

## REVIEW

by Assoc. Prof. Dr. Eng. Radoslava Nikolova Gabrova,  
University of Food Technology, Plovdiv

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

in the field of higher education 5 *Technical sciences* professional field 5.3. *Communication and computer technology* doctoral program "Automation of areas of the intangible field (medicine, education, science, administrative activities, etc.)

**Author:** MEng. Stanislav Mitkov Assenov

**Topic:** "Design, research and optimization of wireless sensor nodes with low power consumption"

**Supervisor:** Assoc. Prof. Dr. Dimitar Mihailov Tokmakov - Paisii Hilendarski University of Plovdiv

### 1. General description of the submitted materials

With order № P33- 3478 from 19.07.2021. of the Rector of Plovdiv University "Paisii Hilendarski" (PU), I am appointed a member of the scientific jury on the procedure for defense of the dissertation of Stanislav Mitkov Assenov, MSc on "Design, research and optimization of wireless sensor nodes with low power consumption" presented for acquiring educational and scientific degree " doctor " in the field of higher education 5 Technical sciences, professional field 5.3. Communication and computer engineering, doctoral program " Automation of areas of non-material sphere (medicine, education, science, administrative activity, etc.) doctoral training Mag. Eng. Stanislav Mitkov Assenov took place in regular form to the department "Electronics, communications and information technologies" (ECIT) at Plovdiv University "Paisii Hilendarski" and supervisor Assoc. Prof. Dr. Dimitar Mihailov Tokmakov, member of the academic staff of the cited primary unit.

Presented by Mag. Eng. Stanislav Mitkov Assenov set of materials on paper is in accordance with Art. 36 (1) of the Regulations for the development of the academic staff of PU and includes the following documents:

- Application to the Rector of PU ent. № K1-62 / 20.07.2021 for opening the procedure for defense of dissertation.
- Autobiography in European format.
- Transcript-extract from the Minutes of the Department Council at the Department of ECIT (PU) № 31 / 30.06.2021, item 1 Preliminary discussion of the dissertation of Stanislav Assenov;
- - Dissertation work in a volume of 165 p.
- A second abstract in the amount of 32 pages.

- List of scientific publications on the topic of the dissertation - 8 scientific publications.
- Copies of the 8 scientific publications submitted under the procedure.
- List of noticed citations - 7 pieces.
- Declaration of originality and authenticity of the attached documents.

## **2. Brief biographical data about the doctoral student**

According to the presented autobiography, doctoral student mag. Eng. Stanislav Mitkov Assenov in 2006 graduated from secondary special education with a degree in Electronic Computing at the Professional High School of Engineering and Technology "Hristo Botev" - Smolyan. In 2010 he obtained a bachelor's degree in Computer Systems and Technologies at the Technical University of Sofia, Plovdiv branch, and in 2014 he received a master's degree in the same specialty from the University of Food Technology, Plovdiv.

By order № P33-573 from 01.02.2019 of the Rector of Plovdiv University "Paisii Hilendarski" (PU) he is enrolled in doctoral studies.

His career began as a teacher of special subjects in the field of "Computer Systems" at PGTT "Hristo Botev", Smolyan, and since 2017 he has worked as an assistant at the Faculty of Physics and Technology at PU "Paisii Hilendarski", Smolyan branch.

He has competencies in programming, database, computer networks and more areas of computer science.

## **3. Relevance of the topic and expediency of the set goals and objectives**

With the development of technology and technology in recent years, wireless sensor networks are attracting increasing interest from professionals in view of their practical application. The use of wireless sensor networks gives a new approach to the task of measurement and control - they allow easy measurement of physical quantities such as temperature, humidity, pressure and more, especially in hard-to-reach, remote or dangerous places, using the wireless architecture. Their flexibility allows for integration into existing measurement system solutions.

Wireless sensors are one of the main blocks of wireless sensor networks. Their increasing use in modern technologies requires the search for continuous improvement, which should be based on in-depth theoretical analysis of problems and the search for practical solutions. One of the main problems with wireless devices is the need for an autonomous power supply, and this problem becomes even more complicated with the requirements for small sizes of sensors, respectively - small sizes of batteries. This requires wireless sensors to operate under very strict limits on energy consumption for longer sensor life.

The presented dissertation work is related to the design, research, and optimization of wireless sensor nodes with low energy consumption and to offering methods and hardware solutions for optimizing the energy consumed by them.

From the above and from the presented work it can be concluded that the peer-reviewed dissertation is related to a current problem in scientific and scientific-applied terms.

The main goal of the research formulated in the dissertation is " to design, research and optimize wireless sensor nodes by applying new approaches and technological solutions leading to a reduction in their energy consumption."

To achieve this goal, the doctoral student has formulated four tasks corresponding to the main tasks in each research - problem analysis, solution proposition and experimental justification and analysis of the applicability of the proposed solutions, as follows:

1. Study of the existing methods and means for minimizing the energy consumption of the wireless sensor nodes.

2. Creation and research of an energy efficient model of LoRaWAN wireless sensor nodes with low energy consumption.

3. Design, research, and optimization of wireless sensor nodes with low power consumption, hardware, and software, including in its architecture modern powerful and low-energy microcontrollers.

4. Design and research of wireless sensor nodes with low energy consumption with harvester systems and battery-free power supplies.

#### **4. Knowledge of the problem**

In the literature review, the doctoral student has examined the current state of the problem and has studied the existing technologies and modern methods for the implementation of wireless sensor nodes with low power consumption. He got acquainted with the main results in the field, considering the types of wireless sensor nodes with low consumption in terms of architectural features, transmission technologies, power sources and analysed the indicators of energy efficiency and consumption. The PhD student has studied the models of energy consumption by various IoT technologies, focusing on the energy models of LPSAN and LPWAN technologies. He has classified the techniques used to ensure energy efficiency of wireless sensors.

From the literature research the doctoral student has highlighted problems related to the contradiction between the requirement for autonomy of wireless sensors and their limited power supply and on this basis has defined the need to develop new methods and technological solutions leading to reducing energy consumption by endpoints.

A thorough literature review of the problem has enabled the doctoral student to gain a good and in-depth knowledge of the studied issues and on this basis to correctly formulate the purpose and objectives of the dissertation.

The doctoral student's literature consists of 165 sources, all in English, which shows that he is familiar with global trends in the field of wireless sensors.

#### **5. Research methodology**

In connection with the implementation of the formulated goal of the dissertation, the doctoral student has used various theoretical and practical approaches and methodologies to solve the tasks. The object of the study is the wireless sensor node, as a main element of the wireless sensor net-

works, and the subject of the study is its energy efficiency, ie. the possibilities for reduction of energy consumption.

Methodically the doctoral student mag. Eng. Stanislav Assenov has correctly structured his work, observing the stages characteristic of each scientific research.

The first chapter is the dedication of the first stage of each study, which is an analysis of the problem. It includes a literature review of the issue, formulation of the goal and tasks.

The next second, third and fourth chapters are related to one of the tasks - to the second, third and fourth tasks, respectively. Each of these chapters is structured according to the need for the other three important stages of the research - ideas for solving the problem, realization of the ideas and conducting experiments and analysis of the obtained results.

In a second voice, the parameters influencing the energy consumed by the wireless LoRaWAN sensor nodes are defined and studied, and a more energy efficient LoRaWAN algorithm is proposed, implemented and studied.

In the third chapter are designed, implemented, and studied four hardware and software solutions for wireless sensor nodes, optimizing energy consumption, and for analysis of the results a comparison is made with their convection implementations.

In the fourth chapter the following are proposed and studied: a mathematical model for determining the values of the capacitors of the capacitors depending on the magnitude of the harvester current; a simulation model of a battery-free sensor unit developed in the middle of MATLAB; two battery-free wireless LoRaWAN end sensor nodes for IoT applications.

The doctoral student has demonstrated abilities to deal with a wide range of complex tasks, which is evidence of in-depth training. The methodology used is correctly selected in accordance with solving the tasks and achieving the goal.

Therefore, from a methodological point of view, in his work the doctoral student has demonstrated the necessary scientific culture and professional skills.

## **6. Characteristics and evaluation of the dissertation**

The dissertation presented for review has a total volume of 165 pages and contains 96 figures (photos, diagrams, graphs), 26 tables and 47 formulas. 165 literature sources were used, all in English. The dissertation consists of an introduction, four chapters, a summary of the results, contributions to the dissertation, a list of scientific papers on the dissertation, approbation, citations, and references. The dissertation is designed according to the requirements, the figures are clear and understandable with appropriate size. The content and text are well structured.

The dissertation research was conducted within the framework of a doctoral program at the ECIT Department of the University of Plovdiv, based on which the main research, design and experimental activities were performed. The doctoral student has participated in three projects with topics related to the field of the dissertation - in one project at the NSF at the University of Doctoral Studies and in two projects under the National Program "Young Scientists and Postdoctoral Students".

In the dissertation work various models and circuit solutions for wireless sensor nodes with low energy consumption are proposed, developed, and researched. Analyses have been made for the effectiveness of the proposed funds, which largely confirm the adequacy of the proposed solutions.

Some of the obtained results were presented at specialized scientific forums, such as Mag. Eng. Stanislav Assenov has presented eight scientific papers, six of which are in scientific journals, referenced and indexed in Web of Science and Scopus.

## **7. Contributions and significance of development for science and practice**

In the presented dissertation there is a correspondence between the goal, the set tasks for its realization and the presented results from the conducted theoretical and experimental developments and in essence the work contains results that can be defined as scientific-applied and applied contributions.

At the end of each of the main chapters (second, third and fourth) a conclusion is made about the usefulness and effectiveness of the proposed solutions and contributions are formulated from the developments in the specific section.

At the end of the dissertation the contributions are united in a general list, as they are divided into two categories - scientific-applied and applied. I believe that the claims presented by the doctoral student with classification of the contributions correspond to and detail the obtained results, according to the specifics of their significance.

Four scientific and applied contributions have been formulated, which refer to:

- development and implementation of energy efficient LoRaWAN protocol, providing reduction of consumed energy.
- development of a mathematical model of the energy life cycle of a battery-free wireless sensor unit.
- creation of a simulation model of a battery-free sensor unit.
- Proposals for innovative circuit solutions to reduce the energy consumption of LoRaWAN wireless sensor nodes in low energy mode.

The six contributions presented in the dissertation can be summarized as follows:

- determination of the parameters influencing the energy consumed by the wireless LoRaWAN sensor nodes.
- design, development, and research of sensor nodes with low energy consumption, realized on the basis of three different microcontrollers.
- development and research of two battery-free wireless LoRaWAN end sensor nodes.

In connection with the growing penetration of wireless sensor networks, I believe that the contributions received can be defined as significant in practice.

## **8. Evaluation of the publications on the dissertation**

The author has presented a list of 8 works, including two in Bulgarian and six in English. There is one separate publication, seven co-authored with scientific supervisor, and in one of the publications they have another co-author. By topics, these 8 publications are related to the topic of the dissertation.

Six of the publications are in scientific journals, referenced and indexed in the world-famous Web of Science or Scopus databases, four of which were presented at the National Conference with International Participation ELECTRONICA (two in 2020 and two in 2021 in print), one - at the National Conference with International Participation TELECOM 2020, one - at the International Scientific Conference Electronics' 2019.

Two of the publications are in refereed editions - Scientific papers of the Union of Scientists in Bulgaria - Plovdiv (one in 2020 and one in 2021 in print).

According to the report on citations, six citations were noticed for one of the publications, three of which were by foreign scholars.

The data presented in this way give me reason to conclude that the necessary publicity of the research in the dissertation has been ensured.

## **9. Personal participation of the doctoral student**

Of the eight publications on the dissertation presented and essentially reflecting the results of the development, in six the doctorate is in first place, and in one it is an independent author. This testifies to the significant contribution of the doctoral student to the obtained results.

## **10. Abstract**

The abstract is 32 pages long and reliably reflects in summary form the content of the dissertation, containing a general description of the dissertation, purpose and tasks, results of the literature, the main highlights of the doctoral students work, presented in the second, third and fourth chapters, main contributions and scientific papers on the dissertation.

## **11. Critical remarks and recommendations**

The doctoral student has complied with some of the remarks and recommendations presented by me, as a reviewer in the preliminary discussion procedure before the Extended Department Council at the ECIT Department at the University of Plovdiv and are reflected in the final version of the dissertation.

The work would only benefit if in some places more detailed explanations are given for determining some parameters, for specific conditions of conducting the experiments and motives for the choice of the elements in the proposed circuit solutions.

The remarks made in no way belittle the significant amount of research carried out, but can only be considered as recommendations, especially for the future scientific activity of the doctoral student.

## CONCLUSION

The dissertation is a valuable scientific work, and the doctoral student has fulfilled the set goals and objectives.

The dissertation **contains original scientific-applied and applied results** and **meets the** requirements of the Law for development of the academic staff in the Republic of Bulgaria (LDASRB), the Regulations for application of LDASRB and the respective Regulations of PU "Paisii Hilendarski" for awarding ESD "Doctor".

The dissertation shows that the doctoral student MEng. Stanislav Mitkov Asenov **has a** profound theoretical knowledge and professional skills in the scientific field 5.3 Communication and computer equipment, as **demonstrated** qualities and skills to independently conduct research.

**I definitely give my positive assessment of the peer-reviewed dissertation, presenting a study with original results and contributions, and I suggest that the esteemed scientific jury award the ESD "Doctor" to Mag. Eng. Stanislav Mitkov Assenov in the field of higher education: 5 Technical sciences, professional field 5.3 Communication and computer technology, doctoral program "Automation of areas of the intangible field (medicine, education, science, administrative activities, etc.)".**

30.08.2021

Reviewer:.....

(Assoc. Prof. Dr. Eng. Radoslava Gabrova )