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Proposal for IoT Implementation of a Distributed Ledger

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Abstract **– In this article we look through the task of ensuring availability and integrity of information processed within the Internet of things (IoT) networks. Such networks include sensors, actuators and other devices that are data sources, gateways and data stream hubs that transmit information from sensors to the Internet, and servers that store the received data, process them and provide access to users. We propose to apply distributed ledger technology (DLT) to ensure integrity and accessibility of data in IoT, which is why it is proposed. As an example, we consider DLT application for data protection in the energy industry. We consider a system for processing and storing data on the production and consumption of electricity in a decentralized electricity network. A review of existing projects related to the use of distributed ledger technologies in the energy sector is carried out. However, an important obstacle for using DLT in IoT is that IoT devices often do not have the required computing power. This paper indicates further ways of research that are associated with overcoming this obstacle in the application of distributed ledger technologies in the energy field.**

Keywords—Distributed ledger technology, energy systems, lightweight cryptography, internet of things

I. INTRODUCTION

In recent years, distributed ledger technologies (DLT), the most famous of which is blockchain, have attracted interest from startups, business organizations, government, the scientific community, developers and researchers from around the world.

At its core, a distributed ledger is an asset database that can be distributed across a network. All network members can have their own, identical copy of the ledger. Any changes to the ledger are reflected in all copies within a short time. The data are stored in the form of records, each of which is signed with a digital signature. Groups of records, in turn, are combined into subsets - blocks. Blocks are ordered chronologically and interconnected, so changing the data in one block requires changing all the blocks before it.

One area of application of DLT is the Internet of things (IOT) [1]. The IOT is an automated system of devices that collect and process information from the external environment and interact with each other using a network. DLT can ensure the safety of data storage and transmission, the system's resistance to technical failures and malicious attacks, and trust between users of the system. In addition, the use of this technology does not require significant computing resources, which is extremely important for devices of the Internet of things.

One example of combining distributed ledger technology and the Internet of things is decentralized power generation and distribution [2-4]. In such systems, local small-scale electricity producers with wind generators or solar panels at their disposal will be able to sell surplus electricity to consumers without intermediaries.

It is supposed to use the so-called "smart" meters to account for generation and consumption, to calculate the payment for electricity and its distribution between suppliers. These are devices that can automatically record the consumption of electricity, gas, water or heat. Further, these data are transmitted via the Internet to a single database, where they are recorded and carried out calculations for the consumer.

Similar systems are being developed in the USA and EU countries, where renewable energy sources are actively used and there is a need to create a new model of a decentralized energy market [5]. In Russia, this industry is underdeveloped, as the energy is generated by a limited number of large producers who are little interested in decentralizing the system. However, the creation of such systems is relevant for settlements of remote regions of the North of Russia, Siberia and the Far East, as well as villages and villages located on the territory of nature reserves. This is because often the creation of infrastructure for the supply of electricity to such settlements is economically illiquid or could violate the environmental regime.

II. DISTRIBUTED LEDGER IN ELECTRICITY METERING

At the moment, all well-known DLT projects in the electric power industry are based on BlockChain technology. In the review [4], 9 uses of BlockChain in the electric power industry were highlighted: distributed trading, charging stations for electric vehicles, remuneration for the production of renewable energy, differentiated payments, payment of electricity with cryptocurrency, wholesale of energy, stabilization of network load, trading in environmental assets, data exchange platforms . Considered theme can be attributed to the first and ninth directions. The solution to the problem of power supply in remote regions may be the use of distributed trading platforms. Thus, local small-scale electricity suppliers that have wind generators or solar panels at their disposal will be able to sell surplus electricity to consumers without intermediaries. This approach will allow you to choose between energy suppliers, which will lead to lower tariffs. More often, such platforms are geographically limited to a quarter or district, for example, LO3 Energy Brooklyn Microgrid and Allgau Microgrid projects [6].

Despite all the advantages of BlockChain technology, it has some disadvantages that create several issues when used in IoT. These issues include high demands on computing resources, poor scalability, the need for a compromise between the time of network synchronization and the speed of writing data to the ledger.

Some projects are moving away from the BlockChain, creating alternative types of DLT. One of the most common is the concept of DAG (Directed acyclic graph) [7]. Blocks or individual records act as nodes of the graph, and hash functions of blocks act as directed arcs. Writing down a new block, its author is guided by a list of such ledger blocks whose hash functions are not yet contained in any other block. After that several of them are selected (usually 2), and their hash functions are added to the block. Thus, the DAG is not a chain of blocks, but a network. Due to this, it turns out to limit the sequential recording of blocks, which makes it possible to conduct more transactions, and solves the problem of scaling. One of the first full-fledged DAG ledgers is IOTA [8] - a cryptocurrency positioned as designed for the Internet of things.

The key advantage of DAG over BlockChain, within the framework of the specifics under consideration, is less demanding on network synchronization. If you use DAG, then while generating a new block at two different ends of the network, both blocks will be added to the ledger, while using BlockChain, this will lead to a collision, and the version that most users will accept first will be added to the ledger. Thus, DAG technology for IoT is preferred. This is justified by the possible delay in the exchange of data between nodes due to the limited bandwidth inherent in IoT and interruptions in communication in remote regions.

III. Smart meters and DAG

Smart meters are devices that can automatically record the flow of electricity, gas, water or heat. Further, these data are transmitted via the Internet to a single database, where they are recorded and carried out calculations for the consumer [9].

Unfortunately, at the moment, manufacturers of smart meters do not disclose information about the computing power of such devices. Description of technical characteristics is limited by operational nuances. A comparative analysis of the devices on the market is not possible, due to lack of data.

It is worth noting that some of the projects reviewed have developed their own smart meters for metering electricity and communication with BlockChain for transactions [10-15].

Based on the specifics of the topic under discussion, the main problem of IoT devices as DAG nodes is insufficient computing power and lack of memory. This is due to the need to calculate hash functions, affixing an electronic signature and storing the ledger.

The article [16] notes three possible interactions between smart meters and DAG:

1. Meters do not have memory and processing power to interact with the DAG. The entire burden is borne by the confirming nodes, which will perform all the necessary functions (checking transactions, storing the ledger, forming blocks and confirming them). In the case of this approach, we must accept the assumption of the complete trust of the counters and confirming nodes.

2. Meters calculate hash functions and affix ES, but do not store a copy of the ledger.

3. Meters act as complete nodes of a distributed ledger.

The main problem of the second and third options are the high demands on the processing power of smart meters. The way out of the situation is to replace the hardware of the controllers of these meters, which will significantly increase the cost of the devices.

The justification of the third option is in great doubt, since this system should be designed for long-term operation and, in the future, a large coverage, which will inevitably lead to the need to significantly increase the internal memory of the controllers. For example, the size of the Ethereum blockchain is hundreds of gigabytes. To solve this problem, it was decided to include a Raspberry Pi type microcomputer using memory cards in the “smart” meter. This option will allow both to increase the computational potential and solve the problem of lack of memory. The flip side is to increase the cost of the meter, increase the size and increase its own energy consumption.

IV. Proposed method and the prototype

The main task is improving current information technologies used in the design, deployment and operation of distributed ledger systems. For this purpose, we are going to use the second generation of such ledgers (that means they support smart contracts). Our approach will be based on the “directed acyclic graph” data structure (currently, second-generation distributed registry systems are being implemented using blockchain technology).

To build a prototype of such a distributed ledger that will correspond to the chosen topic, it was decided to build a prototype. The prototype is based on two segments: virtual and physical. The physical segment consists of several so-called branches, in other words, bundles of hardware. Each branch consists of the following set:

- sensors for Arduino controllers
- Arduino Uno boards
- Raspberry Pi 3 microcomputers

The choice of such initial equipment is made considering the following: to get started with the prototype, an initial selection of data is required. For the first time, it was decided to use sensors for the Arduino platform that are available. This will let us to emulate the necessary data set and simplify the process of building a prototype. Subsequently, when the issues of building a data transmission network are solved, we will change the sensor level to a data set on the energy consumption of several small settlements in Russia. Thus, the passage to the target type of information will be carried out - the electric meters datasets.

We use Arduino Uno boards to combine information flows from the sensor level and redirect the processed information array to the upper level that is fulfilled with microcomputers that combine the Arduino Uno board groups.

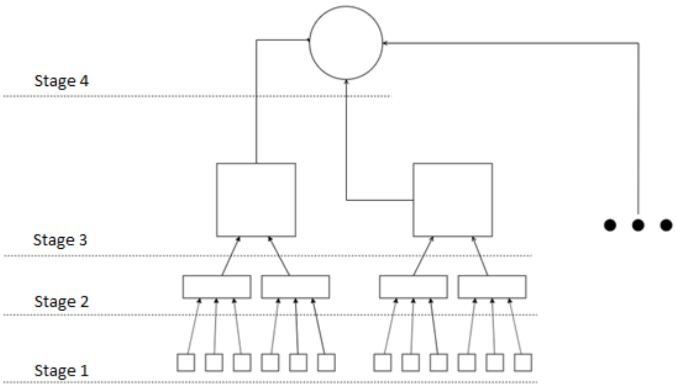
As an independent server, we use computing power of our university department’s local server. Server tasks also include emulating similar branches. Using this approach, it becomes possible to increase the number of branches in a short time to emulate a distributed system of industrial Internet of things.

Among available IDEs we have chosen, the following ones:

• Microsoft Visual Studio 2019
• Arduino IDE

This choice is made due to the lack of obvious difficulties during the development process in the selected environments, their stability and ease of use. Also both code development environments support working with C/C ++ languages.

The prototype network is represented at the picture 1.



Picture 1. Schematic prototype of developing network

- Dots show other similar branches emulated on the server.
- Stage 1 consists of equipment that generates an initial dataset (the sensor level).
- Stage 2 consists of Arduino Uno boards.
- At the stage 3, low-resource single-board Raspberry Pi 3 computers are installed.
- At the stage 4 we have a university department’s server, which should perform the bulk of computing tasks. It also provides interoperability for all branches.

The transmission of information between the first and second stages is organized by a wired method. This means that one single-board microcontroller is attached to concrete set of sensors. Each sensor is connected to “its” Arduino Uno board by wire. Between the second and third stages, a wireless connection is established over the radio channel at a frequency of 433 MHz [11]. For this purpose, we use low-resource LoRa SX1278 transceivers. LoRa (Long Range) is a low-power wide-area network (LPWAN) technology. It is based on spread spectrum modulation techniques derived from chirp spread spectrum (CSS) technology. As a fallback we are going to use the HC-12. This is a 100mW multi-channel wireless transceiver that works with the same frequency.

Stages 3 and 4 are supposed to be connected via the Internet. Due to information security measures VPN will be used. Now, at this part of development, a direct wired connection is organized.

Our current task is providing automatic collection of information from various sensors, for example smart meters, and transferring it to a remote processing server with taking necessary measures to protect the processed information.

Further development strategy

First of all, it is necessary to evaluate free computing resources at all stages considering a working information transfer. As mentioned above, an example of a technology implementation may be a distributed power system. To preserve the integrity and accessibility of information transaction, it is supposed to use a distributed registry based on a directed acyclic graph (DAG). In this regard, it is necessary to understand at which level the computing power of the hardware will allow us to work with DAG technology. There are several ways of development on this issue.

- **First**. Devices at the second stage will be able to independently work with a distributed ledger. This option is unlikely, since the Arduino Uno board has modest computing resources and does not have enough memory to store its own copy of the ledger.
- **Second.** the task of working with a distributed ledger is assigned to the third level. The creation of blocks, the calculation of hash functions, electronic signatures and work with DAG is quite possible with the facilities of Raspberry Pi 3. Additional reason for choosing this way of further project development is that the third stage devices has a built-in slot for microSD memory cards. On this cards Raspberry Pi stores its Raspbian OS. There is more capacity except this OS and other information can be stored. In the case of this option, level 2 will serve only for data collection, initial processing and sending processed data from the sensor level. This option seems optimal.
- **Third.** The capacity of the Raspberry Pi 3 is not enough to work with a distributed ledger technology. In this case, stages 2 and 3 have the only task to ensure the secure transfer of information to the fourth stage where server is located.

Next, we need to try out the possibility of encrypting the information that is transmitted between the stages, which also directly depends on free computing power, in particular, second-stage devices.

Also, it is necessary to determine the optimal number of downstream devices connected to the upstream. This means for example, the flow of information from how many Arduino

Uno boards will be able to process one Raspberry Pi without compromising its main task, how many sensors can be served by one Arduino Uno board, etc.

V. Conclusion

Distributed ledger technology can really be applied in practice in the field of energy, especially in decentralized energy networks. In this article, we reviewed existing solutions based on a distributed ledger technology in the energy sector, most of which are under development. We also noticed the key difficulty in using the Internet of things devices when implementing a distributed ledger in the energy sector and found out the ways to overcome this problem. Also we proposed a scheme of the IoT network for implementing a distributed ledger in the energy sector based on the Directed Acyclic Graph (DAG) with concrete examples of the hardware that can be used in same purposes. Further work on this topic is related to building up the network, performance tests and improving of information security measures.

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