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OPINION

by **Prof. Dr. Georgi Petrov Dimitrov** – member of the academic jury for awarding the educational and scientific degree **of "Doctor"** in professional field **4.6 "Informatics and Computer Sciences**," doctoral program "Informatics," pursuant to a procedure announced by the University of Economics – Varna

1. General Information

Opinion prepared by: Prof. Dr. Georgi Petrov Dimitrov, Department of "Information Systems and Technologies," University of Library Studies and Information Technologies (UniBIT)

Basis: Pursuant to the Order of the Rector of the University of Economics – Varna and the Decision of the first meeting of the Scientific Jury

Author of the dissertation: Author of the dissertation: Petar Dimitrov Dimitrov – doctoral student in professional field 4.6 "Informatics and Computer Science," PhD Program **in** "Informatics" **Thesis Topic:** "Universal Two-Factor Authentication for the Protection of Web-Based Information Systems"

2. General presentation of the dissertation

The dissertation is 168 pages long, including 26 figures, 5 tables, and 129 references, and is structured into an introduction, a main body consisting of three chapters, a conclusion, and a list of references.

In terms of structure, the work is well-balanced and logically coherent. It includes figures, tables, and appendices that aid in understanding the main text.

The relevance of the study is indisputable and stems from the growing cyber threats and the limitations of traditional password-based authentication. As noted in the introduction, a significant proportion of security breaches are due to compromised credentials, which necessitates the implementation of more secure authentication mechanisms.

The research objective of this dissertation is to develop a conceptual and an architectural model for a universal two-factor

authentication based on the FIDO2 and WebAuthn standards, which ensures a high level of security and practical applicability in web-based systems.

3. To achieve this goal, tasks have been formulated related to:

- analysis of existing authentication methods;
- researching the FIDO2/WebAuthn standards;
- designing an architectural model;
- development and testing of a prototype system.
- Publications and Participation in Scientific Forums

The doctoral candidate presents a total of 7 scientific publications (3 articles and 4 conference papers), which reflect the main results of the research and meet the minimum national requirements for the award of the educational and scientific degree of "Doctor."

4. Assessment of the structure and content of the dissertation

The dissertation is structured into three main chapters:

- Chapter One examines the theoretical foundations of authentication, including the limitations of passwords and modern security threats. Various approaches are analyzed, such as OTP, cryptographic methods, and the standards of the FIDO Alliance.
- Chapter Two presents the developed authentication model based on FIDO2/WebAuthn, including conceptual, logical, and communication models, as well as an analysis of security and performance.
- The third chapter is devoted to the practical implementation and deployment of the proposed solution in a web-based environment, including integration into a PHP/MySQL system and an analysis of its applicability in a real institutional environment.

The abstract accurately reflects the content and main results of the dissertation.

5. Identification and evaluation of the scientific and applied scientific contributions

I accept the following major contributions:

A. Theoretical contributions:

- An in-depth analysis of existing authentication mechanisms and their vulnerabilities has been conducted;
- A conceptual model for universal two-factor authentication based on FIDO2/WebAuthn has been formulated;
- Logical and communication models for integration into web-based systems have been developed;
- Surveyed are contemporary threats anda proposed a model for resilience against them.

B. Scientific-applied and applied contributions:

- A system architecture for strong authentication has been designed;
- A prototype system with WebAuthn integration has been implemented;
- A an an of security, usability and applicability;
- Demonstrated has the ability for implementationin real institutional environment.

6. Plagiarism: Detected or Undetected

No evidence of plagiarism was found in the dissertation or the abstract. The citation of sources is correct and complies with academic requirements.

7. Critical comments and recommendations

The following recommendations can be made:

- The experimental section could be expanded through broader testing with real users;
- Conduct a more in-depth analysis of usability through empirical research;

- The possibilities for integration with other platforms outside the chosen technological environment should be examined in greater detail.

The comments noted above do not diminish the scientific value of the work.

8. Questions for the doctoral candidate

I have no questions for the doctoral candidate.

Conclusion

The dissertation constitutes an independent scientific study with clearly defined scientific and applied scientific contributions. The work is timely, well-structured, and demonstrates in-depth knowledge in the field of information security and web technologies.

I consider that the dissertation meets the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria and the regulations for its implementation.

I propose that the distinguished academic jury award Petar Dimitrov Dimitrov the educational and scientific degree of "Doctor" in professional field 4.6 "Informatics and Computer Sciences."

April 6, 2026 Signature: [redacted]

..... Sofia /Prof. Dr. G. Dimitrov/

ИКОНОМИЧЕСКИ УНИВЕРСИТЕТ - ВАРНА
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STATEMENT

by Assoc. Prof. Ivan Kuyumdjiev, PhD
on the doctoral dissertation entitled "Universal Two-Factor Authentication for the Protection of Web-Based Information Systems"
authored by doctoral candidate **Petar Dimitrov**

Grounds: This statement is prepared based on Rector's Order No. RD-06-32/30.01.2026 of the University of Economics - Varna, concerning the appointment of a scientific jury, and the decision of the scientific jury in the open procedure for the defence of a doctoral dissertation.

I. General Presentation of the Doctoral Dissertation

The dissertation comprises 164 pages and includes a list of abbreviations, an introduction, three chapters, a conclusion, a statement of contributions, a bibliography of 129 sources, and a list of publications related to the dissertation.

The **object** of the study is the authentication processes in distributed web environments that handle sensitive data and require reliable verification of user identity.

The **subject** of the study encompasses the architectural solutions, cryptographic protocols, and technologies for implementing universal two-factor authentication based on the FIDO2 and WebAuthn standards, as well as contemporary methods for protecting web applications against current attack vectors.

The **purpose** of the dissertation is to develop a conceptual model and architecture for universal two-factor user authentication in web-based information systems, grounded in the FIDO2/WebAuthn standards, which provides a high level of cryptographic protection using modern algorithms and protocols in accordance with best practices in information security.

The topic is timely and the problems addressed are of critical importance both for cybersecurity and for the processes of digitalisation in Bulgarian higher education. The bibliography is current - over 70% of the sources have been published within the last five years.

Chapter One (approximately 45 pages) traces the evolution of authentication methods from the earliest systems to the modern FIDO2 standards, analyses the weaknesses of historical approaches to storing

authentication data, examines the qualified electronic signature as an authentication mechanism, presents a critical analysis of contemporary threats, and concludes with a clearly formulated scientific problem justifying the need for a new authentication model.

Chapter Two (approximately 40 pages) develops a conceptual model, defines the principal participants in the authentication process and their interrelationships, elaborates a logical model (entity-relationship diagram of the database), describes the communication model with TLS/HTTPS-secured flows, presents in detail the structure and mechanisms of the WebAuthn and CTAP2 protocols, conducts a security and performance analysis, and examines the criteria for authenticator selection along with the integration challenges associated with institutional deployment.

Chapter Three (approximately 46 pages) is devoted to the practical deployment of WebAuthn within the information system of the University of Economics - Varna. It presents the integration into the existing PHP/MySQL environment, the system components, the server configuration, the registration and authentication processes, and both hardware and platform authenticators. The chapter concludes with a proposal for using WebAuthn in the signing of student grades - constituting an advanced electronic signature under Regulation (EU) 910/2014 - which represents a significant contribution of the dissertation.

II. Publications and Participation in Scientific Forums

The doctoral candidate's publications and scientific activities have been reviewed for compliance with the quantitative requirements of the Regulations for the Development of the Academic Staff at the University of Economics - Varna, and with the minimum national requirements for the award of the educational and scientific degree of "Doctor" under the Law on the Development of the Academic Staff in the Republic of Bulgaria. Full compliance with the stated requirements has been established.

III. Assessment of the Structure and Content of the Doctoral Dissertation

The structure of the doctoral dissertation conforms to the stipulated requirements of the Regulations for the Development of the Academic Staff at the University of Economics - Varna. The dissertation is composed of several sections, including a title page, a table of contents, an introduction, the main body of the dissertation, a conclusion with a declaration of originality, and a

bibliography. The abstract succinctly encapsulates the dissertation's primary content and contributions. The writing style is consistently proficient, exhibiting a clear structure and logical progression. The transitions between chapters are meticulously constructed, supported by summaries and coherent connectives.

IV. Scientific and Applied Contributions

The following principal contributions of the doctoral dissertation are identified:

1. The concept of WebAuthn as a paradigm for authentication that overcomes the fundamental vulnerabilities of password-based mechanisms has been theoretically substantiated.
2. An architectural model for the deployment of WebAuthn in a university web-based information system has been developed, adapted to the Bulgarian academic context and to an existing PHP/MySQL infrastructure.
3. A practical integration of WebAuthn has been realised within a real university information system (WSDB of the University of Economics - Varna), demonstrating a complete and fully operational cycle of registration and authentication using FIDO2-compatible authenticators.
4. A mechanism for the cryptographic signing of actions - specifically, the entry and signing of student grades - based on WebAuthn has been proposed and experimentally validated; this mechanism ensures the binding of the authenticated identity to a specific action within the university information system.

V. Findings on Plagiarism

A review of the doctoral dissertation and the abstract using the StrikePlagiarism system yielded similarity scores of CS1 = 30.35% and CS2 = 27.22%. These values were approximately zero at the time of the most recent internal review at the primary academic unit and warrant clarification from the candidate at the defence.

VI. Critical Remarks and Recommendations

The following recommendations are proposed with a view to facilitating broader dissemination of the proposed solution within the Bulgarian higher education system:

1. The publication of the developed source code on GitHub under an appropriate open-source licence would enhance the security and quality of the implementation in accordance with the principle known as Linus's Law.

2. In the event of the solution being extended for deployment across a further universities, it is recommended that the PHP library lbuchs/WebAuthn be replaced with an alternative that has been adopted more widely and is FIDO-certified, such as spomky-labs.

VII. Questions for the Candidate

1. How could the proposed authentication model be adapted for environments with limited technical infrastructure or restricted digital literacy among users?
2. What concrete steps do you envisage for future mitigation of the threats posed by post-quantum cryptography within the context of the proposed model?

VIII. Conclusion

The dissertation presents a complete and coherent concept for the deployment of WebAuthn in a university information system, supported by a genuine implementation and significant applied results.

Based on the review conducted, I give a **positive assessment** of the doctoral dissertation entitled "Universal Two-Factor Authentication for the Protection of Web-Based Information Systems", authored by Petar Dimitrov Dimitrov, and **propose that the scientific jury vote in favour of awarding the educational and scientific degree of "Doctor"** to doctoral candidate Petar Dimitrov Dimitrov.

09.04.2026 г.
Varna

Respectfully:
/ Assoc. Prof. Ivan Kuyumdjiev, PhD /

OPINION

by Assoc. Prof. Dr. Eng. Boyan Kolev Jekov
University of Library Science and Information Technology (UniBIT) – Sofia
in the academic position of **"Associate professor" in field 4.6 "Informatics and Computer Sciences** ", entered in the register of habilitated persons with scientometrics indicators of NACID

Regarding the dissertation for the acquisition of the educational and scientific degree " **DOCTOR** ":

Field of higher education:	4. "Natural Sciences, Mathematics and Informatics"
Professional field:	4.6. "Informatics and Computer Science"
Doctoral program:	"Informatics" at the University of Economics (UE) - Varna
Author of the dissertation:	**Petar Dimitrov Dimitrov**
Topic of the dissertation:	**Universal two-factor authentication for protecting web-based information systems**
Scientific supervisor:	Prof. D.Sc. Pavel Petrov
On the grounds of:	Order No. RD-06-32/30.01.2026 of the Rector of the University of Economics (UE) – Varna and decision of the scientific jury of 11.02.2026.

Based on the documents provided to me, I express the following opinion:

1. General presentation of the dissertation work

Petar Dimitrov Dimitrov's dissertation is dedicated to one of the most pressing problems in modern cybersecurity - reliable authentication of user identity in distributed web environments. In the context of mass digitalization and escalating threats such as phishing, replay attacks and password compromise, the research focuses on the FIDO2 and WebAuthn standards as a modern alternative to traditional authentication methods.

The work is presented in a volume of **167 pages,** including 26 figures, 5 tables and a list of abbreviations used. The bibliography includes **129 sources,** most of which are current international standards, W3C and FIDO Alliance specifications, as well as modern scientific publications in the field. The structure of the dissertation includes an introduction, three chapters, a conclusion and a list of contributions, which demonstrates logical consistency and completeness of the scientific research.

2. Assessment of the structure and content of the dissertation

The dissertation is structured in a way that allows for a smooth transition from theoretical analysis to practical implementation.

- **Chapter 1** provides a detailed overview of the evolution of authentication technologies – from storing passwords in plaintext to the use of cryptographic hash functions, one-time passwords (OTPs), and qualified electronic signatures. The author **critically analyzes the vulnerabilities of traditional models** and justifies the transition to phishing-resistant mechanisms.

- **Chapter Two** is the core of scientific modeling. In it, the author develops **a proprietary architectural model** for universal two-factor authentication, including conceptual, logical, and communication levels. Of particular value is the analysis of security and performance, which places the theoretical statements in the context of real-world exploitation.
- **Chapter 3** describes the practical implementation of WebAuthn in the information system of the University of Economics – Varna (WSDB). Here, the integration into an existing PHP/ MySQL environment is demonstrated and an innovative approach is proposed for using WebAuthn for cryptographic signing of academic actions (e.g., grading), which goes beyond the scope of simple authentication.

Opinion on the abstract: The abstract (35 pages) correctly and completely reflects the main points, structure and contributions of the dissertation work. It is prepared in accordance with the regulatory requirements and provides a clear idea of the results achieved.

Lexical and stylistic feature: The work is written at a highly professional level, using precise terminology in the field of informatics and cybersecurity. **The style is academic, concise, and logically consistent,** which makes the complex material understandable and well-founded.

3. Identification and evaluation of scientific and applied science contributions

The dissertation highlights several significant contributions, which can be classified as follows:

Scientific contributions:

- Theoretical justification of the concept of WebAuthn as a new paradigm that eliminates shared secret strings and replaces the password model with cryptography using public and private keys.
- Development of a conceptual and architectural model for phishing-resistant authentication, adapted to distributed web environments and university information systems.

Scientific and applied contributions:

- **Implementation of a working prototype** and integration of WebAuthn into a real university system (WSDB of the University of Varna) on an existing PHP/ MySQL infrastructure.
- **Development of a logical data model** (ER diagram) supporting multiple authenticators for a single user, tracking security counters, and IP/geolocation logging.
- **Mechanism for cryptographic confirmation of actions:** An experimentally validated model for signing student grades via WebAuthn has also been proposed, ensuring the provability and integrity of data in the learning process.

4. Critical notes and recommendations

The dissertation work is of an extremely high level, but in the spirit of academic discussion, the following notes and recommendations can be made to build on what has been achieved:

1. The research is focused primarily on a PHP/ MySQL environment. Although this is fully justified by the context of the University of Varna, **future research** could extend the analysis to microservice architectures (e.g., using Python /Go with NoSQL databases).

2. The analysis of post-quantum cryptography relies mainly on prognostics. I recommend that the author **experiment with hybrid signature schemes in his future work,** when standard libraries start supporting them.

3. Regarding usability, the author relies on existing empirical data (SUS scale). A large-scale **user survey among the students** at the University of Varna after implementation would provide valuable feedback on the acceptance of the technology.

5. Questions for the doctoral student

During the defense, the doctoral student could answer the following questions:

1. What are the challenges in integrating the proposed WebAuthn model with external identity providers (Identity Providers) through protocols such as OpenID Connect or SAML within a university federation?

2. In the context of scalability, how would latency change when using Redis to cache public keys in the hypothetical case of a system with over 100,000 simultaneously active users?

3. The WebAuthn signature on grades be applied, as an advanced electronic signature according to the requirements of Regulation (EU) 910/2014 - eIDAS?

6. Conclusion

The dissertation work of Petar Dimitrov Dimitrov represents significant, in-depth and up-to-date research in the field of cybersecurity. The author demonstrates excellent knowledge of modern authentication protocols and the ability to transform theoretical models into working technological solutions. **The publication activity (3 articles and 4 reports) fully covers the requirements for protection, both the minimum national requirements (MNR) and the requirements of the Varna University of Economics.**

All of the above gives me reason to give **a highly positive assessment** of the dissertation work and to propose to the esteemed scientific jury to award **Petar Dimitrov Dimitrov** the educational and scientific degree **"Doctor"** in professional field 4.6. "Informatics and Computer Sciences".

Date: 09.04.2026

Signature: [redacted]

/Assoc. Prof. Dr. Eng. Boyan Jekov/