of transparency, provenance, sustainability, and security.

One of the distinguishing characteristics of energy as a product is that it is almost impossible to store energy in large quantities. This means that there is a real-time electricity demand. At the same time, energy demand is not uniformly distributed; energy demand peaks at certain times of the day and drops, the cyclicality of which can be tracked. This leads to high grid loads. This is what the IoE concept is trying to deal with.

The most promising aspects of DLT applications in the energy sector are:

- Energy trading on local markets;
- Energy payment, storing of energy transactions;
- Application platforms;
- Electric vehicle charging payment;
- Data registration;
- Investments, tokenization;
- Renewable energy;
- Energy origin trading.

3. Important DLT characteristics in the energy field

Scalability is probably one of the most obvious requirements for DLT implementation in the context of the smart grid. Also, the technical characteristics (security, scalability, and speed) of blockchains for distributed energy resource (DER) transaction exchange and enhanced resilience are essential in this field. The performance of DLT is the key challenge, as energy sources, the number of users, and transactions continue to grow. The next key aspect is the way information is recorded in the ledger, e.g. to preserve the privacy and anonymity of individual household and industrial consumers.

There is always a trade-off between costs and performance of DLT solution. In billing and pricing systems DLT performance means more than cost because it must have high throughput. To be able to compete with existing solutions DLT must process at least the same amount of information in a limited time.

As the number of validators increases, transaction throughput decreases due to increased coordination between validators, which increases the need for network connectivity as well as computational overhead.

Increased bandwidth will create massive new data sets that need to be carefully monitored and protected from potential cyberattacks. Bitcoin is relatively resistant to cyberattacks but other platforms, such as Ethereum, which has potential in terms of the consensus algorithm, have been seriously attacked in the past..

When implementing DLT in the energy sector it is important to understand that DLT does not guarantee traceability within a block, only between blocks, the limitation is also the block validation time.

The application of blockchain in the energy sector is quite different, so different aspects will be critical to specific solutions. These are the most essential characteristics of DLT solution for implementation in the energy sector:

Table 1.1 Important DLT characteristics

Quantitative	Performance	block creation interval
		block size limit
		confirmation latency
		propagation delay
		stale block interval
		transaction validation latency
		number or transaction per second
	Reliability	number of possible causes for network failures
		data redundancy
		priority levels for critical data
		total outage period
Qualitative	Scalability	load scalability
		geographic scalability
	Interoperability	network layers interoperability
		interoperability with IoT devices
	Flexibility	applicability in various applications
		applicability on different layers
		token support
		Turing-complete smart contracts
	Security	cryptographic strength
		robustness to attacks
		fault-tolerance
		data confidentiality, integrity, and consistency
	Policy	auditability
		legal compliance
	Practical mechanisms	transaction fee
		consensus mechanism
		ease of use
		implementation cost
		maintainability
		accessibility
		specific mechanisms (for example, supply-demand balance)

As essential in energy field characteristics are identified, the next step will be to investigate applicable frameworks of distributed ledger systems and to analyze them from the point of these expected characteristics.

Digging deeper into more specific applications of blockchain, consider the potential application of DLT to the data of IoT devices. The most important characteristics here will be system throughput, latency, scalability, decentralization, and low resource consumption due to the limited computing power of IoT devices.

These characteristics are most strongly influenced by the choice of consensus algorithm in the distributed ledger. Next, consider and compare the consensus options that could potentially be chosen.

4. DLT design for energy sector

The author's previous research on DLT applications in the energy sector focused on the development of a blockchain-based smart grid architecture for the electricity sector. This solution was designed to maximize system stability and efficiency. An aspect that was particularly emphasized in the development of the solution was ensuring the assurance of reliability, integrity and confidentiality of information. The cases of blockchain technology application in different countries were analyzed, the ways of information protection in complex smart grid systems were considered. In addition, there was a conceptual new addition to the best practices that increase the level of trust in the system - the application of the concept of Internet-of-Measurements at the level of calibration of IoT devices. The essence of the proposed architecture is presented in the work and can be described by the scheme presented further in the text. The problem of electricity supply in different underdeveloped areas is really very acute. The high cost of traditional ways of generating electricity provides motivation to use other, renewable energy sources, such as wind.

DLT in this system:

- simplifies the process of user authorization in the system;
- stores data on the electricity consumed and paid for by each node (peer);
- guarantees transparency and reliability of the information.

DLT-based solutions reduce energy costs, reduce non-technical losses in the grid, and prevent electricity theft. These aspects are confirmed by DLT implementation cases in America, Lebanon, and South Africa. Other energy companies using DLT solutions are: Consolidated Edison (USA), Enercity and RWE AG (Germany), Wein Energie (Austria), Fortum OYJ (Finland), E-net Systems (Japan), Living Room of Satoshi (Australia).

5. Conclusion

Research into distributed ledger technology applications in energy supply sector, in general, is a young but rapidly growing field at the moment. At the moment, the most popular and researched solution is DLT-systems based on blockchain, but other alternatives have a great potential courtesy of their properties.

Valuable results:

A selected set of characteristics important for DLT application to energy, which can be used as a framework for DLT evaluation

Unfortunately, there is currently no single distributed ledger technology that is suitable for every task in the energy industry, but the information contained in the first chapter will help assess the technology in terms of the parameters that the case dictates.

Another valuable result of the work is the confirmation of the compatibility of the concept of distributed ledger technology and IoT.

At the same time, the work revealed a peculiarity of the data coming from the measuring devices. Aggregated data is published at intervals over time, which means that when multiple consumers are connected to the system, there will be a discrete load in the system.

Finally, the valuable result is the simulation output and considerations about parameters tuning that can be considered with further researches in this field.

Further development of the research could be a project to implement distributed ledger technologies in local area networks, networks with renewable, green energy. This promising direction is also because it is environmentally friendly.

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