

## **OPINION**

**on the procedure for receiving educational and scientific degree “Doctor” (PhD) in field of higher education: 4. Natural Sciences, Mathematics and Informatics, professional field: 4.6 Informatics and computer sciences.**

**Author: Tsvetan Krasimirov Tsokov, PhD student in department Mathematical Foundation of Informatics, IMI – BAS.**

**Dissertation: IoT platforms and protocols.**

**The opinion was prepared by Assoc. Prof. PhD, Zlatko Georgiev Varbanov, Faculty of Mathematics and Informatics, University of Veliko Tarnovo, field of higher education 4. Natural Sciences, Mathematics and Informatics, in my capacity as a member of the Scientific Jury according to Order No. 322/19.09.2024 of the Director of IMI-BAS and decision of the Scientific Jury (Protocol 1/30.09.2024).**

### **1. General characteristics of the dissertation and the presented materials**

As a main goal of the dissertation is to provide solution for optimal management of computational (CPU, memory, storage) and network (latency, bandwidth) resources in Cloud/Edge/Fog distributed system platforms, which involve dynamic moveable infrastructure. The proposed solution is based on supporting real-time IoT applications with mobile nodes, such as autonomous vehicles, smart cities, augmented/virtual reality, etc. The dissertation makes a comprehensive analysis of the available related works in the field and identifies several major parameters, which should be supported by one Cloud/Edge/Fog platform in order to handle effectively moveable infrastructure nodes and application’s QoS/QoE dynamically. All works, including the proposed solution in the dissertation, are compared against them and at the end the benefits of the proposal are evaluated and highlighted.

The methodology in the dissertation is based on formulating the presented problem as a mathematical optimization problem, and the most optimal solutions are found through the provided model of Mixed Integer Linear Programming (MILP). The solution was implemented using the Golang programming language. The built test cluster emulates a dynamic environment composed of geographically distributed Edge/Fog nodes moving in space. Its main objective is to evaluate how the proposed model

reduces the overall network latency of a business application in this environment. The business application used for the assessment is called Ecologic and is part of the thesis. It is essentially a practical cloud IoT application and its functionality is to measure and control carbon dioxide emissions from vehicles, making it suitable for working in smart city scenarios.

The presented dissertation consists of 70 pages in general. It contains an introduction, five chapters, conclusion, list of author's contributions, bibliography, and list of publications.

## **2. Data of the candidate**

Tsvetan Tsokov graduated with a bachelor's degree in "Computer Systems and Technologies" in 2015 and a master's degree in "Distributed Systems and Mobile Technologies" in 2017, both at Sofia University. Since 2012, he has been working in various software companies, and since March 2013 he has been in a prestigious software company. In 2019, he started doctoral program at IMI-BAS.

## **3. Content analysis of the candidate's scientific and scientific-applied achievements, contained in the presented dissertation and the publications to it, included in the procedure**

The introduction contains a presentation of the problems that are solved in the dissertation, as well as a description of the content of the following chapters. Chapter 1 contains an overview of Edge/Fog distributed systems. It includes the definitions and notations used later in the work, along with a description of the characteristics of such systems enabling their application in business. It should be noted that this chapter is too short with respect to the overall volume of the dissertation and it would have been better to be more extensive.

Chapter 2 is dedicated to the developed EcoLogic application. It is a solution for monitoring and detecting rising levels of carbon dioxide from vehicles. It is also used to evaluate the presented platform for resource scheduling in dynamic Cloud/Edge/Fog platforms with mobile infrastructure nodes. EcoLogic includes a hardware module that measures sensor data related to a vehicle's carbon dioxide emissions. The system architecture of the application is described and the results of the data analysis algorithm are presented.

Chapter 3 presents a comparative analysis of resource allocation in Edge/Fog platforms. The results analyzed relate to the main characteristics identified in Chapter 1. In Fog computing platforms, Edge-layer resources (processing, memory, storage and

network) are restricted in size and amount, but being essential for latency-sensitive applications. This has made resource provisioning in such computing platforms an important research topic. This factor makes resource allocation in such platforms an important subject of research. A very detailed overview of metrics is provided, including resource usage, cost, power, sensitivity, and network latency.

Chapter 4 presents a new mixed-integer linear programming (MILP)-based optimization model for network-aware deployment of microservice containers in dynamic Cloud/Edge/Fog infrastructures composed of mobile and constrained nodes with ARM processor architecture. The objective functions of the model maximize the total number of installed business applications, minimize the total replica movement between nodes, and minimize the network latency of the business applications to provide the best possible placement decision (scheduling). The results obtained from the application of the model are presented and analyzed in the next Chapter 5.

The last part is the conclusion and is marked as Chapter 6, although it is accepted that the conclusion should not be numbered as a separate chapter. It contains a brief description of the obtained results, as well as goals for future work. At the end of the thesis, there is a description of the scientific contributions, an approbation of the results and a list of conferences where the results were reported. A small number of spelling and stylistic errors are noticed, which do not reduce the value of the achieved results.

#### **4. Approbation of the results**

The dissertation is written on 2 papers. They are published as follows:

- 1 in proceedings of international conference with SJR;
- 1 in referenced journal with IF and quartile Q1;

These two publications are fully sufficient to fulfill the minimum national requirements (they give the candidate  $18+75 = 93$  points). In general, the presented scientific works definitely cover and exceed the minimum national requirements and, accordingly, the additional requirements of the IMI - BAS for the acquisition of an educational and scientific degree "doctor" in the scientific field and professional direction of the procedure.

#### **5. Citations of the candidate's papers**

No list of citations of the candidate's works is presented.

#### **6. Evaluation of the candidate's contribution to joint publications**

The presented publications are co-authored with the PhD student's supervisor. It is clear from the attached documents that the applicant's contribution to the joint publications is indisputable and can be considered to be equal to that of the other co-authors.

### **7. Quality of the abstract**

The abstract give a clear and adequate idea of the content and main results of the dissertation.

### **8. Conclusion**

Having become acquainted with the dissertation thesis presented in the procedure and the accompanying scientific papers and based on the analysis of their significance and the scientific and scientific-applied contributions contained in them, I confirm that the presented dissertation and the scientific publications to it, as well as the quality and originality of the results and achievements presented in them meet the requirements of the Law for the Development of the Academic Staff in the Republic of Bulgaria, the Rules for its Implementation and the corresponding Rules at the IMI - BAS for the acquisition by the candidate of the educational and scientific degree "Doctor" in field of higher education 4. Natural Sciences, Mathematics and Informatics, professional field 4.6 Informatics and computer sciences. In particular, the candidate satisfies the minimum national requirements in the professional field and no plagiarism has been found in the presented dissertation and scientific papers. Based on the above, I recommend the scientific jury to award Tsvetan Krasimirov Tsokov an educational and scientific degree "doctor" in the field of higher education 4. Natural sciences, mathematics and informatics, professional field 4.6. Informatics and Computer Science.

16.10.2024 г.

Signature:  
/Assoc. Prof. PhD Z. Varbanov/