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Applying distributed ledger technologies in megacities to face anthropogenic burden challenges

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Abstract. Distributed ledger technologies can support a rapid transition to smart cities and provide a high level of urban quality. Despite the large number of approaches to the problem of synthesizing smart city management systems, there is still no universal solution. One of the most promising areas is the construction of neural network control systems. The optimization module for a neurosimulator is developed that can operate in real time. The study of the neurosimulator on various data of anthropogenic load showed the possibility of obtaining high control accuracy.

1. Introduction

Currently, the point of view is widespread that although cryptocurrency has not become a tool for building a new, more decentralized economic order, the potential of blockchain technology and a wide group of distributed ledger technologies is much greater [1, 2]. After a certain decline in the research interest of scientific centers, international organizations and national regulators in the phenomenon, the technologies underlying them to ensure sustainable development have become the object of closer study. Most of the works [3, 4] consider the distributed ledger technology (DLT) features, the potential of its use in various fields, the risks associated with this, and the feasibility of a regulators special reaction. In addition, theoretical studies appear, the authors of which are trying to understand what changes in socio-economic processes are embodied by the spread of this technology and what socio-economic consequences may arise.

In the current conditions of accelerated globalization, along with an increase in the population in cities due to migration, an increase in the general level of comfort in urban space and general urbanization, the problem of "smart" building of urban infrastructure comes to the fore in the city development management system.

Infrastructure is a necessary factor for smart development, which makes cities more inclusive and society more aware. Digital technologies have an important influence on its development. In turn, with the development of digital technologies, their entry into all aspects of human life, the general level of well-being of society has grown significantly. What scientists and practitioners now call a "smart city" was created thanks to the introduction of digital technologies into various aspects of city management [5, 6]. The ultimate goal of introducing the concept of a smart city is to create a new perspective of city management, which simultaneously focuses on all aspects of urban life [7, 8].

Effective city management requires a smart combination of methods and tools to support DLT implementation, making city management a complex and systemic process. To develop solutions within the framework of the “smart city” concept, the issues of modernization of all aspects of the city's development - social, economic, environmental, are subject to consideration. This includes both the basic component, represented by such industries as, for example, municipal infrastructure, urban roads and transport, development, and the secondary component - public-private partnership, the logic of public service provision, business social responsibility, waste management policy and civic consciousness.

All this, in its synergy, makes it possible to build mechanisms for the interpenetration of technologies and approaches to sensible management of development processes in order to better meet the needs of society in a high-quality, safe and productive environment for life.

2. Taxonomy of distributed ledgers

Keeping records has always been a centralized process, requiring trust in the subject of the formation, maintenance and storage of the register. Hierarchically accessible single ledgers that are distributed, evaluated and edited by a network of contributors have been around for a long time, but the concept of a decentralized, distributed and irrevocable ledger was first implemented in distributed ledger technology. The basic technology for bitcoin is called blockchain, which denotes a way of organizing and storing information and transactions in the form of a chain of blocks [9, 10].

Subsequently, other ways of organizing the transfer of assets in a peer-to-peer network were proposed, which led to the formation of the term "distributed ledger technology" to designate a broader category of technologies [11]. Distributed ledger technology is an approach to recording and distributing data among many data ledgers, each containing similar entries and collectively maintained and controlled by a distributed network of computer servers called nodes. The most important innovation of the DLT is that control over the ledger is exercised by more than one institution, but by several or all of the participants in the system, depending on the type of distributed ledger. In fact, in a distributed ledger, no individual network participant can add to the ledger and no individual participant can approve new additions to the ledger.

At the same time, a predefined decentralized consensus mechanism is used to confirm new entries, after which they are entered into the registry. DLT allows members, guided only by their own interests, in a peer-to-peer network to collectively record verified data, such as transaction records, without involving a third party, which is universally trusted. Eliminating the central participant can not only reduce the cost of operations, but also increase their security, since it means eliminating a single point of attack on the network. To break the registry, an attacker needs to gain control of most of the servers on the network.

Distributed ledger technology is based on the concepts of cryptography, game theory and peer-to-peer networking [12]. Key features of distributed ledger technology are:

- the distributed nature of the ledger;
- consensus mechanism;
- cryptographic mechanisms.

Blockchain, a special type of DLT, uses cryptographic and algorithmic methods to create and verify ever-growing data, without the possibility of decreasing it, which takes the form of a chain of so-called "blocks of transactions". Any electronic payment system must have a reliable method of recording transactions, with the accuracy of which all participants have agreed. For a decentralized system of reducing anthropogenic burden on the megacities ecosystem, this creates two challenges:

- developing a safe and reliable method to supplement the public register;
- ensuring the coordination of resources and creating the necessary incentives for users to invest resources in the verification of transactions in the absence of a central registry authority.

Digital signatures provide mathematical confirmation that a specific message has been approved by a specific person. They use public key cryptography, based on two separate but mathematically related keys: one private and one public. The bitcoin address is a kind of public key that is communicated to

the participants in the system. Addresses and their private keys are random streams of alphanumeric characters.

Verification of a block of transactions involves confirmation and consensus building. It takes very little time to confirm a block of transactions, including validating the digital signature. Consensus building is deliberately made more difficult and requires a demonstration of an investment of computer resources known as a proof of work.

Reaching a consensus among people on the web, where no one can be completely sure who to trust, has long been an unresolved task in the field of computer science. It is not enough to ensure that users vote on whether to accept the proposed change. After all, usually in one person it is not difficult to create many nodes in a computer network in order to distort voting

The Bitcoin system requires users who participate in the verification process to demonstrate cryptographic proof of work to show that they incurred costs in terms of computer time before the offer was accepted.

It is important that all users agree on which transactions have already taken place and in what order. If two users see different transaction histories, they will not be able to come to the same conclusion about balances and double spending. The blockchain serves as a way for all users to come to a consensus on which transactions happened and in what order.

It is important to note that DLT is not the only well-defined technology. Their design and configuration depends on the developers' goals and the distributed ledger purpose. Distributed ledger systems can be open access and closed access, and there are fundamental differences between the two. Bitcoin and Ether are the most prominent examples of a completely open blockchain, where participants can enter and leave the network at will, without obtaining any permission. All you need to participate is a computer and appropriate software.

In closed DLTs, members are selected by the registry owner or administrator who controls access to the network and sets the registry rules. This solves many problems for regulators: identification of network members, the subject of obtaining a license, an object of regulation, and ownership of the register. But it also diminishes the key advantage of open blockchains: the ability to function without a central link that other participants must trust.

However, even with closed DLTs, there is no need for an administrator at all to execute transactions. Closed DLTs that regulate network access usually do not require energy-intensive proof of work to verify a transaction, but rely on other algorithmic rules to establish consensus between participants. In the case of a closed DLT, the administrator is responsible for the members reliability. In a closed DLT, any node can propose transaction additions, then propagate to other participants, even without a consensus mechanism.

In reality, there is no binary categorization, but the degree of openness and decentralization of distributed ledger systems. Many companies use a hybrid approach when they provide DLT for closed networks, built on the basis of public blockchain infrastructure, and thus limit the roles in the open access DLT system [13].

In some cases, the division into public and private blockchains is used (depending on whether all network participants can read block data and send transactions) and permissioned and permissionless (depending on the presence of restrictions on network participants). For example, Ripple is a permissioned registry, but the data is confirmed by all participants, so this system can be classified as a public permissioned registry. A permissioned registry, where data is confirmed by only a part of the participants, will be a private permissioned registry [14].

3. Using a distributed ledger in metropolitan areas

Currently, the concentration trend of technologies and resources in megacities with a high population density continues. This leads to numerous problems for urban developers, planners and local governments. In this regard, the "smart city" is becoming a conceptual answer to solving many modern problems associated with the rapid growth of cities. "Smart city" is a comprehensive concept that focuses on the use of information and communication technologies, integrated into the vast majority of aspects of social and economic life in a city with a high population density [15, 16].

Blockchain technology is able to support a rapid transition to the concept of smart cities, ensured by a high level of development of relationships between various stakeholders and actors. Then the degree of "reasonableness" will depend on various factors. For example, the structural components of smart cities, such as infrastructure and services, must be compatible with the “reasonableness” of the design of its urban environment [17]. As “smart city designers”, local governments should seek innovative ways to build a new technological architecture that can accommodate economic, social and environmental needs.

To maximize the potential of DLT, it is necessary not only to ensure the integration of decentralized systems with the legal framework, but also to change the technologies not only of individual links, which at first glance, benefit most from the use of DLT, but also in the environment with which this problem link interacts.

Despite the large number of approaches to the smart city control systems synthesis problem, there is still no universal and ideal regulator. One of the most promising areas is the construction of neural network control systems based on DLT, which can largely remove the mathematical problems of analytical synthesis and analysis.

The method of training a neural network control system that minimizes the deviation for each step t of the current position $x(t)$ of the control object from the task $c(t)$ is estimated by the expression.

$$F = \left(\sum_{t=1}^{T} \left(c(t) - x(t) \right)^2 \right)^{\frac{1}{2}}. \quad (1)$$

The quality of control deteriorates due to the delay of signals by at least one cycle to the control system of the smart city with feedback. If several cycles are needed to obtain the target position, then while minimizing the current error of the neural network controller of the distributed ledger, it can produce an excessively strong control signal, which will lead to overregulation.

The neural network controller of the distributed ledger minimizes the integral error functional, which is predicted several cycles ahead as follows.

$$S(n) = \sum_{i=N_1}^{N_2} \left(e(t+i) \right)^2 + \rho \sum_{i=N_3}^{N_4} \left(r(t+i) - r(t+i-1) \right)^2. \quad (2)$$

where e is the system output error, ρ is the contribution of the change in the control signal to the total cost functional, and r is the control object output. A direct neurosimulator is used to predict the behavior of the system and calculate errors. An optimization module for a neurosimulator has been developed, which operates in real time. A study by the method of mathematical modeling of the use of various types of neural network controllers on various data of anthropogenic load on the megalopolises ecosystem showed the possibility of obtaining high control accuracy.

4. Conclusion

The innovation in distributed ledger technology is to create a consensus mechanism without a centralized arbiter. To maximize the potential of DLT, in many cases it is necessary not only to ensure the integration of decentralized systems with the legal framework, but also to change technologies not only in the problematic links that benefit most from the use of DLT, but also in the environments with which these links interact.

The use of DLT technologies in a smart city management system will in many cases be effective only for entire ecosystems. The proposed solutions based on neural network controllers are the most successful for technical and institutional reasons, since they are in the middle between a centralized and a decentralized ledger. A smart city governance system needs an arbiter, a coordinator, a subject of responsibility, and the flexibility that can be achieved through authoritative intervention in the protocol. The increased use of DLT is helping to improve a number of processes and information security. Even the maximum spread of DLT does not mean the victory of networks over hierarchies and the democratization of the smart city management system: firstly, because any networks are

characterized by the processes of further hierharization, and secondly, the recovery of the hierarchical order may be necessary to prevent dysfunction of the national environmental protection system.

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