

OPINION
for dissertation
for the acquisition of an educational and scientific degree "Doctor"

Area of higher education:	4. Natural Sciences, Mathematics and Informatics
Professional field:	4.6. Informatics and Computer Science
Doctoral program:	Informatics
Dissertation topic:	IoT Platforms and Protocols
Author of the dissertation:	Tsvetan Krasimirov Tsokov
Scientific supervisors:	Assoc. Prof. Hristo Nikolov Kostadinov, PhD
Author of the opinion:	Assoc. Prof. Krasimira Minkova Ivanova, PhD Institute of Mathematics and Informatics at BAS
Based on:	Order of the Director of IMI No. 322/19.09.2024

The opinion has been prepared in accordance with the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application, and the Regulations on the Conditions and Order for Acquiring Scientific Degrees and Occupying Academic Positions at BAS and IMI-BAS, as well as based on the Decision of the Scientific Jury (Protocol No. 1/30.09.2024) regarding the distribution of activities among the members of the Scientific Jury under the procedure.

For the procedure, the main documents for the doctoral studies, CV, dissertation, and autoreviews in Bulgarian and English are presented.

GENERAL INFORMATION FOR THE AUTHOR

Tsvetan Tsokov has a bachelor's degree from 2015, acquired at the Technical University - Sofia, specialty "Computer Systems and Technologies" and a master's degree from 2017 from SU "St. Kliment Ohridski", specialty "Informatics – Distributed systems and mobile technologies". On 01.01.2020, he was enrolled as a part-time PhD student at IMI and, by decision of the Scientific Council of IMI, on 21.12.2023, he was disenrolled with the right to defend.

He worked as a software developer at Fadata Ltd. in 2012, and since March 2013 he has been working at SAP Labs Bulgaria as a senior software developer.

GENERAL DESCRIPTION OF THE DISSERTATION WORK

The dissertation is prepared in English, covers 76 pages, and includes 6 tables and 10 figures. It consists of an introduction, 5 chapters, a conclusion, 3 appendices, a list of the contributions of the dissertation, lists of publications and author reports presenting elements of the dissertation, and a bibliography.

The subject of research in the dissertation are the so-called Cloud/Edge/Fog platforms, which include dynamic and mobile infrastructure nodes and end users. The research focuses on the management and optimization of computing and network resources in these distributed systems that support real-time IoT applications.

The aim of the dissertation is to provide a solution for optimal allocation and management of computing and network resources in these platforms, especially for IoT applications that operate in real time and include dynamically moving infrastructure nodes and end users at the same time. It aims to improve the quality of service (QoS) and the quality of user experience (QoE) by reducing network latency and ensuring adaptability in conditions of changing infrastructure topology.

The first chapter examines the key aspects of the new platforms that provide low network latency and mobility support for various applications, such as augmented and virtual reality and autonomous vehicles. The analysis of the literary sources has led to the confirmation of the hypothesis of the lack of an effective solution to the task at which not only the end users, but also the infrastructure units move.

The second chapter describes the implemented and tested innovative solution for monitoring and controlling carbon dioxide emissions from vehicles, which offers a system for automatic detection and response to emissions anomalies. The system consists of hardware modules installed in cars and cloud microservices that analyze sensor data to measure emissions and other parameters. The application includes anomaly detection algorithms that identify vehicles with suboptimal emission levels and automatically trigger control measures. The presented results from experiments conducted on test and real data sets confirm the applicability of the proposed solution in the automotive industry.

The third chapter explores the management of limited resources such as processors, memory, and networking, which is critical for latency-sensitive applications. Analysis covers resource allocation methods, including integer and nonlinear programming, heuristic algorithms, and machine learning-based techniques. Dynamic algorithms for replicating microservices to minimize network latency are considered. It concludes with a description of the ORCH distributed system for orchestrating computational tasks in a dynamic environment.

The fourth chapter presents a new mixed-integer linear programming (MILP) optimization model designed for dynamic deployment of microservice containers in cloud and edge infrastructures with mobile nodes. The model optimizes the placement of microservices to maximize the number of installed business applications, minimize replica traffic and network latency. The main variables and constraints of the model reflect the realistic conditions of the operating environment, including the resource constraints of the ARM architecture.

The fifth chapter includes a description of two examples that demonstrate how the proposed MILP algorithm works in a mobile environment within a test setup using Kubernetes, with Ecologic used as the application. The placement of 11 receding nodes is analyzed, and in the second example the nodes are receding twice as much. The results show that the MILP model optimizes the total network delay by up to 48% compared to traditional Kubernetes schedulers. The execution time of MILP is longer than that of other schedulers, which in a real environment can be compensated by its less frequent application.

The set of cited literary sources includes 86 references, a quarter of which are references to documentation or program code repositories, the rest are references to journal articles or series related to the researched topic.

One of the appendices contains information about the publicly accessible repositories where the source code of the components of the developed application is shared. The other two are a list of available abbreviations and a brief glossary of terms.

The dissertation work is entirely original and independently developed by the author. The sources used are correctly cited, which guarantees the absence of plagiarism.

EVALUATION OF THE ABSTRACT FOR THE DISSERTATION WORK

The abstract is presented in Bulgarian and in English, according to the requirements of the Law. It is clearly structured and adequately reflects the main objectives, methods and results of the study. It provides enough information to understand the significance of the development and successfully summarizes the author's key contributions.

DISSERTATION CONTRIBUTIONS

The thesis offers significant contributions to the field of IoT applications running in real-time on clusters of devices with limited resources and dynamic movement in space. Key contributions include:

- Scientific contribution: Extending the existing MILP model with new features for minimizing network latency and the movement of replicas between mobile nodes, as well as introducing new variables for node availability and dynamic optimization.
- Scientific-applied contribution: Successful implementation of the modified MILP model in a practical environment using the Kubernetes platform.
- Scientific-applied contribution: Design and implementation of the IoT application EcoLogic for monitoring and controlling vehicle carbon emissions, validated through real tests. The validation results show a reduction in network latency by up to 48% compared to state-of-the-art solutions in the field, confirming the effectiveness of the proposed solution.
- Applied contribution: Publicly accessible open-source repositories have been created to share the core source code and information on the microservices of EcoLogic, facilitating future developments and improvements.

These contributions demonstrate an innovative approach to addressing complex IoT scenarios and offer significant improvements in the field of real-time systems.

PUBLICATIONS AND OTHER ACTIVITIES RELATED TO THE TOPIC OF THE DISSERTATION

Tsvetan Tsokov presents two publications related to the topic of the dissertation. Both are co-authored with his scientific supervisor, and Tsvetan is the first author of both. One is presented in the proceedings of an international conference (International Conference on Service Oriented Computing), whose primary focus is on research, technology, and applications related to service technologies, cloud computing, microservices, distributed systems, and the IoT. The second was published in the prestigious journal Internet of Things (Q1 in Web of Science). Publications reflect essential elements of dissertation research. The requirements of the Law and the Regulations for its application have been fulfilled.

Elements of the thesis work have been presented at the aforementioned international conference in 2020, at the National Coding Workshop "Acad. St. Dodunekov" in 2020 and at the seminar "Problems and Methods Related to Coding Theory", organized by IMI in 2022.

NOTES TO THE DISSERTATION

I have no notes on the thesis. As a positive feature, I also note the fact that the defense is held within the year after the disenrolling, which shows that almost all the work on the preparation of the dissertation work was carried out during the studies.

CONCLUSION

The dissertation complies with the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application, and the Regulations on the Conditions and Order for Acquiring Scientific Degrees and Occupying Academic Positions at BAS and IMI-BAS for acquiring an educational and scientific degree "doctor" in a professional field 4.6. Informatics and Computer Science, doctoral program "Informatics". Tsvetan Tsokov has in-depth theoretical knowledge and excellent professional skills for conducting scientific independent research. The submitted dissertation is evidence of his skills in solving complex research tasks and ability to adapt scientific concepts in a practical environment.

I confidently give my positive assessment of the presented dissertation work and propose to the Honorable Scientific Jury to award **Tsvetan Krasimirov Tsokov** the educational and scientific degree "**Doctor**" in area of higher education 4. Natural Sciences, Mathematics and Informatics; professional field 4.6. Informatics and Computer Science; doctoral program "Informatics".

10.10.2024

Sofia

Signature:

Assoc. Prof. Krassimira Ivanova