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Introduction to doors Workshops on Edge Computing (2021-2023)

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Abstract. The Edge Computing Workshop, known as "doors", has evolved as a prominent international forum for researchers, practitioners, and industry experts to converge and discuss the latest advancements and applications in the field of edge computing. This paper provides an overview of the *doors* workshops held from 2021 to 2023, highlighting their objectives, topics of interest, committees, and the significant contributions made by researchers during these years. The workshops have played a pivotal role in fostering collaboration, sharing insights, and exploring emerging trends in edge computing, addressing challenges related to infrastructure, systems, security, applications, and more. This paper underscores the importance of these workshops in advancing the field and promoting innovation in the era of digital transformation.

Keywords: edge computing, workshop, doors (acronym), Internet of Things (IoT), distributed systems, edge applications, edge infrastructure, fog computing, machine learning at the edge, privacy and security, edge-cloud interaction, resource management, quality of service (QoS), edge device architecture, edge-cloud interoperability, data analytics, edge programming models, edge data storage, edge fault tolerance, blockchain at the edge, edge AI, edge sensors, real-time responsiveness, situational awareness, cybersecurity, IoT data processing

1. Introduction

The landscape of computing is undergoing a paradigm shift with the rise of edge computing, a distributed system approach that brings computation and storage closer to data sources and end-users. This transformation has led to the emergence of the Edge Computing Workshop, aptly named "doors", as a dynamic platform for researchers, practitioners, and industry leaders to convene and exchange ideas on the forefront of edge computing advancements. This paper offers a comprehensive overview of the *doors* workshops held over the span of three years, from 2021 to 2023, shedding light on their significance and contributions to the field.

E**d**ge C**o**mputing W**or**k**s**hop (*doors*) is a peer-reviewed international Computer Science workshop focusing on research advances and applications of edge computing, a process of

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building a distributed system in which some applications, as well as computation and storage services, are provided and managed by

> (i) central clouds and smart devices, the edge of networks in small proximity to mobile devices, sensors and end users, and
> (ii) others are provided and managed by the center cloud and a set of small in-between local clouds supporting IoT at the edge.

The primary aim of the *doors* workshops is to provide an international forum where experts in edge computing can collaborate, share insights, and explore innovative solutions. The workshops serve as a bridge between academia and industry, enabling participants to discuss ongoing research, work in progress, and emerging trends in edge computing. The workshops offer a unique opportunity to address the challenges posed by the proliferation of the Internet of Things (IoT) and the growing demand for real-time responsiveness, privacy, and situation-awareness. By delving into the design, implementation, and deployment aspects of edge computing, *doors* workshops pave the way for open discussions and collaborations in this transformative domain.

doors workshops cast a wide net, encompassing an array of topics relevant to edge computing. These include:

- algorithms and techniques for machine learning and AI at the edge
- cellular infrastructure for edge computing
- distributed ledger technology and blockchain at the edge
- edge computing infrastructure and edge-enabled applications
- edge-based data storage and databases
- edge-optimized heterogeneous architectures
- fault-tolerance in edge computing
- fog computing models and applications
- geo-distributed analytics and indexing on edge nodes
- hardware architectures for edge computing and devices
- innovative applications at the edge
- interoperability and collaboration between edge and cloud computing
- monitoring, management, and diagnosis in edge computing
- processing of IoT data at network edges
- programming models and toolkits for edge computing
- resource management and Quality of Service for edge computing
- security and privacy in edge computing

These topics mirror the diverse challenges and opportunities in the edge computing domain, encouraging interdisciplinary discussions that drive innovation and knowledge exchange.

2. Workshop committees

doors workshops are organized by a dedicated team of experts from academia and industry. The program committee, consisting of reputable researchers, plays a vital role in the review and selection of papers:

- *Tetiana Voloshyna*, National University of Life and Environmental Sciences of Ukraine, Ukraine
- *Volodymyr Voytenko*, Athabasca University, Canada
- *Valentyn Yanchuk*, Zhytomyr Polytechnic State University, Ukraine

The organizing committee oversees the logistics and operational aspects of the workshops, ensuring a seamless experience for participants:

- *Nadiia Lobanchykova*, Zhytomyr Polytechnic State University, Ukraine
- *Andrii Morozov*, Zhytomyr Polytechnic State University, Ukraine
- *Andrii Striuk*, Kryvyi Rih National University, Ukraine

Workshop co-chairs:

- *Serhiy Semerikov*, Kryvyi Rih State Pedagogical University, Ukraine
- *Tetiana Vakaliuk*, Zhytomyr Polytechnic State University, Ukraine

3. Workshop highlights

The *doors* workshops held in 2021, 2022, and 2023 have been instrumental in fostering collaboration and knowledge dissemination in edge computing. Notably, *doors* 2021 featured papers covering graph models for Fog Computing systems, microclimate monitoring systems using IoT, and methods for assessing vulnerabilities in web applications. *doors* 2022, despite challenges posed by the ongoing war, addressed topics like cardiovascular diagnostics using pulse wave analysis and cyber deception for critical infrastructure security. The most recent event, *doors* 2023, saw discussions on academic events sub-systems, genetic algorithm-based PID controller optimization, and more.

3.1. doors 2021

This part represents the Edge Computing Workshop (*doors* 2021), held in Zhytomyr, Ukraine, on April 11, 2021 (figure 1). It comprises 7 contributed papers [4–6, 9, 13, 15, 17] that were carefully peer-reviewed and selected from 14 submissions (https://notso.easyscience.education/doors/2021/). Each submission was reviewed by at least 3, and on the average 3.2, program committee members. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

The development and effective application of Fog Computing technologies require the most complex tasks related to the management and processing of huge data sets, including the tasks of rational construction of low-level networks that ensure the functioning of end devices within the IoT concept. The article “Graph model of Fog Computing system” [13] authored by Andriy V. Ryabko, Oksana V. Zaika, Roman P. Kukharchuk and Tetiana A. Vakaliuk (figure 3) describes the use of graph theory methods to solve such problems. The proposed graph model can provide the ability to determine the basic properties of systems, networks, and network devices within the concept of Fog Computing, the optimal characteristics, and ways to maintain them in working condition. This paper shows how to plot graphs, and then customize the display to add labels

Figure 1: Joint workshop opening.

Figure 2: Pandemic times in Zhytomyr Polytechnic State University.

or highlighting to the graph nodes and edges of pseudo-random task graphs which can be used for evaluating Mobile Cloud, Fog and Edge computing systems. The graphs are described and visualized in Matlab code. Each task has an amount of computational work to perform, expressed in Megacycles per second. Each edge has an amount of data to transfer between

Figure 3: Presentation of paper [13].

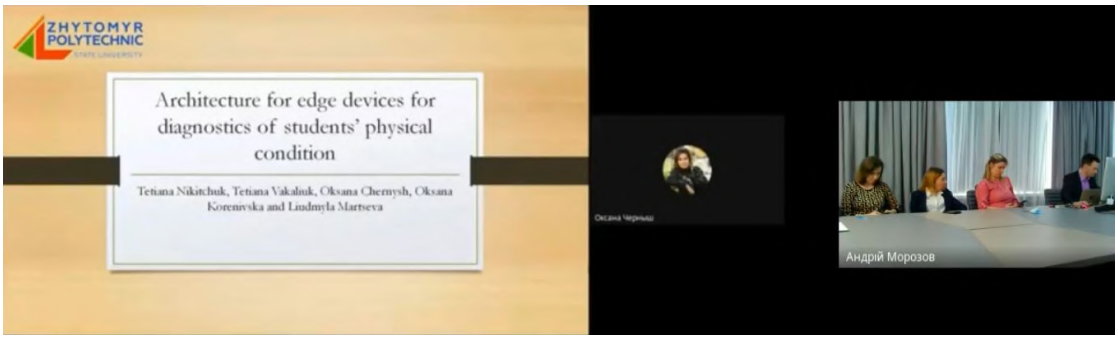

Figure 4: Presentation of paper [9].

tasks, expressed in kilobits or kilobytes of data. The set can be used by researchers to evaluate cloud/fog/edge computing systems and computational offloading algorithms. The task graphs can be used in single-user systems, where one mobile device accesses a remote server, or in multi user systems, where many users access a remote server through a wireless channel.

Tetiana M. Nikitchuk, Tetiana A. Vakaliuk, Oksana A. Chernysh (figure 4), Oksana L. Korenivska, Liudmyla A. Martseva and Viacheslav V. Osadchyi in the article "Architecture for edge devices for diagnostics of students' physical condition" [9] investigates the possibility of technical realization of hardware complex. It presupposes the use of sensors of registration of a photoplethysmographic curve, which describes a pulse wave and defines the parameters of students' cardiovascular system functional state. The method of photoplethysmography allows the use of non-contact sensors. Therefore, there is no artery compression, which eliminates circulatory disorders and allows the use of calculations to determine the saturation of oxygen by the pulse wave. It is recommended to use several optocouplers connected in series, parallel or parallel-series in a chain, with control of their mode of operation from the intensity of the received pulse wave signal depending on human body constitution. The edge device hardware is a part of the IoT system, which also includes another edge device, which instantly transmits data to the database on the edge server for the data further processing and storage.

The concept of the Internet of Things is increasingly defining the development of commu-

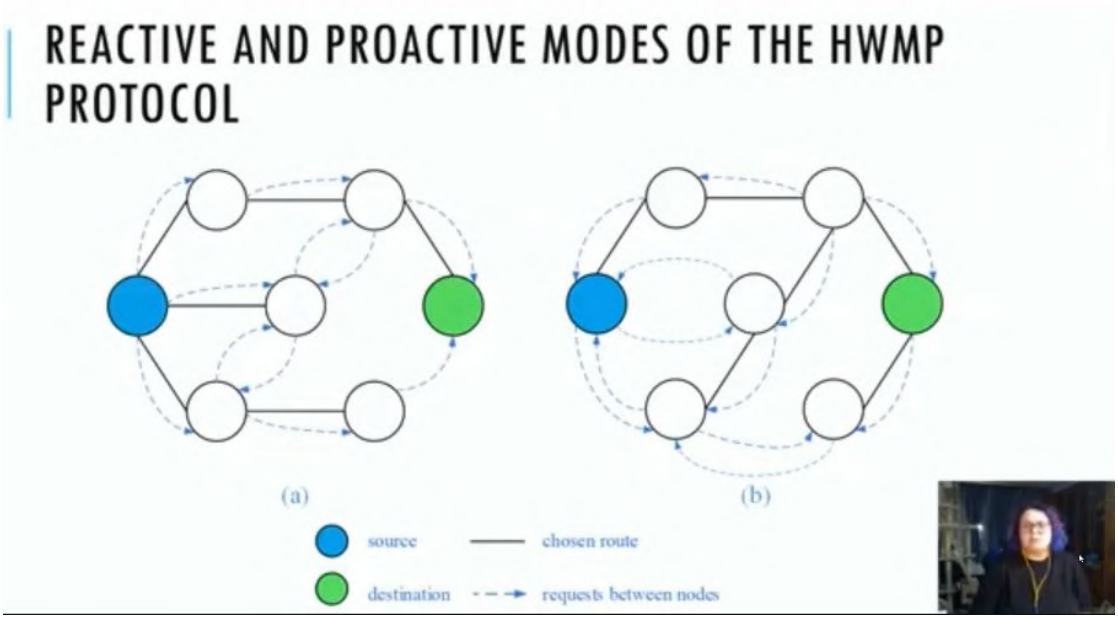

Figure 5: Presentation of paper [15].

nication networks both now and in the future. The largest application of the IoT concept is wireless touch networks (WTN). Due to the potentially widespread use of WTN in all areas of human life, they are also called pervasive sensory networks. WTN belongs to the class of self-organizing networks, for which the construction principles, routing protocols, quality of service parameters, traffic models, and characteristics are significantly modified compared to traditional infrastructure networks, etc. The features of the application of dynamic routing protocols for the construction of a self-organizing network of autonomous IoT systems are considered. Anastasia D. Sverdlova (figure 5), Artur O. Zaporozhets, Ihor V. Bohachev, Oleksandr O. Popov, Anna V. Iatsyshyn, Andrii V. Iatsyshyn, Valeriia O. Kovach, Volodymyr O. Artemchuk and Nataliia M. Hrushchynska in the article "Self-organizing network topology for autonomous IoT systems" [15] provides an overview of the main methods for calculating the topology of self-organizing networks. A review of known dynamic routing protocols for mobile radio networks is given, the advantages and disadvantages of proactive and reactive approaches are shown.

Edge computing is an extension of cloud computing where physical servers are deployed closer to the users in order to reduce latency. Edge data centers face the challenge of serving a continuously increasing number of applications with a reduced capacity compared to traditional data center. Tania Lorido-Botran (figure 6) and Muhammad Khurram Bhatti in the article "*ImpalaE*: Towards an optimal policy for efficient resource management at the edge" [6] introduces *ImpalaE*, an agent based on Deep Reinforcement Learning that aims at optimizing the resource usage in edge data centers. First, it proposes modeling the problem as a Markov Decision Process, with two optimization objectives: reducing the number of physical servers used and maximize number of applications placed in the data center. Second, it introduces

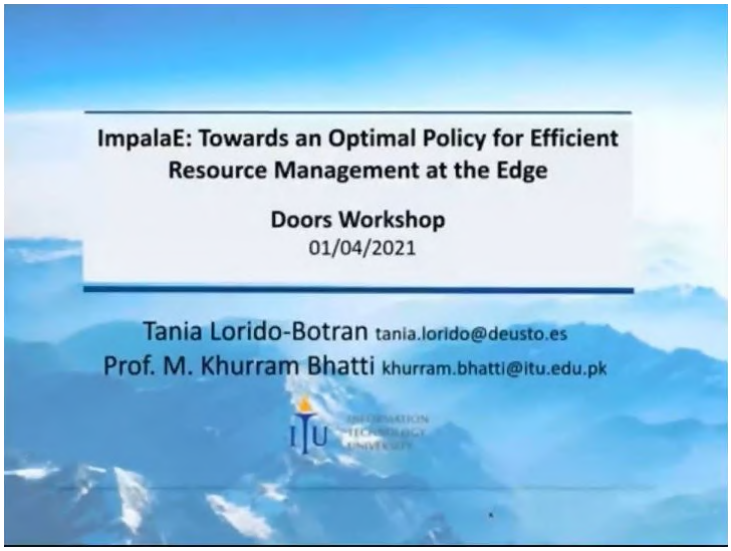

Figure 6: Presentation of paper [6].

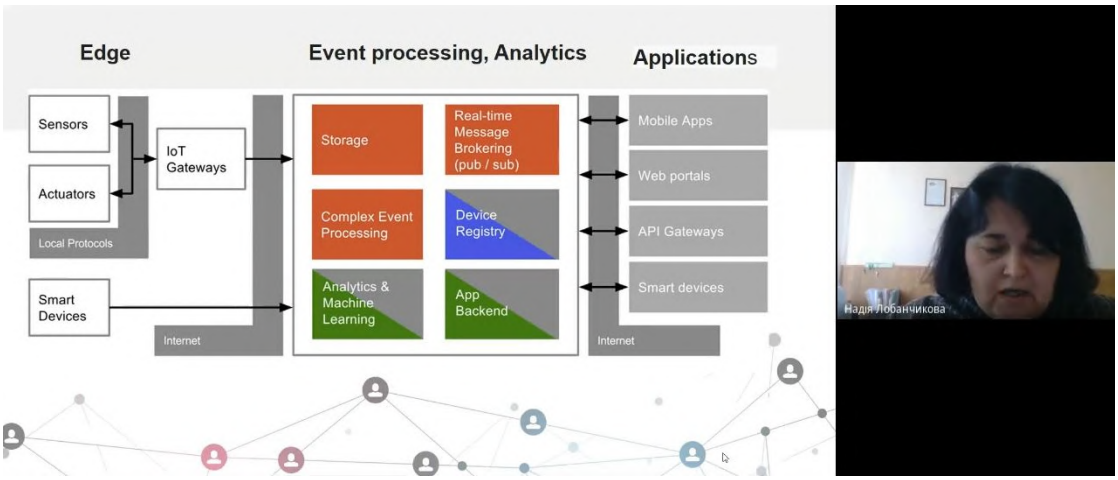

Figure 7: Presentation of paper [5].

an agent based on Proximal Policy Optimization, for finding the optimal consolidation policy, and an asynchronous architecture with multiple workers-shared learner that enables for faster convergence, even with reduced amount of data. We show the potential in a simulated edge data center scenario with different VM sizes based on Microsoft Azure real traces, considering CPU, memory, disk and network requirements. Experiments show that *ImpalaE* effectively increases the number of VMs that can be placed per episode and that it quickly converges to an optimal policy.

Nadiia M. Lobanchykova (figure 7), Ihor A. Pilkevych and Oleksandr Korchenko in the article "Analysis of attacks on components of IoT systems and cybersecurity technologies" [5] presents

the results of IoT analysis, methods and ways of their protection, prospects of using edge computing to minimize traffic transmission, decentralization of decision-making systems, and information protection. A detailed analysis of attacks on IoT system components was carried out and protection recommendations were developed.

Taras A. Uzdenov in the article "Task scheduling in Desktop GRID by FSA method: a practical example" [17] considers a new approach to solving the problem of dispatching task flows, the complexity of which is known, for GRID-systems with inalienable resources, the performance of which can be determined. A method based on this approach has been developed. The efficiency of the proposed method is compared with the well-known and widely used in various projects method FCFS. A feature of this method is the simplicity of implementation. An example of a simple practical problem that can be solved using the proposed method is described in this paper.

Volodymyr Kvasnikov (figure 8), Mariia Kataieva and Victor Kobylyansky in the article "Analysis of metrological support of nano-measurements" [4] analyzes the existing methods and means of measuring objects in the nanometer range and develops their classification based on the main principles of use. The main parameters on which each described method is based are considered and the conditions for their most effective application are determined. It is proved that the chemical and electrical sets of properties of the nanomaterial can change when the particle size decreases to the nanometer size, which requires the inclusion of additional chemical and electrical tests in existing methods. Based on the analysis, it was determined that the most functional and universal in solving a wide range of problems is the method of scanning probe microscopy. The classification of existing methods of scanning probe microscopy based on the nature of their applications is developed. The main information parameters on which each described method is based are considered, and the conditions of their most effective application are determined. To increase the accuracy of nanomeasurements, a methodology based on the principle of integration of information provided by different methods has been developed. The use of the differential-digital method is proposed, which includes the use of an additional

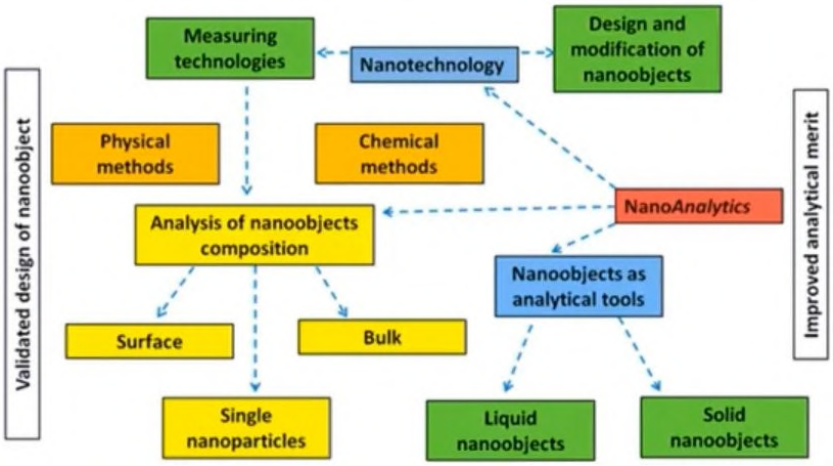

Figure 8: Presentation of paper [4].

information parameter in the mathematical model. An algorithm for including additional (a priory) information in the conditions for measuring the nanostructures has been developed, which leads the problem to the correct one according to the method of the control link, which characterizes the deviation of the parameters of measuring nanoobjects from their nominal values. It is proved that increasing the number of measurement methods used in the metrological analysis of nanoobjects will increase the reliability and accuracy of measurement results, and each method will provide additional information parameters to create a computerized method of calculating the control link. The main condition for correct comparison of the result is knowledge of the specific parameters on which each method is based.

3.2. doors 2022

The Second Workshop on Edge Computing (*doors* 2022) (https://doors.easyscience.education/2022/) was held on May 18, 2022 in cooperation with the XIV International Conference on Mathematics, Science and Technology Education (ICon-MaSTEd 2022).

Due to the war in Ukraine, unfortunately, only 1 article was accepted at the *doors* 2022. This paper [8] is devoted to the improvement of methods of rapid diagnosis of the cardiovascular system based on the analysis of model pulsegrams and presented by T. M. Nikitchuk (figure 9), T. A. Vakaliuk, O. V. Andreiev, O. L. Korenivska, V. V. Osadchyi and M. G. Medvediev. In this article, an adequate mathematical model of the pulse wave, which corresponds to real pulse signals in different states of the human body and contains mathematical relationships between

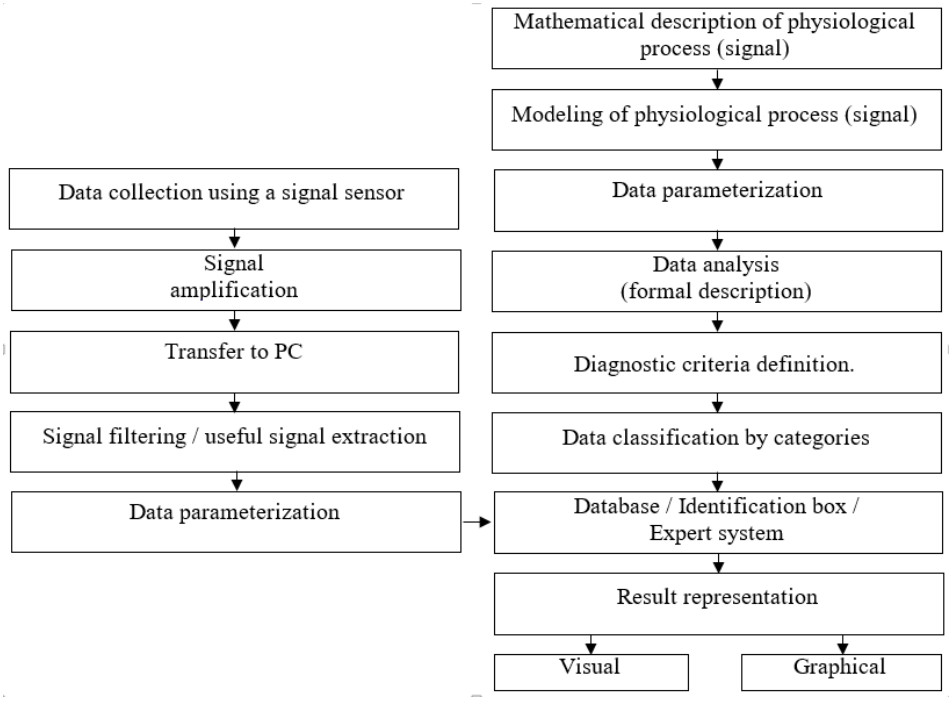

Figure 9: Presentation of paper [8].

the main parameters of pulsegrams, has been refined, and also algorithm of express diagnostics with the established criteria of the analysis of pulsograms is offered.

3.3. doors 2023

This part represents the 3rd Edge Computing Workshop (*doors* 2023), held in Zhytomyr, Ukraine, on April 7, 2023. It comprises 9 contributed papers that were carefully peer-reviewed and selected from 12 submissions (https://notso.easyscience.education/doors/2023/). Each submission was reviewed by at least 3, and on the average 3.2, program committee members. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for

Figure 10: *doors* 2023 highlights.

future research.

During the war in Ukraine, the *doors* 2023 was in hybrid mode (both in-person and online) (figure 10).

The proliferation of web applications in various aspects of our lives has increased the possibility of application security issues. With the rise of attacks on web applications, it is imperative to understand the typical weaknesses in web applications and the methods to minimize them. The study "Common vulnerabilities in real world web applications" [3] by Natarajan Krishnaraj, Chirag Madaan, Sanjana Awasthi, Raggav Subramani, Harsh Avinash and Sankalp Mukim (figure 11) examines the major security threats that can affect web applications, including request forgery attacks, injection attacks, cryptographic failures, and broken access control mechanisms, in the context of modern web frameworks widely used for developing web applications. The study is based on the OWASP Top Ten, a list of the most common and serious security threats to web applications. Authors also present best security practices recommended by professionals for each attack category that can prevent or mitigate attacks. This study aims to provide web developers with a better understanding of how to secure web applications.

Ensuring high reliability, fault tolerance, and continuity of computing processes in computer systems is achieved through the use of failover clusters, which combine computing resources for virtualization and enable the movement of virtual resources, services, or applications

Figure 11: Presentation of paper [3].

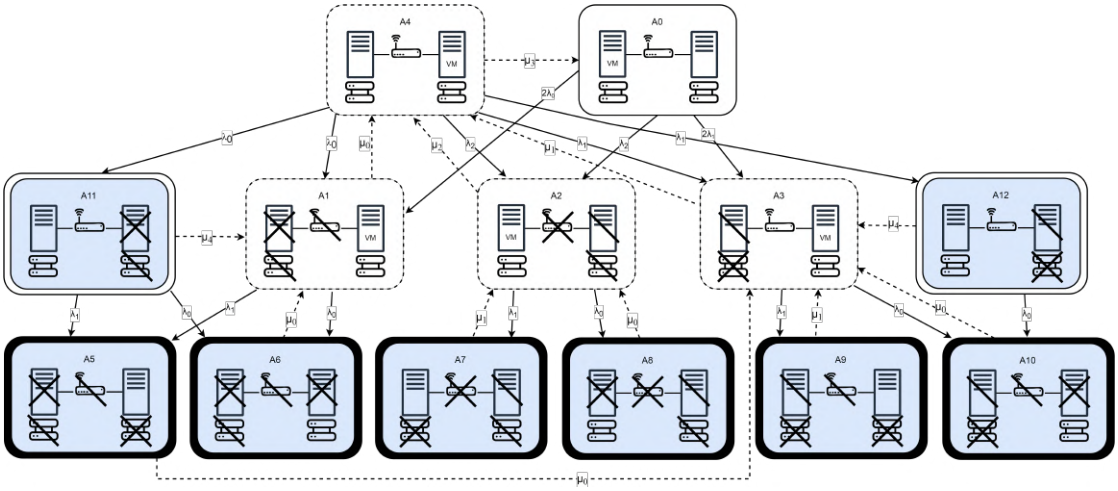

Figure 12: Presentation of paper [12].

between physical servers while supporting continuity. The study "Cluster fault tolerance model with migration of virtual machines" [12] by Andrii V. Riabko, Tetiana A. Vakaliuk, Oksana V. Zaika, Roman P. Kukharchuk and Valerii V. Kontsedailo (figure 12) focuses on failover clusters, consisting of two physical servers connected through a switch and a distributed storage system with synchronous data replication. A Markov model of the reliability of a failover cluster is proposed, taking into account the costs of migrating virtual machines and mechanisms that ensure continuity in the event of a failure. A simplified model is also presented, neglecting migration costs and providing an upper-reliability estimate. The reliability of the failover

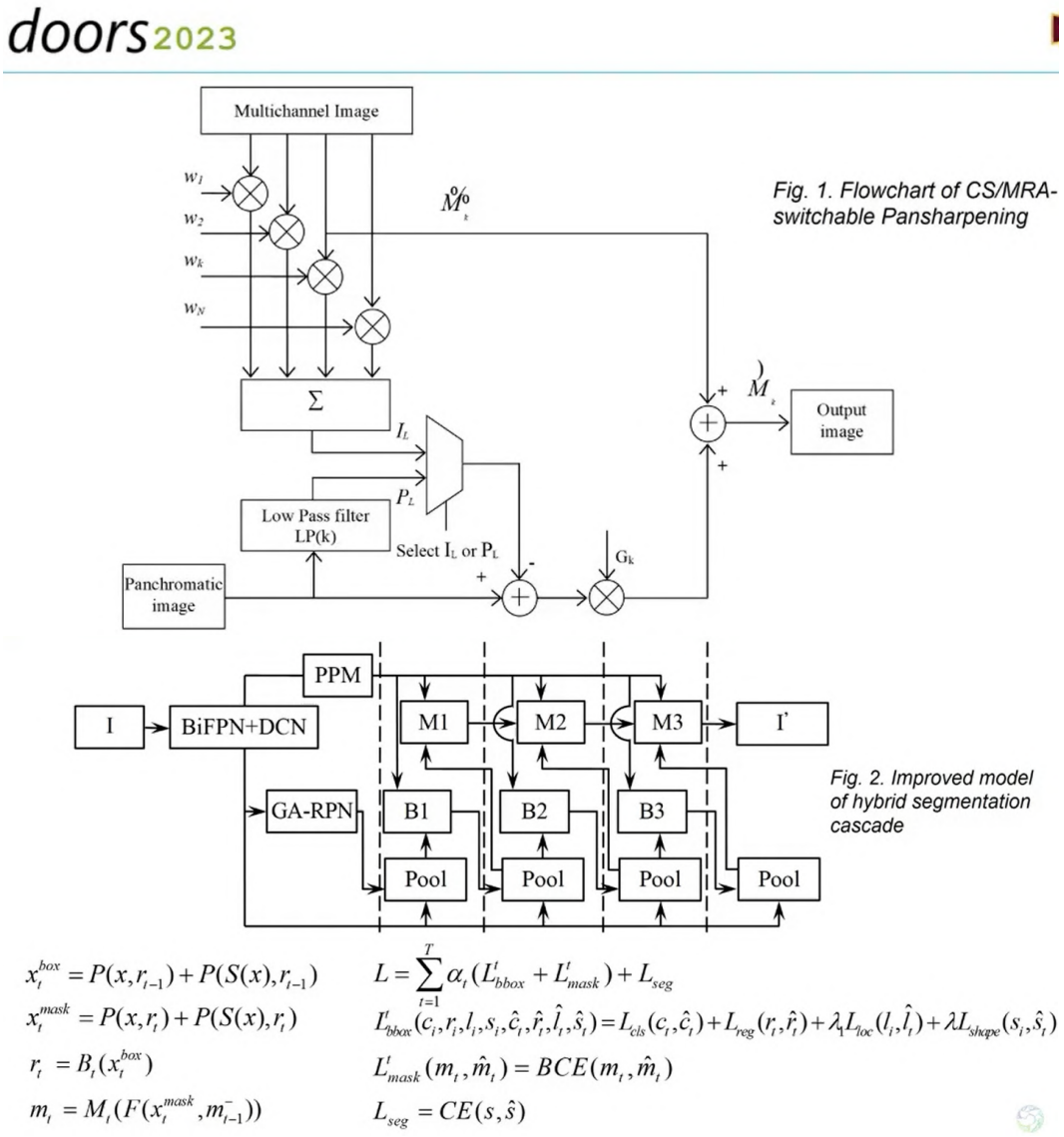

Figure 13: Presentation of paper [2].

cluster is measured using the coefficient of non-stationary readiness, and the impact of virtual machine migration on the reliability is demonstrated. The results obtained can aid in selecting technologies for ensuring the failure stability and continuity of computing processes in computer systems with cluster architecture.

The article "Object detection method based on aerial image instance segmentation received by unmanned aerial vehicles in the conditions rough for visualization" [2] by Serhiy V. Kovbasiuk, Leonid B. Kanevskyy, Mykola P. Romanchuk, Serhiy V. Chernyshuk and Leonid M. Naumchak (figure 13) explores the potential of unmanned aerial complexes for aiding in decision making during crisis situations that require object detection through aerial images obtained by unmanned aerial vehicles under conditions of atmospheric fog and smoke. The authors employ the Pansharpening method for image sharpening, which involves injecting dimensional details from a panchromatic image to a multispectral image. To improve the operational efficiency and accuracy of automotive vehicle detection in aerial images received by unmanned aerial

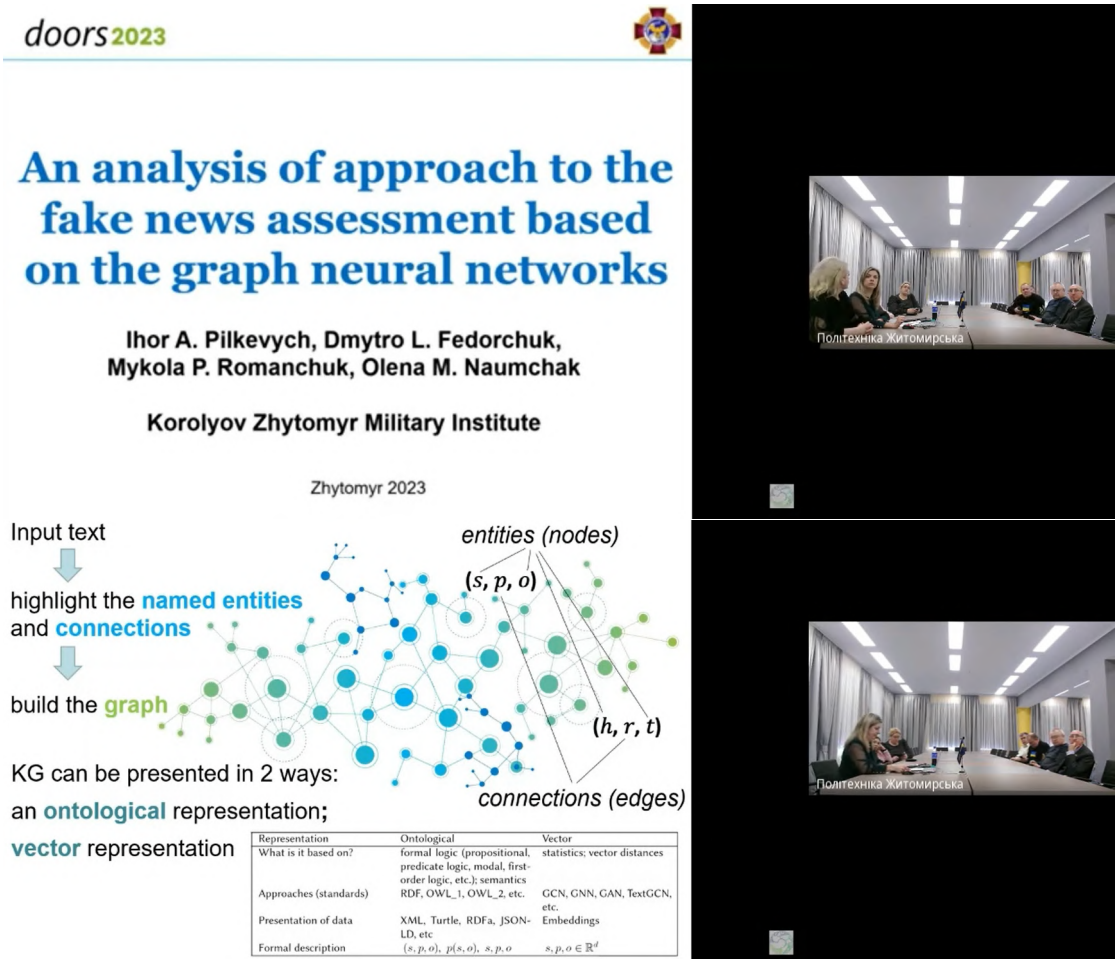

Figure 14: Presentation of paper [11].

vehicles, the authors implement the Hybrid Task Cascade for Instance Segmentation model. This model is particularly suitable for tasks involving small-sized object multiclass classification and detection in aerial images using indirect signs. The findings of this study can contribute to the development of effective decision support systems for crisis management.

In the context of Russia's war against Ukraine, the article "An analysis of approach to the fake news assessment based on the graph neural networks" [11] by Ihor A. Pilkevych, Dmytro L. Fedorchuk, Mykola P. Romanchuk, Olena M. Naumchak (figure 14) explores the challenges posed by disinformation campaigns and propaganda efforts, particularly their negative psychological impact on populations. The authors focus on the problem of identifying and monitoring online media content that contains such negative influence. To address this issue, they propose a novel approach based on graph neural networks for automating the process of detecting fake news. The article presents a thorough analysis of existing techniques for automated content analysis, highlighting the advantages of machine learning methods and graph neural networks in particular. The authors then describe their proposed approach and demonstrate its effectiveness through simulated detection of fake news. The results of the study indicate that the proposed approach using graph neural networks can successfully detect and respond to the threat of fake news spread by Russia, thus providing a valuable tool for maintaining information security in Ukraine.

The past few years have witnessed the swift growth of information systems, Internet of Things (IoT) technologies, and edge devices, resulting in the development of new sensors for constructing such systems, which have been increasingly integrated into people's lives, including their domestic and social environments. The microclimate of living spaces, workplaces, and educational institutions plays a critical role in maintaining people's well-being. Deviations from the norm in the environmental microclimate can negatively impact human physiological conditions, reduce concentration, and decrease work or study efficiency. To address this challenge, Oksana L. Korenivska (figure 15), Tetiana M. Nikitchuk, Tetiana A. Vakaliuk, Vasyl B. Benedytskyi and Oleksandr V. Andreiev develop an autonomous IoT system based on edge devices to monitor the microclimate of classrooms around the clock. This system measures climatic parameters, such as temperature, relative humidity, carbon dioxide levels, and light air ion concentrations, records data on a smartphone, and stores it on a remote server. The system is a part of a larger project aimed at studying the impact of microclimate parameters on the physiological state of students. The findings of "IoT monitoring system for microclimate parameters in educational institutions using edge devices" [1] will facilitate the development of measures to ensure optimal conditions for studying in enclosed spaces. Authors' development is based on IoT technologies, edge devices, and network technologies.

With the growth of cyber attacks targeting critical infrastructure and industrial IoT networks in Ukraine, effective solutions for detection and response are needed. These attacks have made Ukrainian networks a testing ground for new tactics and methods employed by Russian hackers. The study "Honeypot and cyber deception as a tool for detecting cyber attacks on critical infrastructure" [7] by Dmytro S. Morozov, Tetiana A. Vakaliuk, Andrii A. Yefimenko, Tetiana M. Nikitchuk and Roman O. Kolomiiets (figure 16) focuses on the use of honeypot/honeynet networks and cyber deception platforms as sources of information for better understanding these attacks. While there is no universal solution for such systems, highly interactive honeypot systems and deception platforms can be used to build believable systems that collect information

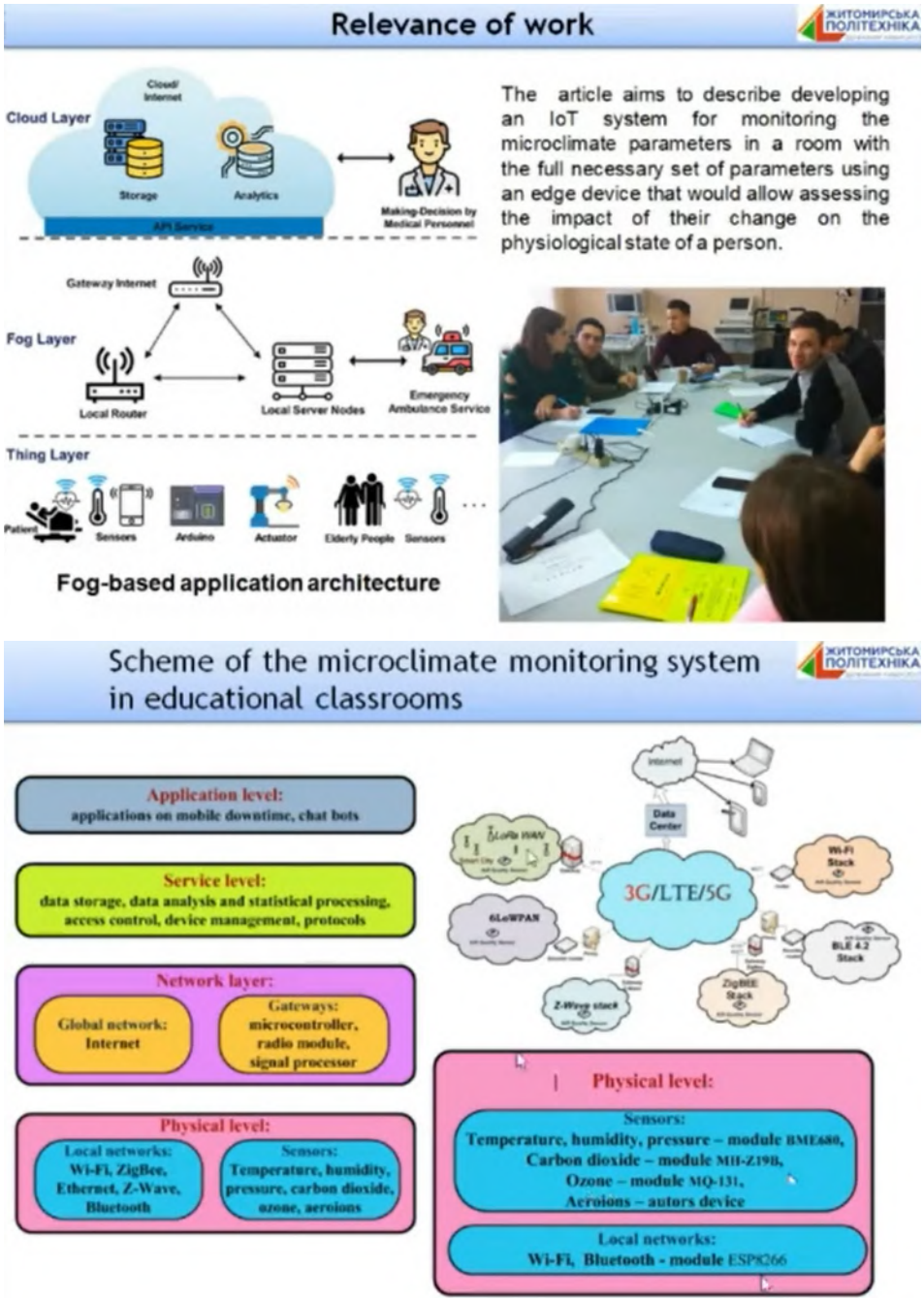

Figure 15: Presentation of paper [1].

on the attack and actions of the attackers. The analysis of this information can improve network security and serve as evidence for prosecution. This article provides an overview of the use of honeypot/honeynet solutions and cyber deception for both general-purpose networks and

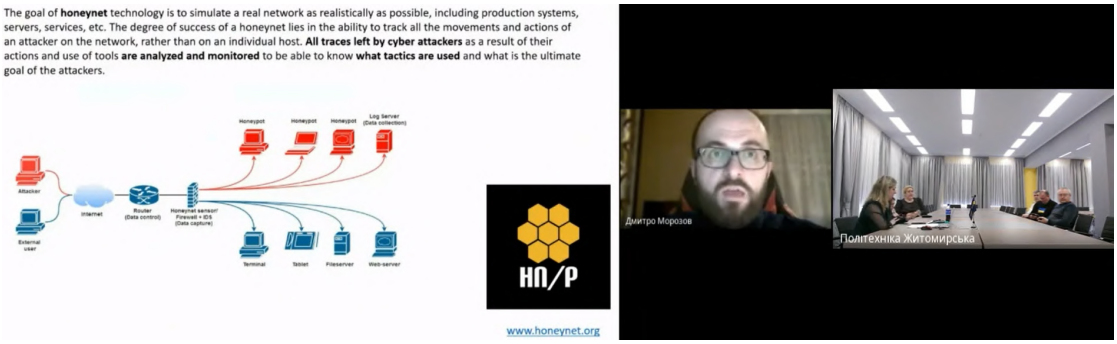

Figure 16: Presentation of paper [7].

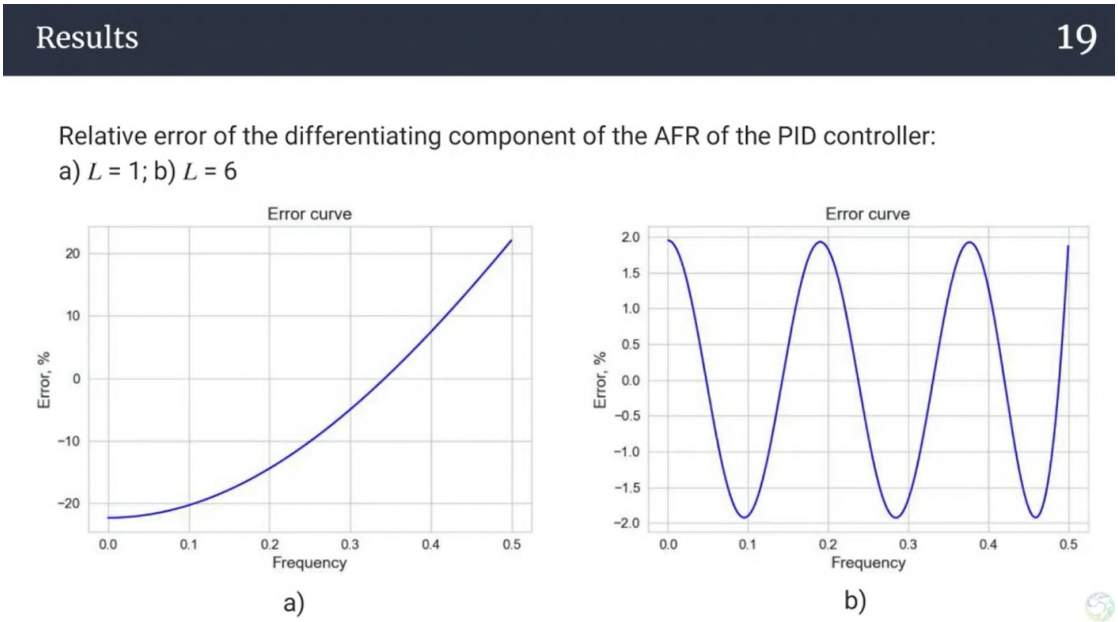

Figure 17: Presentation of paper [10].

industrial IoT networks.

Digital signal processing has become ubiquitous in modern science and technology, and the demand for improving the digital proportional-integral-derivative (PID) controller model remains high. The paper "Algorithm for optimizing a PID controller model based on a digital filter using a genetic algorithm" [10] by Ruslan V. Petrosian, Ihor A. Pilkevych and Arsen R. Petrosian (figure 17) addresses the challenge of constructing a model of a digital PID controller suitable for use in robotic systems with microcontrollers and programmable logic integrated circuits. Authors propose a novel approach that employs digital filtering methods as the foundation for the regulator and calculates digital filter coefficients with a genetic algorithm. This technique enhances model accuracy while using classical methods to calculate PID controller coefficients for an analog PID controller. The software implementation of the proposed method uses Python

programming language, and the modeling results demonstrate the efficacy of the developed model. Authors' findings suggest that their genetic algorithm-based digital filtering approach can help to optimize PID controllers in robotic systems.

PHP is a widely used programming language for web development, with numerous website engines and frameworks written in it. The paper "The system for testing different versions of the PHP" [16] by Mariia Yu. Tiahunova, Halyna H. Kyrychek and Yevhenii D. Turianskyi (figure 18) presents an in-depth analysis of various versions of PHP, including the recently released PHP 8. Authors describe the new and useful features of PHP 8, such as the JIT compiler and error correction, and their impact on both users and developers. To evaluate the performance of different PHP versions, authors have developed a testing system that can be extended with additional modules. Their results indicate that PHP 8 offers significant performance improvements over earlier versions, with the JIT compiler playing a crucial role. Authors also discuss the implications of their findings for web developers and suggest future

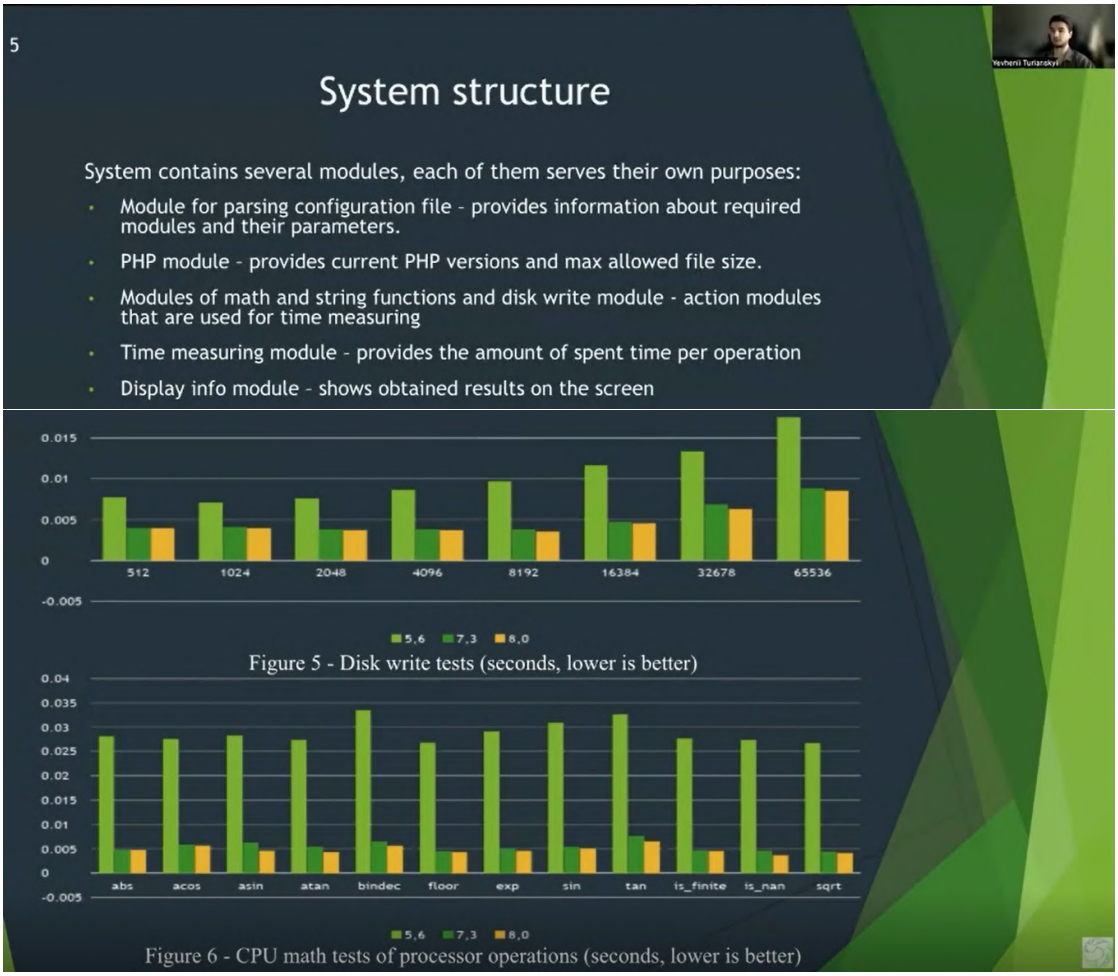

Figure 18: Presentation of paper [16].

research directions, including investigating the impact of PHP 8 on web application security and analyzing its use in large-scale web development projects.

In the paper "An academic events sub-system of the URIS and its ontology representation to improve scientific usability and motivation of scientists in terms of European integration" [14], Yevhenii B. Shapovalov, (figure 19), Viktor B. Shapovalov, Alla G. Zharinova, Sergiy S. Zharinov, Iryna O. Tsybenko and Oleksiy S. Krasovskiy propose an edge-based approach for collecting and processing academic event data in Ukraine. Authors first provide an overview of edge computing and its benefits, particularly in the context of data collection and processing. Authors then review existing systems in Europe, such as NARCIS, SICRIS, and Research.fi, and

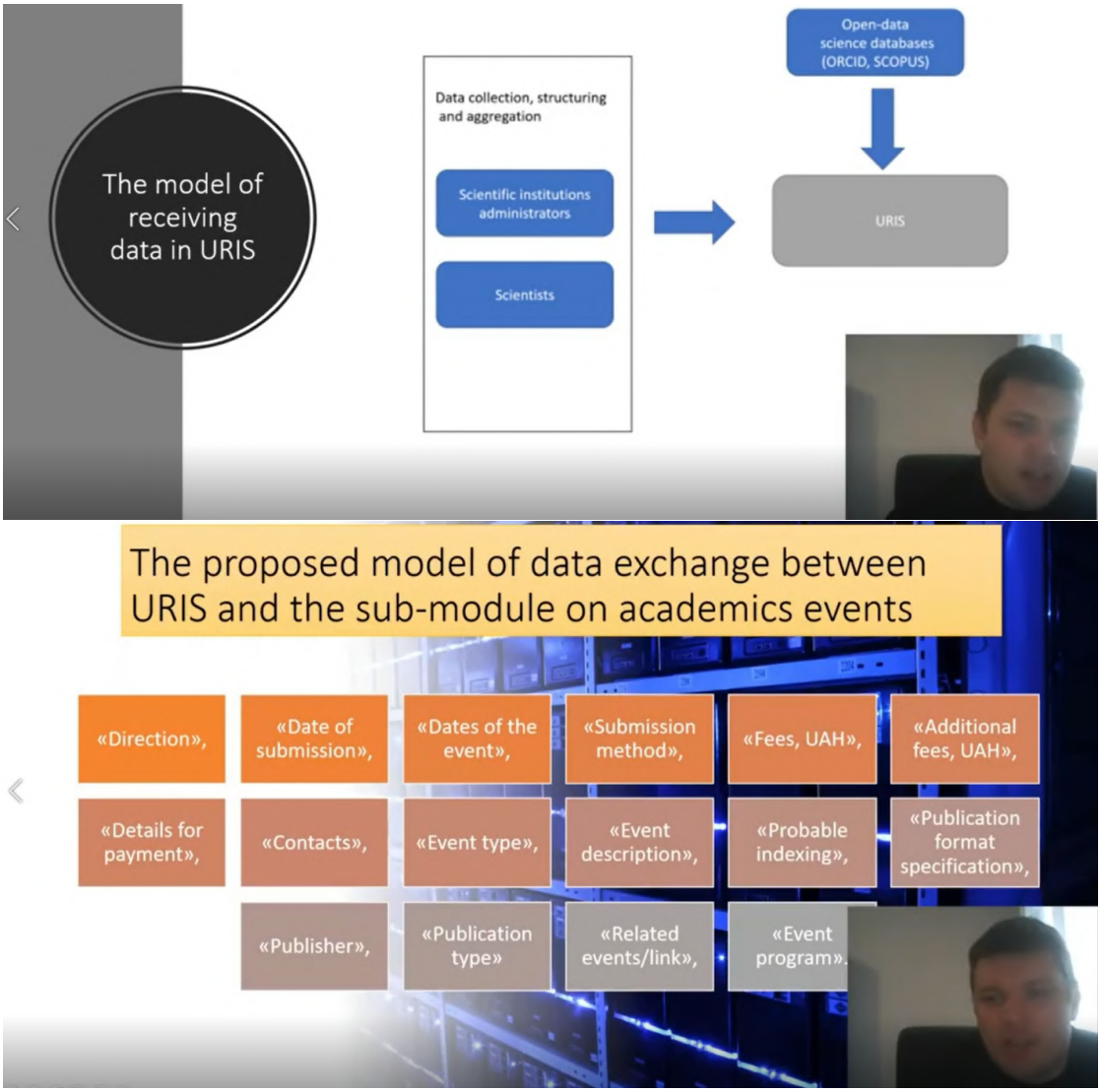

Figure 19: Presentation of paper [14].

highlight the need for a similar system in Ukraine. Authors present a case diagram and list of relevant data for the proposed academic events system, as well as the essential EU legislation that must be considered. Authors investigate and describe systems proposed for interoperability with the proposed system, and present models for receiving data, URIs as the main component of the decentralized approach in science, and data exchange and interaction with their proposed database. The proposed system offers a novel solution for efficient and effective academic event data collection and processing in Ukraine, with potential applications for knowledge discovery from data.

4. Conclusion

The *doors* workshops have evolved into a thriving platform for advancing edge computing research and applications. These workshops have facilitated interdisciplinary discussions, knowledge sharing, and collaboration among researchers, practitioners, and industry leaders. With an expanding scope and growing relevance, *doors* workshops are poised to continue their impactful contributions to the evolution of edge computing in the digital age.

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