STATEMENT

On a thesis for the acquisition of an **educational and scientific degree "PhD"**

Author of the thesis: **M.Sc. Eng. Edita Ananieva Djambazova**

Thesis topic: **STUDY OF THE DEPENDABILITY CHARACTERISTICS OF A FAULT-TOLERANT DISTRIBUTED REAL-TIME SYSTEM WITH ADJUSTABLE RELIABILITY**

Member of the scientific jury: Prof. Dr. Eng. IVAN KRUMOV KURTEV

1.   Relevance of the problem developed in the PhD thesis in scientific and scientific applied terms. Degree and levels of relevance of the problem and specific tasks developed in the thesis:

The problem developed in the thesis is extremely topical, dedicated to an interesting and modern topic in scientific and applied science. It is related to the problems of distributed computer systems with all their characteristics, allowing them to process data and exchange information with the outside world by means of sensors and actuators, giving them the opportunity to manage real processes.

This defines the main characteristic of these systems to operate under time constraints imposed by the environment. Thus, they can be defined as cyber-physical systems.

The **scientific attributes** of the present research are based on:

- **The object** of the study, which are fault-tolerant distributed systems for real-time work;
- **The subject** of the study is adjustable reliability in fault-tolerant distributed real-time systems;
- **The purpose** of the thesis is to investigate the reliability characteristics of the proposed fault-tolerant distributed real-time system with **adjustable** reliability, comparing these characteristics with known similar systems, and based on them to develop an **adjustable** reliability approach for use in fault-tolerant systems for real-time operation.

Thus, the purpose set for resolution determines the high level of relevance of the problem in scientific and scientific applied terms.

The author develops and offers his own approaches and solutions for realizing the purpose set in the PhD thesis through **four specific tasks**:

1. To make a study, a survey, and a critical analysis of dependable distributed systems. To synthesize a classification of the existing dependable distributed systems. To outline the research opportunities in structural redundancy distribution;

2. To propose a model and architecture of a fault-tolerant distributed system with adjustable reliability that gives a solution to the high-reliability requirements of the application;

3. To define a research method for the study of the proposed model. To develop a tool applying the method. To compose a research protocol;

4. To design and conduct experimental research to test and analyze the dependability characteristics of the proposed fault-tolerant system with adjustable reliability using the chosen research approach and developed software product. To develop and implement an adjustable reliability approach.

The set tasks have been developed in the individual chapters of the PhD thesis submitted for this competition, and each of the tasks is the subject of five author's publications in editions with high scientific applied and scientific levels.

The Ph.D. thesis is organized into: **Introduction, four Chapters, Conclusion and future work, List of publications on the PhD thesis, Approbation of the results, Main scientific and applied scientific contributions, Declaration of originality, Bibliography, two Appendices A and B.**

The **Introduction** briefly describes the actuality of the topic, the object and the subject of the PhD thesis, as well as the motivation for carrying out this dissertation research. The goal of the PhD thesis and the tasks to achieve it, the leading hypothesis and the applied methodology in the conducted research are set.

The presented in **Chapter 1."Dependable distributed real-time systems"** corresponds to **the implementation of Task 1**. The results achieved in this chapter are based on the creation of a conceptual model of a decision-making approach in ensuring guaranty and a proposal for the synthesis of a classification of guarantee able distributed systems with structural redundancy.

The architecture of the system, proposed by the author, is created and the methods for modeling the system are presented in **Chapter 2. "Modeling of the fault-tolerant distributed system with adjustable reliability"**, and the model and assumptions of such a system are synthesized. The investigated reliability characteristics are described, on the basis of which this system can be evaluated and compared with other similar ones. The scientific results achieved here are concluded in the choice of a research approach –

simulation modeling, on the basis of which a model of the proposed fault-tolerant distributed system with adjustable reliability was created. As well as synthesizing an author's architectural model of such a system with the definition of requirements for its components and for it as a whole. These scientific results fulfill **Tasks 2 and 3**.

Chapter 3."Study of the fault-tolerant system with adjustable reliability" is devoted to the research tasks and the obtained results of a simulation study of this system. For this purpose, a software product was created - a **simulation program - Appendice B**, developed according to the requirements specified in this chapter. The basic structure and block diagram of the program for simulation modeling of the system with adjustable reliability are presented, based on the research protocol developed in this chapter. The reliability characteristics of system components and the entire system such as reliability, availability, mean time to failure, mean time to repair were studied. The adjustable reliability approach developed in the dissertation is presented, which allows choosing an appropriate configuration of the structural redundancy depending on the overall system reliability requirements of the application. The scientific and applied scientific contributions achieved here fulfill **Tasks 3 and 4** of the PhD thesis.

Analysis and discussion of the results are made, and the advantages and possible applications of the proposed system are indicated in **Chapter 4."Discussion and analysis of the results"**. The main results of the PhD thesis, generated so far, are brought out, which present its scientific, scientific and applied contributions. Opportunities for further research and application of a fault-tolerant distributed system with adjustable reliability are outlined.

In the development of the present work, an appropriate mathematical apparatus, presented in **Appendix A**, is used, based on the theory of probabilities and mathematical statistics, and the mathematical representations of the reliability characteristics used in the study are derived. The application of this mathematical apparatus for the mathematical expression of the attributes of guarantee ability, as well as the study of reliability characteristics of **fault-tolerant** systems, proves the high level of that developed scientific work.

The **Conclusion and Future Work**, which summarizes the obtained results and directions for future development of the considered problem, precisely defines the achieved results, summarizing them and setting the aspects of the future development of the considered problem arising from the achieved results of the present work. These results confirm the degree and level of relevance of the subject matter developed in this PhD thesis, which provides the present work a high level in its presentation for external PhD thesis defense.

The fact that some of the developments on the topic of the doctoral student's dissertation are included in the work on two national projects makes a very good impression, and the author has conducted significant experiments in the development of the tasks set in the work.

2.   Degree of knowledge of the state of the problem and creative interpretation of the literary material:

The degree of knowledge of the problem and the creative interpretation of the literary material by the doctoral student covers 97 sources out of a total of 102, presented in a period from 1973 until 2022, which I justify in item 6 "Opinions, recommendations and notes". All literary sources are on the issues of this dissertation work. Almost all of them or 94 pcs are in English, 2 pcs in Bulgarian and 1 pc in Russian. With the bibliography used in this way, the author of the dissertation shows a high degree of knowledge of the current state of the problem, by giving a creative interpretation of the review material that is appropriate in terms of volume and content. Thus, he shows his high erudition as a specialist in the theory and practice presented by the world's leading authors on the study and modeling of fault-tolerant distributed systems for real-time operation.

3.   **Correspondence of the chosen research methodology and the set goal and tasks of the dissertation with the contributions achieved:**

The main tasks specified by the author correspond to the purpose set in this dissertation work. The applicability of the developed model and approach for analyzing a fault-tolerant distributed system with adjustable reliability is correctly indicated. As well as the designed and implemented software product for simulation modeling of this type of system under investigation using modern, latest generation and generally available standard and specific software tools.

On the basis of solving these tasks, the 8 (eight) contributions achieved by the PhD student are indicated in three groups, which I accept in their presented content.

This gives me reason to give a high degree of correspondence between the tasks set for implementation and the achieved contributions of this PhD thesis, which proves the results achieved by the author, reflected in his scientific work.

4.   Scientific, applied scientific and applied contributions of the PhD thesis:

As I have already reflected above, the PhD student defines 8(eight) contributions, with a further appended contribution added to his internal defense preliminary material. All these contributions, the result of his dissertation work, show the high scientific, applied scientific and applied levels he has achieved in the materials presented under this procedure. The PhD student proves with a new model and approach developed by him for the analysis of fault-tolerant distributed systems for real-time operation of the existing problems to solve them in their applicability.

All defined contributions in the three groups correctly prove the research carried out by the author using the methods and tools offered by him, which defines the model and approach he developed for the analysis of a fault-tolerant distributed system with adjustable reliability, as well as the designed and implemented software product. These contributions are actually possible for use and implementation in future work on this topic.

On the basis of the above in this point, I assess the mentioned contributions as sufficiently significant for science and especially for practice. I believe that the contributions achieved cover and exceed the normative requirements of one PhD thesis and, in parallel, ensure the future scientific development of the PhD student in his chosen field.

5.   Evaluation of publications on the PhD thesis:

In the current competition, the author participated with 5 (five) publications for the period of 1995 until 2023. These publications present the tasks set in the dissertation work, being published in sufficiently prestigious forums and editions: one referenced and indexed in Scopus and four in non-refereed editions with scientific review - national and international, all on the subject of the PhD thesis. Of all of these, 3 (three) are independent and two co-authored, with 4 (four) being in English and 1 (one) in Bulgarian. I have not found the cited and indicated impact factor, as well as indexing of these publications from foreign libraries.

In general, I allow myself to give a high assessment of the author's publications on his PhD thesis, noting explicitly that they meet the normative criteria of the LAW on the development of the academic staff in the Republic Bulgaria (LDASRB), the Regulations to the mentioned law and the Regulations of the BAS and IICT for the implementation of that law.

6.   Opinions, recommendations and notes:

After my detailed acquaintance with the materials provided to me – thesis abstract, PhD thesis and publications on this thesis, I can express my positive opinion on their arrangement and presentation, so that they can be properly evaluated by the members of the scientific jury under this procedure.

Based on the **declaration of originality** available in the dissertation and on the basis of my opinion formed from the materials presented to me, I can state that the **present PhD thesis work fully meets the requirements of academic integrity as a scientific work by containing original results**. The results, published on this topic by other scientists are duly cited in the bibliography of the present PhD thesis, which has not been applied for the acquisition of a scientific degree in another scientific and academic structure.

I would like to note here that all my remarks from my written opinion on the preliminary material of this dissertation work are reflected in the materials submitted for external defense.

I express here my own opinion and have notes on the editing of contributions #4, #7 and #8, for which I offer a clearer presentation to strengthen the author's achievement:

No4. A conceptual model of an approach for decision-making in providing dependability is developed after a critical analysis of dependable distributed systems.

No7. An approach of adjustable reliability is developed and applied, based on a comparative analysis of the fault-tolerant system with adjustable reliability and systems without structural redundancy distribution.

No8. A simulation program is created that can be used for modeling and studying the dependability characteristics of other fault-tolerant systems, as well as to investigate the impact of transient hardware failures.

As well as my opinion, that from the presented literary material I do not consider items 44, 73, 74, 76, 94, which represent the author's publications on this dissertation work, evaluated by me here in item 5.

1.   Conclusion:

In general, I give a positive assessment of the materials presented to me by the author of this PhD thesis. They contain more than the necessary number of scientific, applied scientific and applied contributions, all of them with proven significance for participation in this procedure, as the specified materials meet and exceed the requirements of the LDASRB and its Regulations, as well as the Regulations of the Bulgarian Academy of Sciences (BAS) and the Institute of Information and Communication Technologies in the BAS for obtaining the educational and scientific degree "DOCTOR / PhD".

Based on my familiarity with the presented materials, their importance, the scientific, applied scientific and applied contributions contained in them, I find it reasonable to strongly recommend to the members of the scientific jury to vote positively for awarding a M.Sc. Eng. **EDITA ANANIEVA DJAMBAZOVA** of the educational and scientific degree "DOCTOR / PhD" in the Field 5."Technical sciences", Professional direction 5.3."Communication and computer engineering" and Doctoral program "Computer systems, Complexes and Networks".

The 14ᵗʰ August 2023.   **MEMBER OF THE SCIENT**

На основание

ЗЗЛД

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