R E V I E W

by Assoc. Prof. Irina Alexandrovna Radeva, PhD - Institute of Information and Communication Technologies - BAS

dissertation for the award of the educational and scientific degree **"Doctor"**

area of higher education: 4. Natural Sciences, Mathematics and Informatics
professional field 4.6. Informatics and Computer Science
Doctoral programme: Informatics
Author: Irina Krasimirova Krasteva
Title: Blockchain-based synchronization of personal assistants
Scientific supervisor: prof. Stanimir Stoyanov, PhD

General description of the submitted materials

By Order No. RD-21-236 of 29.01.2024 of the Rector of Plovdiv University "Paisii Hilendarski" Prof. Rumen Mladenov, PhD to provide a procedure for the defence of a dissertation on "Blockchain-based synchronization of personal assistants" for the acquisition of the educational and scientific degree "Doctor" in the area of higher education 4. Natural Sciences, Mathematics and Informatics, professional field 4.6. Informatics and Computer Science, Doctoral Program Informatics, Report No. RD-20-189/25.01.2043 by Prof. Angel Atanasov Golev, PhD - Dean of the Faculty of Mathematics and Informatics and in accordance with Art. 4. of the LDASRB, Art. 2. (2), Art. 30. (3) RILDASRB and Art. 37. (1) RDASPU, I have been appointed as a member of the scientific jury.

The author of the dissertation is **Irina Krasimirova Krasteva** - a PhD student at the Department of Computer Systems with scientific supervisor Prof. Stanimir Stoyanov, PhD.

The materials submitted by Irina Krasimirova Krasteva are in accordance with Article 36 (1) of the Regulations for the Development of Academic Staff of PU and include the following documents:

- An application to the Rector of PU for the opening of the dissertation defence procedure;
- CV in European format;
- Minutes of the departmental council related to the reporting of the readiness to open the procedure and the preliminary discussion of the dissertation;
- Dissertation;
- Abstract in Bulgarian and English;
- List of scientific publications on the subject of the dissertation;
- Copies of the scientific publications;
- Declaration of originality and authenticity of the attached documents;
- Reference for fulfilment of the minimum national requirements for obtaining the educational and scientific degree "PhD" in 4.6. Informatics and Computer Science;
- Official note for participation in the project Ex. No. NPD 561/18.12.2023;
- Opinion of the supervisor.

The dissertation is 139 pages long and includes: a list of 35 figures, an alphabet of terms used, an introduction, four chapters, a conclusion and a bibliography of 150 titles.

The main goal of the dissertation is stated in the introduction on page 8: as "To analyze and conduct experiments to reconcile intelligent personal assistants with block chains.". There is an additional objective formulated as "Development and testing of blockchain-based models synchronized with personal assistants and their application to different adaptations of the ViPS virtual-physical space."

Two sub-objectives have been formulated to implement the main objective:

- Development and testing of an "Electronic School Diary" model based on synchronization between intelligent agents and the use of blockchain technologies in the framework of the adaptation of the reference architecture in the field of secondary education.
- Development and testing of a model for the application of the technology in the adaptation of the ViPS architecture in smart agriculture.

Three main tasks related to the formulated objectives have been identified for implementation:

1. After studying various aspects and approaches in the development of Blockchain technology, to create a general concept for their use in synchronizing information so that personal assistants can use it.
2. To create models for the application of this concept in the adaptation of the ViPS reference architecture in the fields of education and smart agriculture.
3. To develop prototypes and test the application of these models.

Topic relevance and feasibility of the set objectives and tasks

The relevance of the chosen topic is undeniable. Combining intelligent personal assistants with blockchain technologies addresses important aspects of digital transformation, especially in the context of the growing need for data security and reliability. The development and testing of blockchain-based models synchronized with personal assistants for different adaptations of the virtual-physical space (ViPS) offers broad opportunities.

The study's feasibility is confirmed by its potential to contribute to solving specific problems in areas such as smart agriculture, tourism and education. The introduction of blockchain technologies to increase the level of trustworthiness in communication between intelligent components in multi-agent systems is an approach that can increase the efficiency and security of these systems.

The main objectives and sub-objectives formulated in the text are ambitious and cover a wide range of applications. The development of an "Electronic School Diary" based on blockchain technology and a model for the application of the technology in smart agriculture are concrete examples that illustrate the potential of the research to contribute real solutions to current problems.

Methodology of the study

The chosen methodology and general approach in the dissertation allow conducting a systematic study, adapting the methods and tools in the process of work and create

prerequisites for the fulfilment of the set goals and objectives. The structuring of the stages from development to testing and analysis allows flexibility and efficiency of the work process.

Characteristics and evaluation of the thesis

Chapter 1 of this dissertation discusses the motivation and status of the research problem, focusing on the importance of blockchain technologies for ensuring trust and privacy in multi-agent systems. The chapter describes the key features of blockchain technologies and highlights their ability to support transparency, data integrity and asymmetric cryptography to identify users and protect against unauthorised access. Applications of blockchain in various fields including education, tourism and agriculture are also discussed, highlighting the potential for secure data management and transactions.

The operation of blockchain technology, the validation of transactions through consensus mechanisms, and the role of smart contracts in automating the business logic of decentralized applications are explained.

Cyber-physical and cyber-physical-social systems (CPS and CPSS) are discussed, and the integration between physical and digital processes is emphasized. Virtual Physical Space (ViPS) is presented as an example of such integration, with potential for adaptation in various application domains.

Chapter 2 explores the application of blockchain technologies in multi-agent systems and the adaptation of the ViPS architecture in the educational domain, through the development of BLISS (Brezovo's Learning School Space). BLISS is a multi-agent system that supports the learning process in a secondary school by integrating personal assistants and blockchain technologies to manage an electronic school register. The architecture includes three layers: an agent layer with personal assistants, a server layer for administration and a blockchain layer for the school register. The main components of the system include different types of personal assistants (PAStudent, PATeacher, PAParent, PAPrincipal) that support students, teachers, parents and principals in the learning process. The system uses blockchain oracles to connect between external sources and the blockchain network, provide integrity and trust in the interaction process between different agents. In addition, an application of blockchain for managing and coordinating factory-numbered documents is discussed, and a model for creating a closed blockchain network between educational institutions and printing houses is proposed. This approach enables tracking, verification and security of educational documents.

Chapter 3 discusses the application of blockchain technology in multi-agent systems and the adaptation of ViPS in agriculture. The concept of integration of personal assistants and blockchain for seed management in national genebank and their dissemination is described. Two key applications are discussed: a "GenBank Validator" for seed specimen verification and a multi-agent system for genetic species dissemination. The Validator is based on a closed blockchain system involving experts and institutions for the verification and validation of new plant varieties. Separately, a "GeneBank Store" has been developed as part of "Agriculture 2.0-Plovdiv", which includes an automated seed ordering and delivery system organized in a consortium blockchain network. Mechanisms for user identification and protection, as well as specialised smart contracts for various operations are provided.

Chapter 4 discusses ideas and future plans for the use of blockchain technology in supply chain management and the integration of personal assistants in various fields. It

discusses the supply chain model associated with the national GenBank and the involvement of various parties such as seed producers, farmers, manufacturers, logistics, financial institutions and government regulators. Different channels in the supply chain such as GenBank Validator and GenBank Store are discussed and smart contracts for transaction automation are proposed. In addition, adaptations of ViPS for the enhancement of travel services are presented, highlighting the importance of blockchain for guaranteeing the origin of products and synchronization with personal assistants to provide integrated services.

The bibliography, which is entitled "Sources", contains 150 titles in English and Bulgarian.

From the above, it can be concluded that **the PhD student is familiar with the state of the art of the issues investigated in the thesis and appreciates the creative use of literature.**

Contributions and Significance of the Development for Science and Practice

According to Article 6 (3) of the LDASRB "**the dissertation must contain scientific or applied results that constitute an original contribution to science**". The dissertation (p. 112) formulates results that are not determined to constitute an original contribution to science.

The results in this dissertation can be defined as scientific applied and applied.

Scientific applied results:

1. A general concept for blockchain-synchronization of information and interaction with personal assistants within a cyber-physical multi-agent system is developed. This result includes the elaboration of a theoretical concept that extends the knowledge in the field of blockchain technology and multiagent systems.

2. Concrete models are created for the application of the developed concept in the adaptation of the ViPS reference architecture in the fields of education and smart agriculture. This result includes the development of specific models that apply the theoretical concepts in a practical context and demonstrate how these ideas can be implemented in real situations.

Applied result:

3. Prototypes were developed to test the application of the designed models. This result includes the creating of functional and usable prototypes that allow testing and validation of the developed models in real-world environments.

I accept that the results are consistent with the scope and content of the aims and objectives and have potential for further development. The PhD student has demonstrated the necessary theoretical and practical knowledge of the specialty, developed skills and gained experience in conducting research.

I am confident in Irina Karsteva's personal involvement in the dissertation research, and that the results obtained are to her personal credit.

Assessment of the publications on the dissertation thesis

The dissertation presents "Publications on the dissertation" - 4 publications - on page 115. The analysis of these publications reveals the following:

- 2 publications are in proceedings of international conferences indexed in Scopus (NNo.1 and 2);
- 1 publication is in a Bulgarian language journal (No. 4);
- 1 publication is in an international journal in English (No. 3).
- All publications are co-authored and are for the period 2019 - 2021.

No citations are mentioned.

As an approbation of the results, on pages 112 - 113 are mentioned participation in the Project KP-06 H36/2/2019 - BG PLANTNET "Establishment of a national information network Genebank - plant genetic resources", Competition for Funding of Basic Scientific Research - 2019, Fund "Scientific Research" at the Ministry of Education and Science and publications at 5 scientific conferences.

Publications on the thesis and approbation show that the stages in the work on the thesis and the main results obtained have been presented to the scientific community.

The scientometric indicators, compared with the minimum requirements for the educational and scientific degree "PhD" according to RILDASRB **are as follows: Group D - 36 points with minimum requirements 30, thus the conditions of RILDASRB are met.**

The abstracts are 32 pages in Bulgarian and English and present the content of the dissertation.

I have no evidence of plagiarism or implausibility of the scientific data presented in the dissertation.

Questions and critical remarks

Questions:
1. On p. 13, it is written, "The purpose of the Blockchain is to store a huge amount of data..." and references [142]. How would you comment on this statement?
2. Where and how is defined the concept or process of "Blockchain-based synchronization", "Blockchain-based synchronization of personal assistants" and "synchronization model" in the thesis (p. 79)?
3. What is meant by "personal assistant-blockchain model" (p. 80)?
4. Where in the dissertation are presented arguments or is explained why "blockchain oracle - it is an intelligent agent" (p. 90)? Assuming that this statement is true, how would such an analogy be proven?

Notes and recommendations:
1. The formulation of the aims and objectives of the dissertation is complicated. It is important to make them clear and measurable in order to conduct the research successfully. A more direct and simple statement would improve the comprehension of the content presented, where the balance between the information required and its clear communication is key to the accessibility of the work presented.

2. There is no presentation and/or description of the main tool used in the dissertation, the Hyperledger Fabric platform, and the motivation for choosing this platform.

3. There are inaccuracies in terminology or translations of terminology in the text, e.g. (please refer to the Bulgarian text).

4. According to Art. 27 (2) of the RILDASRB, instead of "Conclusion", "Conclusion - summary of the results obtained" should be used, and accordingly not "Declaration" but "Declaration of originality", and not "Sources" but "Bibliography".

5. On the contents page (p. 3) of the English abstract, Chapter 1 is missing. The contents page (p. 3) in the thesis has hyperlinks with errors.

6. The bibliographic entries of the references used are described according to different standards, and for some this entry is incomplete.

7. In the section "Approbations" (p. 112), there is no indication of the PhD student's participation in the National Science Programme "Smart crop production" (2021 - 2024), which is indicated in the "Acknowledgement" for publication No. 2 of the list of publications on the dissertation. No official note has been submitted for it and Irina Krasteva is a member of the scientific collective.

8. There are no citations mentioned for the publications on the topic of the dissertation (p. 115), but a quick check in Scopus showed 10 citations for papers No. 1 and 2.

Personal impressions

In relation to this review, I can express my personal and professional opinion because I know the PhD student Irina Krasteva personally. During the period of our acquaintance, she has demonstrated a high degree of responsibility, perseverance, attention to detail and individual approach to solving the set tasks. She has the ability to see problems from different perspectives and creatively interpret approaches and methods for their solutions.

My recommendation is that conceptual models and future plans related to or extending the dissertation topic be realized, and that this be accompanied by appropriate active independent or co-authored publication activity.

C O N C L U S I O N

The dissertation contains scientific and practical results, which represent an original contribution to science and meet all the requirements of the LDASRB, the RILDASRB, the relevant Regulations of the Plovdiv University "Paisii Hilendarski" and the additional faculty requirements of the FMI on the ASD of the University.

The dissertation thesis shows that the PhD student Irina Krasimirova Krasteva possesses in-depth theoretical knowledge and professional skills in the professional field 4.6 "Informatics and Computer Science" demonstrating qualities and skills for independent scientific research.

Due to the above, **I give my positive evaluation for the presented dissertation, abstract and results, and I propose to the honorable scientific jury to award the educational and scientific degree "Doctor" to Irina Krasimirova Krasteva in the area of higher education 4. Natural Sciences, Mathematics and Informatics, professional field 4.6 "Informatics and Computer Science", doctoral programme "Informatics".**

16.02.2024 г.

Reviewer: _____

Assoc. Prof. Irina Alexandrovna Radeva, PhD