

The Application of Distributed Information Systems Based on Blockchain Technologies in Higher Education: Benefits and Challenges for Ukraine

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Abstract— The research specifies benefits and drawbacks related to the application of distributed information systems based on blockchain technologies in higher education. The authors also examine conditions for implementing distributed information systems based on blockchains in higher educational establishments. Special attention is paid to the primary directions of these technologies application in the system of higher education. The authors also define the types of educational services which can be automated by using blockchains. The research describes the examples of higher educational establishments using distributed ledgers in their activity. Certain recommendations for the terms of reference on designing distributed information systems based on blockchains are formulated. The research also outlines the perspectives for the prospective research.

Keywords — *automation of educational process, a blockchain, a distributed information system, a distributed ledger, a higher educational establishment, terms of reference.*

I. INTRODUCTION

Education industry in Ukraine has enjoyed a long period of stability which seems to be coming to an end with the arrival of various digital technologies. Our students are becoming more and more interested in new ways of accessing to education such as online learning. That happens because information and communication technologies are able to meet their needs for qualitative education which can be accessed in a quicker and more convenient way. But students are not the only who enjoy benefits of newest technologies. Educators also admit that digital technologies can help cope with a heavy regulatory burden most domestic educational higher establishments face.

Significant expansion of information and communication technologies application in higher educational establishments, which is characterized by the development of electronic libraries, various online-programs, research media-repositories and video content as well as their systematic integration into learning and teaching processes, emphasizes the need for the increase in operational capacity of local information systems for the domestic higher educational establishments [1; 2, p. 134]. Furthermore, considerable changes in the ways of delivering learning materials to students caused by the prevalence of online learning and teaching in higher education have led to the necessity to find out the most successful technical tools for the assessment of learning outcomes, ensuring the integrity and

consistency of learning materials delivering, as well as secure identification of educational process participants [3, p. 150].

One of the ways to fulfill the abovementioned objectives suggested by the theory of applied software systems is the application of distributed information systems based on blockchain technologies.

II. RESEARCH ACTUALITY

Despite a great number of technical and organizational advantages of the abovementioned types of information systems for higher educational establishments [4], their application in Ukraine is not widespread. There are several reasons for that, namely the complexity of software development capable to fully combine properties of distributed information systems and blockchain technologies, the unstructured digital content used in higher education, the need for a clear and unambiguous formulation of interrelated and technically neutral requirements for each component of the relevant information systems in the terms of reference (TOR), etc.

The aims of this research are to determine the main directions and conditions of the application of distributed information systems based on the blockchain technologies for the needs of higher educational establishments and provide specific recommendations on TOR development for such information systems designing and their further implementation in higher educational establishments of Ukraine.

Theoretical and practical aspects of the application of distributed information systems based on the blockchain technologies in education have been studied by Ahituv N. [5], Bykov V.Yu. [6], Dmytrenko T.A. [7], Kalinichenko L.A. [8], Kudin A.M. [9] Pleskach V.L. [10], Spirin O.M. [11; 12], Swan M. [13] and others. However, the rapid changes in educational process, the expansion of distributed information systems technical capacities as well as the appearance of new directions for blockchain technologies application in the field of higher education indicate the need for additional research on the issues raised in this work.

During the study a number of methods have been used. The application of analysis, synthesis, logical and comparative methods has allowed us to determine general and specific features of distributed information systems and block chain, as well as to identify their mutually exclusive, complementary and

neutral properties by using local information systems of higher educational institutions as an example. By the means of system-structural, scenario modeling and expert evaluation methods we have specified key parameters for distributed information systems functioning and identified their advantages, drawbacks and risks of their application in higher education.

III. THE RESULTS AND DISCUSSION

In light of our research the definition of the concept of a distributed information system traditionally used in cybernetics is of particular importance. Thus, a distributed information system is considered as a series of integrated central processors working together on a shared software basis to manage and redistribute computing power, storage and other components within a single decentralized information system [5]. As mentioned in N. Ahituv, a distributed information system is not automatically a completely distributed system since the responsibilities over some of its components can be delegated to end users while others are carried out by a central body. Thus, to name a few, the user undertakes the requirement definition and the routine operation, while a central body carries out analysis, design and programming as well as the insert of software changes and the upgrading of equipment [5]. Taking into account the abovementioned point of view, we are able to specify certain groups of benefits and drawbacks related to the application of distributed information systems in higher education in our country.

The benefits of distributed information systems application include the autonomy of all distributed information systems components, easiness of their distension and new users connecting, a friendly integration of technological solutions within the system, flexibility and clear adaptation to the technical conditions of distributed information systems operation, the ability of joint use of operational, computational and other capacities of system various components for performing difficult centralized tasks, etc.

As for the main drawbacks which any higher educational establishment may face when designing and exploiting distributed information systems the following are worth stipulating: complex software, a low degree of data protection, possible failure of new components, difficulties in accessing data in distributed information systems, etc. Considering blockchain specifics, M. Swan defines it as a multifunctional and multi-level information technology designed for registration, inventory and transfer of different assets [13, p. 3].

The UK Government Chief Scientific Advisor Sir Mark Jeremy Walport outlines that “distributed ledgers are inherently harder to attack because instead of a single database, there are multiple shared copies of the same database, so a cyber-attack would have to attack all the copies simultaneously to be successful. The technology is also resistant to unauthorized change or malicious tampering, in that the participants in the network will immediately spot a change to one part of the ledger. Added to this, the methods by which information is secured and updated mean that participants can share data and be confident that all copies of the ledger at any one time match each other” [14].

However, the conclusions drawn by the group of Spanish scientists seem to be of particular interest in light of our research since they outline challenges Ukraine may face when implementing these technologies in its system of higher education. Thus, A. Bartolome et al. outline major risks posed by blockchain in education. Firstly, the implementation of blockchain requires time and efforts due to social, technological, and economic reasons. Secondly, blockchain technologies face challenges in areas such as privacy, transparency, functionality, and value of the certifications. Moreover, the blockchain application can lead to unacceptable consequences depending on the directions and reasons it is used for [15]. Thus, we would like to emphasize that the application of distributed information systems based on blockchains in Ukraine requires some time for their implementation and is supposed to be done not immediately but in the coming years. However, the challenges outlined above can be minimized at the stage of terms of reference drafting. Having compared and summarized the characteristics of the abovementioned technologies, we come to the conclusion that designing distributed information systems on blockchain technologies in higher educational establishments of Ukraine provides the formation of a multifunctional, structured multilevel information environment, directly oriented to meet the needs of each participant in research and educational processes. As a result of designing distributed information systems on blockchain technologies a number of problems related to their functioning can be eliminated, namely the lack of systematization, low security and inaccessibility of data within the local university environment. Management processes, structuring information in databases, and user identification, by contrast, become more flexible and consistent. In addition, the combination of distributed information systems and blockchain technologies contributes to a significant reduction in operational, resource and other costs for higher education establishments providing educational services, quality control of learning outcomes, diploma and certificate processing, etc.

Thus, the application of distributed information systems based on blockchain technologies in higher education of Ukraine provides the automation of the following processes: 1. Formation of students’ achievements database by creating an electronic record book for each participant in the educational process; 2. Formation of online courses system within an educational program with automatic tracking of each student’s achievements; 3. Automatic identification of research and educational process participants; 4. Formation of electronic libraries; 5. Designing distance courses for academic internship; 6. Retention and accounting of intellectual property rights owned by higher education establishments and their employees.

At the same time, a Science for Policy report called *Blockchain in Education* published by the Joint Research Centre of the European Commission specifies eight scenarios for the application of the Blockchain in an education context, based on the current state of technology development:

1. Using blockchain technologies to permanently secure certificates.

The proofs of the certificates will be stored completely, securely and permanently on a blockchain. Thus, even if the institutions that issued the certificates were to close down, or if

the entire system of education collapses, those certificates are still verifiable against the records stored in a blockchain.

2. Using blockchain technologies to verify multi-step accreditation.

A fully automated process would be able to visualize the accreditation chain and verify that certificates had indeed been issued, and (critically) that they were still valid for each step of the chain.

3. Using blockchain technologies for automatic recognition and transfer of credits.

The primary advantage of this is that not only would the proofs of the validity of a certificate be stored on a blockchain, but the certificate itself would be stored on a blockchain – meaning that the certificate itself becomes permanent and immutable.

4. Using blockchain technologies as a lifelong learning passport.

The advantage of this scenario is that every student would have an automatically verifiable CV containing a record and evidence of all learning and employment they had received

5. Using blockchain technologies for tracking intellectual property and rewarding use and re-use of that property.

From a structural standpoint, this scenario is very similar to the existing system which is used to track citations for journal articles.

6. Receiving payments from students via blockchains.

Students do not always have access to bank accounts or to credit cards, depending on the country they are from, their age, employment status etc. This can sometimes serve as an additional barrier to access education. Cryptocurrency based payments would allow this issue to be solved.

7. Providing student funding via blockchains, in terms of vouchers.

By using blockchain based smart contracts, funders can provide the entirety of the funding up-front, but only release it when certain criteria are met. This process can also happen automatically without the need for any intermediaries, vastly decreasing the bureaucracy required to manage such a system.

8. Using Verified Sovereign Identities for Student Identification within Educational Organizations.

By using verified sovereign self-identities, only the persons responsible for verifying the student's identity in the first instance require access to the data. Other than that, the only person who holds the data is the student themselves. This means that the organization no longer needs to manage the complex systems for access rights, and only needs to secure the device or network where the verifications initial verification is taking place. This would save significant resources spent in hardening the network against data breaches, staff training on data-protection and in managing access rights [16].

IV. PRACTICAL IMPLEMENTATION

The University of Nicosia (Cyprus) is claimed to be the first to apply blockchains in education by accepting Bitcoin for tuition for any degree program at the university, teaching a university-level course, offering an accredited academic degree programme, issuing academic certificates onto the Bitcoin blockchain, using its own in-house software platform [16, p. 68]. Another higher educational establishment successfully applied blockchains include Open University UK, the Massachusetts Institute of Technology and others. Thus, the project of the Massachusetts Institute of Technology called Blockcerts includes four main components (Issuer, Certificates, Verifier and Wallet) and enables to create and issue digital certificates, collect a wide range of statements about skills, achievements, or characteristics of the student, etc. [15].

Despite a potentially wide range of opportunities for using blockchains in higher education, their integration into distributed information systems should be based on certain provisions mentioned further: 1. Higher educational establishment administration should determine the directions and the objectives for Blockchain application within the local distributed information system; 2. Structuring scientific, technical and educational information integrated into the databases of distributed information systems using blockchain technologies should be based on the one-line criterion by taking into account the types of datasets, their sizes, storage methods, transmission and user access conditions; 3. To provide the centralization of distributed information system management rights and to confirm the authenticity of transactions involving educational process participants public blockchain should be used; 4. Differentiation of distributed ledgers should be carried out with simultaneous determination of access rights according to subject and territorial principles; 5. The same rules for identifying users of distributed information systems based on blockchain technologies should be established; 6. Methods for confirming transactions in distributed information systems considering the type of educational services provided, for each of the areas of application of blockchain technologies in the educational process should be established; 7. They should specify the requirements for cyber security to be met by the distributed information system in general and its individual components in particular, including the specifics of those based on blockchains.

The important aspect of practical implementation of the abovementioned provisions for designing distributed information systems based on blockchains is their enshrining in the Terms of Reference. Drafting Terms of Reference for the distributed information systems, special attention should be drawn to the need to specify the role of an administrator, a user and a system operator. Defining these conditions at the stage of designing a distributed information system on the blockchain helps to solve tasks such as the separation of functions of the administration of a higher education institution, a teacher and a student, restricts access to personal data and other official information for people forbidden to access such information. At the same time, it is fundamentally important to agree on the type of blockchain technology chosen and their functions.

However, in solving the general issues of designing distributed information systems, a fundamentally important issue that requires resolution is the harmonization of the type of blockchain technology with specific groups of functions that rely on the distributed system in higher education. In fact, this means that for a particular homogeneous group of system functions a blockchain technology must be selected, which is integrated into a locally distributed system of higher education and is determined by the range of homogeneous tasks performed in the system.

Furthermore, along with the IT architecture for distributed information systems created for the needs of higher education establishments, setting goals and conditions of their application, authority of the administrator, requirements for technical protection of information in the distributed information system, requirements for blockchain technologies, methods for user identification, TOR conditions they should provide rules for balancing the information processed in the system and user access rights, as well as requirements for the use of blockchain technologies designed to automate different procedures in higher education of Ukraine.

V. CONCLUSION

In conclusion, the proposed model for local information systems of higher educational establishments is one of the first attempts in Ukraine to combine technological advantages of distributed information systems and blockchain technologies based on their specific complementary properties. It has been proved that designing and implementing distributed information systems based on blockchain technologies is an important tool for automation of higher educational establishment activities since they increase the quality of education by reducing computing, management, energy and other resources. They also ensure a sound record of educational documents, student achievements, intellectual property rights, thereby creating a technological framework for the secure protection for documented information in higher education. In addition, the application of distributed information systems based on blockchain technologies helps to manage the flow of information created in the course of educational activities, provides its consistent structuring by defined parameters, and significantly reduces the requirements for hardware and software functioning of local networks in higher educational establishments of Ukraine.

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