CHAPTER II: E-LEARNING METHODOLOGY – IMPLEMENTATION AND EVALUATION

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INTELLIGENT SCHOOL EDUCATIONAL ENVIRONMENT FOR DISTANCE AND BLENDED LEARNING

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Abstract: *The synergy between physical and virtual space determines the need to develop Cyber-Physical Spaces (CPS) systems that are used in all areas of life, including education. The Virtual Physical Space (ViPS) is an ecosystem of the Internet of Things that is being developed at the Distributed Learning Centre (DELC) Lab of the Plovdiv University in Bulgaria. The space is the successor to the e-learning environment DeLC, providing electronic learning materials and e-services for different groups of learners. ViPS is being developed as a reference architecture that can be adapted to various Cyber-Physical-Social-Space (CPSS) applications. The article will present an intelligent school educational multi-agent system called BLISS built on ViPS. As part of this system, we will present an electronic school diary based on Block chain technology, which will limit the ability to manipulate data sensitive to change. The goal of the system is to provide adequate and timely assistance and support to all participants in the learning process through specially developed personal assistants, while ensuring reliability and security of storing sensitive information.*

Keywords: Cyber-Physical Social Space, ViPS, IoT, Blockchain technology.

INTRODUCTION

Rapid development in all areas of life is based on the stormy progress of digital technology. They are becoming more sophisticated and integrated, and set the stage for a world where virtual and physical systems collaborate flexibly and globally. It is expected that the closely related Internet of Things (IoT), Cyber-Physical Systems (CPS), and Cyber-Physical Social Systems (CPSS) will play a significant role in the Fourth Industrial Revolution (Schwab, 2017). A "things" must have sensory, computational and processing capabilities that define it as an autonomous, proactive identity that can share knowledge and information with other surrounding "things" to plan and make decisions to achieve personal and common objectives.

Virtual Physical Space (ViPS) is an ecosystem of the Internet of Things that is being developed in the Lab of Distributed eLearning Center (DELC) of the Plovdiv University "Paisii Hilendarski". Because of its versatility, the reference architecture of ViPS enables it to be applied in various fields of application such as intelligent agriculture, tourism, smart cities, but also in education.

This article presents an intelligent multi-agency educational environment for the secondary school developed as a ViPS - adaptation. It briefly examines its evolution - originally developed as a distributed e-learning environment, expanded with the ability to take into account the physical world in which the learning process takes place, to a CPSS-type space.

The rest of the paper is organized as follows: a short review of ViPS as CPSS space is considered in Section 1. This section briefly presents the development of the e- learning system and the ViPS reference architecture. Section 2 presents BLISS as ViPS application in two parts – BLISS Server with personal assistants and BLISS School Diary. The final section briefly summarizes the current state of implementation and presents some ideas for the future extension of the application.

1. ViPS AS CYBER-PHYSICAL SOCIAL SPACE

The Internet of Things (IoT) paradigm allows every "thing" around us to exchange information at a higher semantic level - it is no longer simply a method of transporting messages, it is the basis for knowledge sharing. This paradigm can be applied to any dynamic CPS environment. By placing the user in the centre of such spaces, they become Cyber-Physical-Social Spaces (Wang, 2010). From a software architecture point of view, CPSS includes many components designed to provide effective support to different user groups, taking into account changes in the environment (Guo, 2015). Effective software models for building CPSS spaces support the creation of distributed, autonomous, contextually-sensitive, intelligent software. CPSS can be built for different areas, including education.

From DeLC to ViPS

DeLC (Distributed e-Learning Center) is the first e-learning platform developed by the DeLC Lab of the Plovdiv University. It aims to provide e-learning resources and services for different groups of students. The system is structured as a network of educational and specialized portals that exchange their services and resources. DeLC supports SCORM 2004 standard for creating, sharing and using electronic learning resources and QTI 2.1 for combined learning with electronic testing (Stoyanov, 2010). A school educational portal has been developed within the DeLC system (http://sou-brezovo.org). DeLC continues to be used to train students at the Faculty of Mathematics and Informatics of the Plovdiv University and of the different groups of students in Secondary School “Hristo Smirnenski”-Brezovo.

Although DeLC is a successful project, one of its main shortcomings is the lack of close integration of the virtual environment with the physical world where the learning process is de facto done. CPSS and IoT paradigms reveal completely new opportunities for taking into account the needs of disabled people, in our case disabled students. For these reasons, in the past few years, the DeLC system has been transformed into a Virtual Educational Space (VES), which functions as an ecosystem of the Internet of Things (Stoyanov, 2016). VES integrates the functionality of DeLC by adding a large number of additional services. This was made possible by the development of a system of intelligent components on which VES was built (Ivanova, 2017).

Personal Assistants play a special role in assisting the learning process, providing users with easy access to the space and services the system provides, regardless of the location of the user (Todorov, 2017). The component for representation of the user's location in the physical world was realized using a formal, Ambient-Oriented Modeling (AOM) approach. The use of this component is proven to help disadvantaged students (Glushkova, 2018)

Summing up the experience of constructing VES, we began to develop a reference architecture known as Virtual Physical Space -ViPS (Stoyanov, 2018) that can be adapted to different CPSS applications. An adaptation of ViPS is being developed for the secondary school. The current prototype of the BLISS environment (Brezovo's Learning Intelligent School System) is approved at the Secondary School "Hristo Smirnenski" in Brezovo.

1.1 ViPS architecture

ViPS architecture can be adapted to different CPSS applications. The essential aspects of ViPS are as follows:

- Users are in the focus of attention.
- Physical "things" are virtualized.

- Integration of the virtual and physical worlds.

ViPS architecture reflects and represents in the digital world an essentially identical model of the real physical world in which processes, users and knowledge of the area of interest, as well as the interaction between them, are realized in a dynamic, personalized and context-aware way (Figure 1). ViPS architecture is divided into two sub-spaces. The first is the Analytical Subspace that provides tools for the preparation of field-specific analyses supported by three modelling components:

- AmbiNet, which presents the spatial aspects of "things" and events that are modeled as ambients.
- TNet provides the opportunity to present and work with the time aspects of things. It is based on the official Interval Temporal Logics specification (Moszkowski, 1998).
- ENet - models different types of events and their arguments such as identification, conditions for occurrence and completion. It is essential to distinguish between three types of events - basic, system and domain-specific. Domain-specific events are realized as intelligent agents and they have proactive behaviors, ie when an event occurs, the agent is dynamically generated to represent it and send a message to the respective intelligent helpers (Guglev, 2017).

The second subspace of ViPS is Digital Libraries. They are implemented as open digital repositories. The OntoNet component is a hierarchy of ontologies that represents the essential characteristics and relationships of "things".

The main components in ViPS are the assistants, implemented as rational BDI agents (Wooldridge, 2009). We've made three types of assistants:

- Personal assistants (PA) that help users to work with the specific application.
- Operating Assistants (OA) - Typical intelligent agents located on the system server. They maintain access to the repositories and services located on the server.
- Guard Assistants (GA) - they provide an interface between the physical world and the virtual world.

Normally, for the creation of a new CPSS- application, we do not adapt the entire ViPS, but only its individual components. Thus, after each new application, the reference architecture is expanded and enriched with new functionalities.

Due to the nature of ViPS, users are placed in the spotlight, and due to the expected complexity of a CPSS- ecosystem, a GPA (Genetic Personal Assistant) has been developed to create a specific personal assistant for new users in the space. GPA manages, stores, and restores the personal assistant versions it has created in the past. The components that are adapted to develop BLISS from ViPS are: the genetic personal assistant, ENet, TNet and AmbiNet. New types of specific personal assistants have been developed.

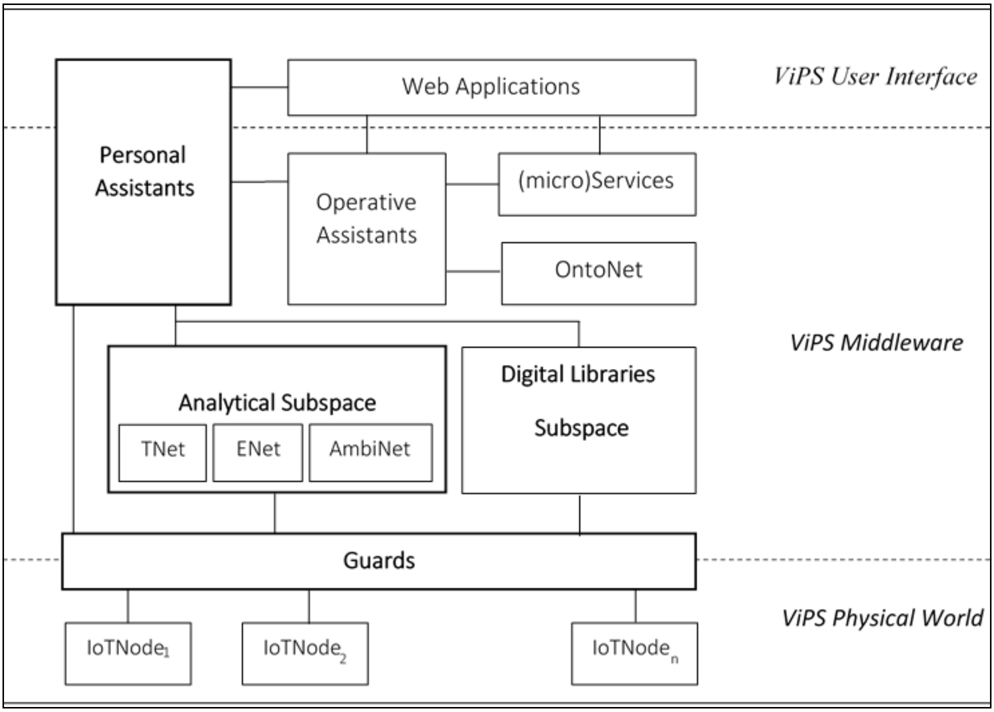

Figure 1. Architecture of ViPS
Source: Own work

2. BLISS AS ViPS APPLICATION

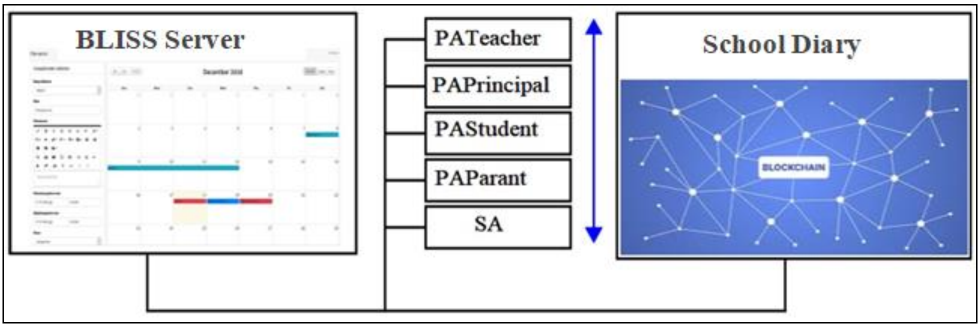

Figure 2. BLISS architecture
Source: Own work

BLISS is an adaptation of ViPS reference architecture to support the learning process in the secondary school. The system is accredited to work with students in a self-contained and blended form of secondary school education. BLISS (Figure 2) is implemented as a multi-agent system and includes two basic components. The first component of its core are Personal Assistants (PA). The second component is a school diary realized through blockchain technology.

2.1 BLISS Personal Assistants

The main task of the BLISS- personal assistants is to assist different user groups in fulfilling their specific functionalities.

PAStudent. A PA, assisting students to fulfil their daily duties in accordance with the established curriculum, informs about all upcoming events that concern it like exams, lessons, training sessions, consultations, and more. It monitors and reminds the student what they need to prepare before the upcoming event. For example, as the exam date approaches, the assistant begins to prompt the user to begin training, while at the same time can provide the necessary learning content in the form of electronic textbooks, SCORM e-lessons, training tests or links to external sources. The PA is able to prepare analyses of the results of the students's participation in the learning process. Figure 3 presents the interface for mobile device of the prototype developed PAStudent. It informs the student of all upcoming events. Event days are marked with a different color. Different colors indicate different types of events.

PATeacher. This assistant is intended for teachers. As in the case of PAStudent, it can also remind of upcoming events and the necessary preparation. Its main function, however, is to assist teachers to track and analyze the participation, outcomes and progress of their students' learning process. Analyses can be used for various improvements. For example, if the teacher notices that a large number of students have failed in a particular part of the exam but they also devoted considerable time to self-preparation on this topic, then PATeacher may conclude that the teacher may need to make some adjustments to the lessons, to ensure that it is easier for the students to learn.

PAPrincipal. The purpose of this assistant is to assist the school principal to effectively manage the school institution. The assistant is primarily intended to assist in planning, conducting and controlling the learning process. This is the most difficult to implement personal assistant.

PAParent. The aim of this assistant is to provide information to parents about the progress of their child at school. The parent can see information about the assessments, the events on its their child has to attend, and the notes made by the teachers. Due to the constant internal communication between the agents and the analysis of the information received by the student's PA, the parent can be warned of change in student behaviour. For example, if a child was an excellent student and started receiving lower grades, the parent would be warned about it. If the child ignores the recommendations he receives from his PA, then it will send a notification to the parent PA.

Figure 3. PAStudent visual interface
Source: Own work

All agents in the space have a common life cycle that is an adaptation of life cycle of a practical agent and is built up of four phases (Figure 4).

Registration Phase. To be eligible for a personal assistant, new users must sign up. The purpose of the registration is to generate a profile that is used to provide personalized help. In the current version of the account there is information about the user's personal identification, types of events that the personal assistant should respond to (for each event there is a type, a pre-notification time, and event information). When working with the system, the profile is updated.

Initialization Phase. Initialisation generates personal agent wishes (create_PC). In this case, the role of the wishes is played by a personal calendar representing the user's participation in the learning process for a certain period (term, school year). The generated personal calendar is stored in a storage database on the server and a copy thereof is sent to the person's device assistant to the user. Every update by a mobile agent is also reflected on a server data base, so that it is possible to completely restore the personalized assistant to a particular user if needed. Apart from this, the assistant can also be used in parallel on several devices without this interfering with his work.

```
/* Registration */
B0 ← get_percept;
profile ← register(B0, student_id);

/* Initialization */
Desires ← create_PC(profile, B0);
B ← B0;
I ← I0;

/* Deliberation */
while true do
        percept ← get_percept;
        B ← update(B, percept);
        D ← identify_goal(B, Desires);
        I ← compose_goal(B, D, I);

/* Planning */
        π ← plan(B, I, Ac);

        while not (empty(π) or succeeded(I, B) or impossible(I, B)) do
                α ← head(π); execute(α); π ← tail(π);
                percept ← get_percept;
                B ← update(B, percept);
                if reconsider(I, B) then
                Desires ← update(B, I, Desires);
                if needed then update(profile);
                break; // go to external while cycle
                end-if
        end-while
end-while.
```

Figure 4. PA Life Cycle
Source: Own work

Deliberation Phase. At this stage of the life cycle, the immediate goal (I) should be defined - to which event the user will be targeting. The goal represented as a domain event is identified by searching (identi_goal) in the personal calendar depending on the beliefs (B) of an assistant. In some cases, the assistant needs to respond to more than one goal, that is, to compile a composite goal (compose_goal).

Phase planning. Once this goal has been determined, the agent must prepare a plan to achieve it. In some cases, it is necessary to reconsider the objective (reconsider) . This usually requires updating of the assistant's environmental information, with the goal of identifying what updating is required in a student's personal calendar or profile before defining a new goal.

The around environment of assistants consists of BLISS Server and School Diary. In the BLISS Server, all information objects (such as schedules, lessons, exams, consultation, self-preparation, meetings) are presented as Domain-specific events. Authorized teachers supported by the server can create, update, and remove events. The server stores these events, controls access to them, and provides them with the personal assistant to students to generate, manage, and control customized curricula and schedules. Any change to the server is automatically perceived by the all "interested" assistants.

The BLISS Server prototype allows to manage all the information on the server. Figure 5. shows the server application menu with its main functionalities.

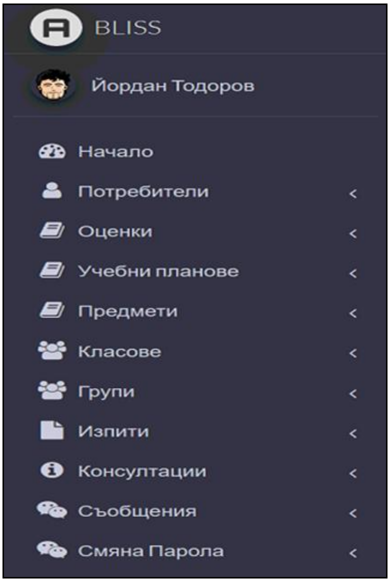

Figure 5. BLISS server menu
Source: Own work

The School Diary, implemented with the help of Blockchain Technology, is also located in the assistant's environment. In essence, the electronic School Diary is a multi-agency system in which assistants with different rights and roles communicate and coordinate their activities.

2.2 BLISS School Diary

BLISS School Diary is developed using hybrid technology. Blockchain technologies succeed in achieving integrity and trust in a clean peer-to-peer (P2P) system that consists of an unknown number of peers of unknown reliability. P2P architecture is a distributed software system that consists of nodes, all of which have only functional capability and responsibility. Participants (nodes) exchange information and assets with each other. They work together with the help of a communication environment to achieve a goal without having a central element of coordination and control. A key role in building and maintaining the chain of blocks is the use of cryptographic security technologies. Blockchain technology is based on a distributed system of records (ledgers) that support property information and store the entire history of transaction data in the chain. Each node has its own copy of the register, allowing the individual nodes to collectively and sequentially identify the ownership through the blockchain algorithm.

The block chain uses a public-private approach to asymmetric cryptography, which is the basis for identifying users, transferring ownership, and protecting against unauthorized access to the system. The purpose of the block chain is to store vast amounts of data and to remain unchanged after their creation or attempting to manipulate these changes to be discovered very quickly and easily (Guy, 2017). Ensuring security and the rapid identification of attempts to manipulate data can be successfully applied in the development of an electronic School Diary (Seyoung, 2017)

Block chains are public and private depending on ownership. Public ones are "open": they are open source and no inclusion rights are required. Private block chains are owned by a separate organization. As can be seen, they are "closed" and not every Internet user can join them and add transactions. For the development of "School Diary" we use a private block chain. Nodes in the system will be all the teachers and the director of the respective school. Each teacher sends a request to the school principal to become a node in the system. Once access is enabled, the system provides a public and private key to the teacher, through which he can check and sign the transactions in the e- diary. At the end of each day, one block will be validated in the block chain where all the transactions for that day will be completed. The blocks will be of varying size each day, depending on the number of transactions.

For the purposes of this development, we define four kinds of roles of system participants that are described in the BLISS module- students, teachers, school principal and parents. Each role belongs to a group of users who have the same functionality and rights. For each of the roles, genetic personal assistants are developed to assist users with the system.

The goal we have set is on the one hand to record the change-sensitive content that will remain unchanged over time using a block chain and, on the other hand, as using all of the benefits of the Data Module (DM). We will use both approaches to building an electronic School Diary. For a link between the block chain and the DM we will place an operative specialist assistant (SA) which is an intelligent agent and is committed to responding to the environmental change of the electronic diary. Upon a block chain change, as a validation of a new transaction block, SA responds and informs all assistants concerned about this change and simultaneously writes the information into the data module on the server. Each teacher introduces the appraisals of the students concerned as separate transactions in the block chain, signing them with his or her respective private key. Students are not nodes in the system, and the recipient of the transactions will be the school principal.

Once transactions have been signed, the block chain checks them for formal and semantic correctness and authorization. Only the correct transactions are completed in a block at the end of the day and validated in the block chain, updating all the registers in the system. Upon adding a new block to a chain, SA responds to changing its environment by sending the information to the corresponding PAStudent and PAParent for the change. Once the personal assistants inform the users, they record the grade in the student's notebook. Every personal assistant remembers as what it is created. It stores the information received in its knowledge base and monitors the progress of the individual student.

As already mentioned, the VIPS domain events are realized as intelligent agents. For example, if there is a notice of an upcoming event (Exam) L1 = <Mathematics, Exam, attr (20.05.2019, time (10: 00,10: 45))>, PAStudent not only informs the user, but also to be in a state of pre-emptive action and prevention, ie having a preventive interval based on its knowledge base for this type of events. For example the preventive interval is 15 days and PA has to draw up a plan to help the student to participate in the event and to achieve the goal. It can provide student with the necessary resources for self-preparation and assists him in the learning process. Information resources in ViPS are stored in digital libraries that are open to storage with different information - electronic content, test questions, and more. For intelligent search and support of the use of information, a meta-level, implemented as interrelated ontologies, is developed in ViPS. Libraries are served by specialized operational assistants, realized as BDI rational agents. Also, PAStudent may offer other resources provided by the teacher for self-preparation.

The School Diary allows for the realization of other BLISS features. Once the student has successfully completed the appropriate education level, the School Diary may initiate the student's diploma by connecting with another block circuit that allows the transfer and tracking of Factory-Numbered Documents (FND) in the school. Our idea is to build a private block chain between the Ministry of Education and Science, the Publishing for Factory-Numbered Documents; the Regional Management of Education (RME)-Plovdiv and other schools, and thus provide a secure way to process and transfer documents with factory numbers. Each individual organization will be a separate node in the system, such as:

- Each school sends a request to become a node in the system to the RME - Plovdiv. Once access is enabled, the system provides a public and private key to the relevant director through which it can check and sign the transactions for receiving and sending the factory-numbered documents.
- The Publisher prints the documents and introduces FND as assets in the system and sends them on the basis of the preliminary applications to the respective schools.
- The Director checks and accepts the transactions by signing them with their own private key received by the system.

Once the documents become assets in the school's portfolio, they can go through different states. An asset can be passed to another organization, it can be used or scrapped. The block chain checks every transaction for formal and semantic correctness and authorization. Only correct transactions are recorded and completed in a block at the end of the day and validated in the block-chain. In this way, each node will have its own copy of the entire history of transactions that occurred in the system. This allows us to track the movement of all factory-numbered documents ever created in the system and to guarantee their origin.

CONCLUSION

The dynamics of social development in recent years and the requirements imposed by the Fourth Industrial Revolution determine the need for lifelong learning inclusive and continuing training. There are a lots poorly educated or under-qualified people from ethnic groups in Bulgaria that are returning to secondary school. It is essential for them to have intelligent assistants and environments to support them in their learning process. The first prototype of BLISS is tested at Secondary School "Hristo Smirnenski", Brezovo. PAStudent is fully implemented, and the other aides are in the process of being developed. We have successfully implemented a block chain using Etherium's open-source technology, which is being tested at this stage. More than 40 students who study on individual plans use and test their personal assistant. The learning outcomes of the previous school year are very good. All students are motivated to continue their education using the developed environment.

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