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BLOCKCHAIN BASED SERVICES IN SCHOOL EDUCATIONAL SPACE

Irina Krasteva[1] **& Todorka Glushkova**[2]
[1,2] Plovdiv University "Paisii Hilendarski",
4000 Plovdiv, 24 "Tzar Asen" str., Bulgaria
[1] irina_krasteva@uni-plovdiv.bg, ORCID 0000-0003-0842-8143
[2] glushkova@uni-plovdiv.bg, ORCID 0000-0002-6243-9364

Abstract: *The global pandemic COVID-19 has changed the stereotypes of learning and transferred much of the learning process from the physical world to the virtual space. Education platforms such as Moodle, Microsoft Teams, Google Classroom, etc. have rapidly entered school education. Regardless of the opportunities that these platforms provided, many problems were also identified, mostly related to security when working with critical information, such as when working with an electronic diary, as well as when issuing documents with factory numbering. Blockchain technologies provide opportunities to largely solve these problems, as they ensure and maintain shared, programmable, cryptographically secure and reliable information. The article examines one possibility for the application of Blockchain technologies for the implementation of some services in a school educational platform. The goal is preliminary modelling and prototyping of these services, before their real implementation in the educational platform.*

Keywords: Blockchain technology, Cyber-Physical-Social Space, Educational platform for school education.

INTRODUCTION

The rapidly changing conditions in the digital society determine the need for dynamic changes in the field of education (Schwab, 2017). In the last three years, educational platforms such as Moodle, Microsoft Teams, Google Classroom, etc. have been widely used in the school education system. and each one of them provides both access to learning resources and services such as a test system, electronic diary, game-based learning, etc. Despite the advantages of these platforms, there are also many problems, mostly related to security in online-based work with critical information. These problems are most visible when managing an electronic diary, as

well as when issuing documents with factory numbering such as diplomas, certificates of completion of an educational degree, etc.
Blockchain technologies provide opportunities to solve these problems. The main advantages of this technology are related to the fact that it maintains a shared, programmable, cryptographically secure and therefore trust-proof ledger.
The purpose of the presented research is to create a conceptual model for the use of blockchain technologies in the implementation of some services in a school educational space and to present a partial prototype implementation of two such services related to an electronic diary and work with documents with factory numbering.

1. MOTIVATION AND RELATED WORKS

1.1. Blockchain technologies

Blockchain technologies manage to achieve integrity and trust in a pure peer-to-peer (P2P) system that consists of an unknown number of nodes (peers) with unknown trustworthiness. The blockchain is based on Distributed Ledger Technology (DLT), with each ledger contained in the nodes maintaining the ownership information and storing the entire history of transaction data on the chain. Through fast and secure transactions, participants exchange information and assets with each other, without the intervention of intermediaries. Nodes cooperate together using a communication medium to achieve a certain goal without having a central element for coordination and control. A key role in building and maintaining the blockchain is the use of cryptographic and security technologies to achieve integrity.
Blockchain consensus mechanisms (Alsunaidi, 2019) allow distributed networks of computers to work together and agree on the state of the network. They ensure that public ledgers are fair, reliable, efficient, and that transactions and activities on the network reflect the truth.

1.1.1. Smart contract

Smart contracts provide the business logic of a given decentralized application deployed on Blockchain. Provide an opportunity for participants to enter into various agreements with each other. Transactions will be executed exactly as they agreed. Each user can track the execution of their smart contracts at any time (Dwivedi, 2021). Smart contracts include logic, data, properties and events. They are event-driven, meaning they can be activated when certain conditions are met.
Smart contracts can only work with resources available inside the blockchain network and cannot interact with external data.

1.1.2. Blockchain Oracle (BO)

The Smart contract receives information from an external agent program called an oracle about the occurrence of an event in the physical world. Oracles are essentially a form of communication between the outside world and the Blockchain world. Because Blockchain and Smart contracts are closed systems, oracles represent a way to securely provide data off-chain to the Blockchain network (Mammadzada, 2020).

Smart contracts are often required to have relevant and correct information from the outside world to fulfill the agreement made between network participants. An Oracle is an external data agent that observes real-world events and reports them to the Blockchain for use by Smart contracts.

1.2. Some learning platforms used in Bulgarian schools

The coronavirus is having a negative impact on education systems (Tadesse and Muluye, 2020). According to the Strategic Framework for the Development of Education, Training and Learning in the Republic of Bulgaria (2020–2030) of the Ministry of Education and Science, the focus is placed on the development of students' digital competences and the use of appropriate learning platforms with opportunities for adaptive and personalized learning. The use of an electronic diary in all Bulgarian schools from the spring of 2020, on the other hand, is a prerequisite for the search for solutions for integration with the relevant educational platform. We will analyze some of the most widely used learning platforms in secondary school in Bulgaria in terms of knowledge verification services and their integration with an electronic diary.

Microsoft Teams is provided free of charge to all teachers and students in Bulgaria, according to a national agreement with Microsoft. It supports a communication environment and a platform for storing and structuring digital learning content (AlAdwani, 2022). Feedback is provided through the creation and assessment of assignments and online tests. There is no built-in interface to an electronic school diary in the platform.

Google Classroom is a free and very widely used learning environment worldwide (Safitri et al., 2022). In Bulgaria it is used by over 60% of schools. It has all the advantages of a standard virtual classroom – uploading material files, tests, homework and independent work. Tests are developed through the Google Forms module, and although a record of student results is generated, there is no built-in interface to an electronic journal. The security of the information is not at a high enough level – it is ensured only by the users' Google accounts.

Only about 4% of schools in Bulgaria use specialized learning LMS (Learning Management System) platforms such as **Moodle** or **Blackboard**. Moodle (Yugo et al. 2022) is a modular, dynamic, object-oriented and free learning platform. Although the system has a built-in module that provides some services from a virtual diary, transferring the information to an external electronic diary is not trivial. Despite the many advantages of these platforms, they are rarely used due to the higher degree of complexity and the need for constant training of teachers and administrators.

The considered learning platforms have different advantages and disadvantages. With them, the learning process largely transfers the traditional learning methodology from the real to the virtual classroom. The generation of reports of student results and their analysis is also difficult, and integration with an electronic diary is difficult to implement. These spaces operate entirely in virtual space and do not take into account the features, conditions and changes in the physical world that are essential to users.

The cyber-physical-social system (CPSS) is a fusion of physical space, cyberspace and social space (Pasandideh et al., 2022). The creation of CPSS learning spaces

enables educators and learners to interact in person or through their personal assistants. The learning content and learning process in these environments are adapted to the background knowledge and personal characteristics, characteristics and goals of individual students.

In recent years, a team of PU "P. Hilendarski" Bulgaria developed a reference architecture called Virtual Physical Space (ViPS) (Stoyanov et al., 2021). This space can be adapted to various application domains such as tourism, healthcare, education, agriculture and others. In the field of school education, the developed environment is called BLISS. BLISS extend the base ViPS architecture by adding specific components and services based on Blockchain technologies, such as an electronic school diary and a system for working with documents with factory numbering.

2. BLISS LEARNING SCHOOL SYSTEM

BLISS is an adaptation of the ViPS reference architecture to support the learning process in secondary school. BLISS (Figure1.) is implemented as a multi-agent system. The core of the system is built by personal assistants that interact with each other. The environment of the agents consists of two parts – BLISS server, driven by events and school diary, realized through blockchain technology.

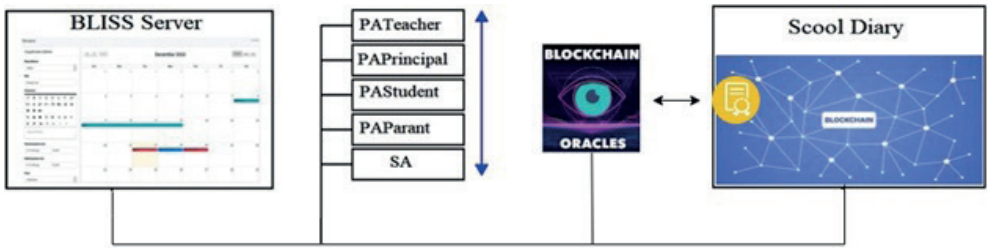


Figure 1. BLISS main components

Source: Own work.

At BLISS, specific personal assistants were developed as an instance of the genetic personal assistant of ViPS.

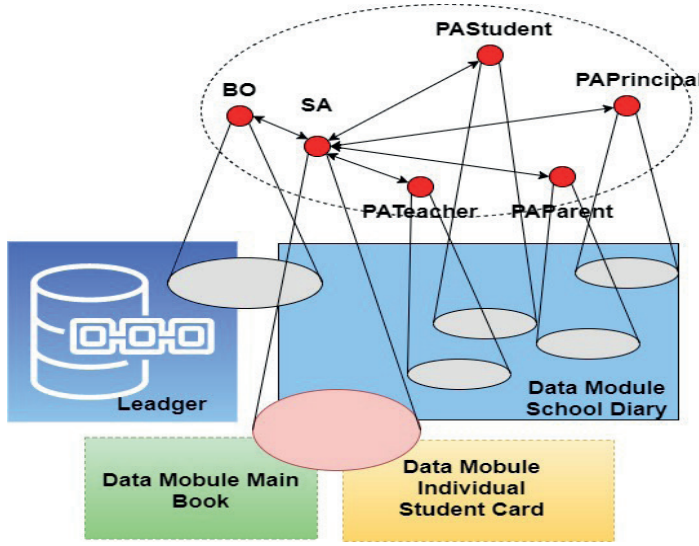
- **PAStudent.** A personal assistant assisting students in carrying out their daily duties in accordance with an established curriculum.
- **PATeacher.** This assistant is designed for teachers by reminding them of upcoming events and necessary preparation. Its main function, however, is to help teachers track and analyze the participation and progress in the learning process, as well as the results of their students.
- **PAParent.** The assistant provides information to parents about their child's participation and progress in school. A parent can see information about grades, events their child must attend, and notes made by teachers.
- **PAPrincipal.** The purpose of this assistant is to assist the principal of the school in effective management. The assistant is mainly intended to help in planning, conducting, and controlling the learning process.

The environment of the personal assistants consists of a BLISS server and a school diary, which is implemented using the Hyperledger Fabric Blockchain technology.

3. BLOCKCHAIN BASED SCHOOL E-DIARY

In its essence, the "E-Diary" service is a multi-agent system in which the personal assistants described in BLISS and other specialized intelligent agents interact.
We use a private blockchain to build the system. Joining the chain takes place with the special permission of the school principal. After access is allowed, the system provides a public and private key to the respective teacher, and the public key will also be recorded as a unique identifier of his/her personal assistant, and the private key will be contained in it as a corresponding pair.
As mentioned earlier, since Blockchain and Smart Contracts are closed systems, Blockchain Oracles (BOs) present a way to securely provide data off-chain to the Blockchain network. To write the ratings in the blockchain so that they remain immutable over time, we use BO. An Oracle is an external data agent that observes real-world events and reports them to the Blockchain for use by smart contracts. It will invoke a Smart Contract upon the occurrence of a „Valuation Entered and Confirmed" event. Through the Smart Contract, transaction data is created in the blockchain. After transactions are created and signed, the blockchain checks them for formal and semantic correctness and authorization. Only correct transactions are completed in a block and validated in the block chain. Once a block is validated, all ledgers in the system are updated with the new data.
We distinguish four types of grades that are recorded in the electronic diary: current, term, annual and grades from state exams. Each grade contains the following variables: the date it was entered, the subject for which it was set, the student who received it, the value of the grade, status (entered and confirmed), as well as the hash value of the transaction itself, which was validated in the blockchain.
To link the Blockchain Oracle, the data module and the various PA groups, we create a Specialist Assistant (SA), which is an intelligent agent and aims to respond to a change in the E-diary environment. Upon approval of transactions in the chain, i.e. their entry into the server's ledger, the Blockchain Oracle extracts this data and informs the SA that a change has occurred in its environment. The SA reacts and informs all assistants who are interested in this change. The BO writes the information (the hash value of the rating transaction) into the data module, which is accessed by all personal assistants and SA.
The SA environment consists of three modules – the Data Module of Electronic Diary (DMSD), the school's Data Module of Main Book (DMMB), and the DM of Individual Student Cards (DMISC).
The environment of the Blockchain oracle is the DMSD, the Blockchain ledger and the Blockchain itself, calling the Smart Contract. The environment of all personal assistants is DMSD and event-driven BLISS server. Examples of such events are teacher consultations, exams, online content discussion, meetings, etc.
A very important part in building a multi-agent system is communication between assistants. By definition, based on these messages, they can change their view of the

world and, in the next stage of deliberation, they choose another plan to achieve a given goal or subgoal. The communication between them would look like in Figure 2, and for clarity we have included only the communication of the SA with the other assistants in the system. Another important clarification is that the environment they observe may overlap.

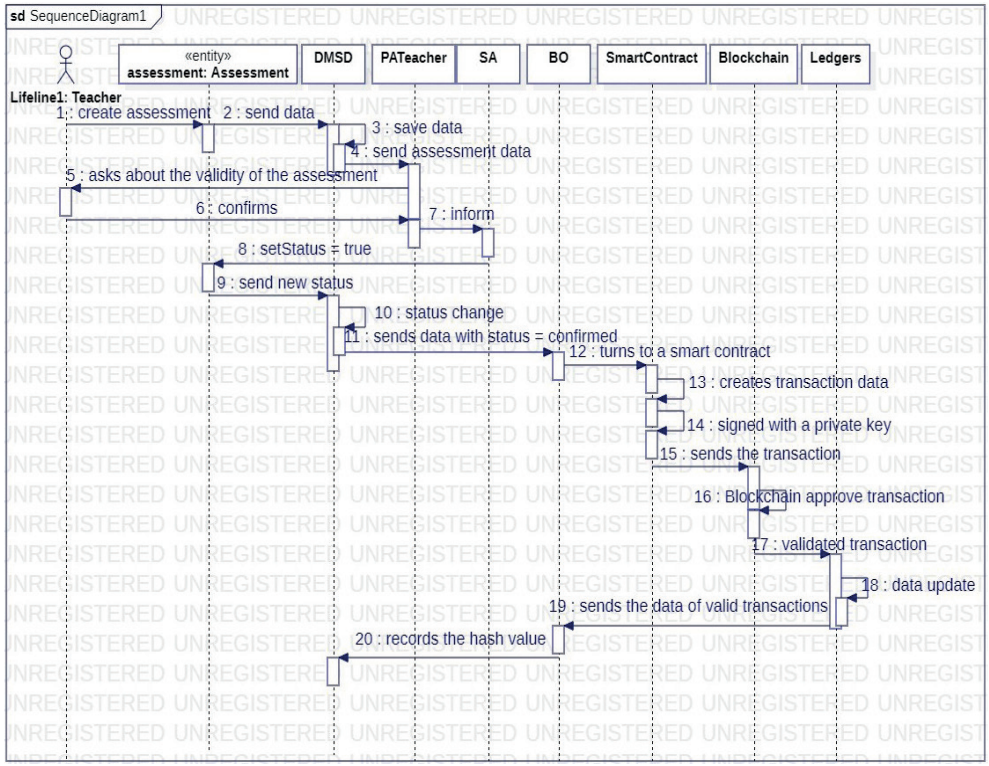


F i g u r e 2. Communication between agents in the E-Diary system

Source: Own work.

When an assessment is entered in DMSD by the teacher, it receives an automatic „entered" status. PATeacher's environment, in DMSD, is changing. It reacts to this change by sending a query to the teacher about whether the grade is valid. PATeacher checks the average assessment of the student in the given subject and if it detects a serious deviation, it sends this information to the teacher. If the teacher made a mistake during the entry, he can change it or delete it from the log before confirming the validity of the grade. If the teacher confirms the assessment, PATeacher sends the confirmation to the SA, which changes the status of that grade from „entered" to „confirmed".

The Oracle monitors the DMSD mainly for the change in the status of the assessment, when it changes to „confirmed", it calls the Smart Contract, which completes the transaction data and broadcasts it to the blockchain. After the data is checked for formal, semantic correctness and authorization, the transaction is validated in a block and recorded in all the ledgers in the Blockchain nodes. The Oracle also observes the change in the BLISS server's registry, knowing which values it submitted for execution from the Smart Contract, it expects them to be written, after validation, to the ledger. Upon the occurrence of this data, the BO records the hash value of the transaction from the registry in DMSD in the field hashValueOfTheTransaction. Figure 3 describes this process.



F i g u r e 3. UML Sequence diagram of the „Assessment Validation“ process

Source: Own work.

After applying a value to hashValueOfTheTransaction in DMSD, the SA distributes the assessments to the students‘ electronic notebooks and notifies all PAs affected by this change of a new event in their environment. Personal assistants inform users (students and parents) and record assessments in their knowledge base. Every personal assistant remembers how it was created. It stores the received information in its knowledge base and monitors the student‘s progress.

Upon receipt of an annual grade or grade from state exams, for each student, the SA transfers these grades and their blockchain-derived hash values to the school‘s Main Book (DMMB) or electronic Individual Student‘s Cards (DMISC). SA monitors data changes in DMMB and DMISC. Only SA can write information about assessments in them. If a data change occurs, during a manipulation attempt, it reacts, synchronizes the data with the Blockchain Oracle, and records the correct values. Thus, we guarantee that the ratings recorded in these documents guarantee the truth and cannot be manipulated.

On the basis of the information from the School Main Book or the Individual Student‘s Cards, documents with factory numbering are issued for the completed class and educational stage of training.

4. BLOCKCHAIN-BASED MODEL FOR DOCUMENT PROCESSING WITH FACTORY NUMBERING IN BULGARIAN SCHOOLS

Another important service is tracking the movement of documents with factory numbering (DFN). According to the regulations of the Ministry of Education and Science (MES), schools declare the necessary DFN for each school year. Applications are submitted by the schools to the Regional Departament of Education (RDE), then from the RDE to the Printing office and to the MES. RDE is an organization at the local level of the Ministry of Education and Science, which supervises the process of preparing a complete independent expert assessment of the quality of education of individual educational institutions in the given area. We will consider the functionalities of RUO-Plovdiv in the modeling of the service.

School documentation can be with or without factory numbering. According to Ordinance No. 8/11,08,2016 of the MES, documents in which a factory-printed series and number are called DFN. Each acceptance and transmission of DFN is carried out with a bilaterally signed acceptance-transmission protocol.

In the education system, the problem of security and verification of the authenticity of issued diplomas and certificates is becoming more and more serious. The use of Blockchain technologies is a reasonable choice when building this system. These technologies allow us to transfer and track factory-numbered documents, which we'll call assets, between organizations in a secure, reliable and integrity manner.

Our idea for the realization of this service is to build a private Blockchain between the MES, the National Printing House for the DFN, the RDE-Plovdiv and all schools in the Plovdiv region. All participants are known in advance and will be separate nodes in the system. They will have the following basic rights in the system:

- *MES*:
  - Receives requests for DFN from RDE-Plovdiv;
  - Sends a request to the DFN Printing House for the required number of DFN;
  - Monitors the process of using each individual DFN in the system.
- *DFN Printing House:*
  - receives a request from the Ministry of Education and Science for the necessary DFN to be printed;
  - prints and registers every DFN in the system as an asset;
  - sends the necessary DFN to RDE-Plovdiv.
- *Regional Department of Education-Plovdiv:*
  - allows access to the system of individual schools;
  - receives and processes applications for DFN from all schools in the Plovdiv region;
  - sends a request for the total number of DFNs in the Plovdiv region to the MES;
  - sends the necessary DFNs, through transactions, to each school.
- *School* (only the school director will have access to the system):
  - sends a request for the necessary DFN for the school year to RDE-Plovdiv;
  - receives the necessary DFNs in his wallet;
  - sends DFN to another school in case of excess;

- makes a request to another school if there is a shortage of DFN;
- marks and removes the used DFNs from the wallet.

Description of the process of distribution of DFN among blockchain network participants.

Step 1. Each school sends a request to become a node in the system to RDE-Plovdiv. Once access is granted, the system provides a public and private key to the respective school principal, through which he/she can verify and sign transactions for receiving and sending DFN.

Step 2. Each school principal sends a request to RDE-Plovdiv, for the required number of DFN for the relevant school year.

Step 3. RDE-Plovdiv collects the necessary number of DFN, which will be needed by all schools in the Plovdiv district, and sends this request to MES.

Step 4. MES makes a request to the DFN Printing House.

Step 5. The DFN Printing House creates the printed documents as assets in the Blockchain. Sends a physical DFN, with the necessary documents, through a courier company of RDE-Plovdiv. Creates a transaction in the system, including all assets sent, as well as the bill of lading number to RDE-Plovdiv.

Step 6. RDE-Plovdiv accepts a physical DFN and, after verification, signs the transaction in the system, which validates the request. After the transaction is accepted and approved in the blockchain, the necessary documents are transferred to the wallet of RDE-Plovdiv.

Step 7. In a similar way, RDE sends physical DFN to the respective schools, as well as creates transactions with the sent assets in the blockchain. After verifying the documents, they validate the transactions with their private keys.

Once documents become assets in a school's wallet, they are written off the blockchain network when they are used. Unused documents can be transferred to another school upon request, by a similar blockchain mechanism.

In the described E-Diary system, upon issuance of each DFN, its number is recorded in Scool's Data Module of Main Book (DMMB), and the DM of Individual Student Cards (DMISC) for the respective student who received the document – diploma or certificate.

CONCLUSION

The educational environments used in school education have indisputable advantages, but also disadvantages, mainly related to guaranteeing credibility and trust. From the results obtained so far when testing the prototypes of the presented blockchain-based services in the BLISS system, we can claim that the application of this technology largely satisfies the security and reliability requirements. The team's future plans are to realize the integration between the two blockchains – of E-Diary and DFN and to explore the co-dependency and applicability of these two services.

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