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Empowering the Edge: Research advances from doors 2024

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Abstract. The 4th Edge Computing Workshop (doors 2024) held in Zhytomyr, Ukraine, aimed to bring together researchers to share advances and applications in edge computing, a critical technology for enabling the Internet of Things and analytics close to data sources. This report summarises the event, highlighting the peer-reviewed papers covering topics from edge hardware to AI and security. The nine accepted papers, selected from 19 submissions, propose innovative approaches to advance the field. Common themes include leveraging edge computing for sensing applications and addressing resource utilisation and management challenges. The workshop stimulated valuable discussion and collaboration around these important research directions.

Keywords: edge computing, edge device, IoT, UAV, distributed systems

1. Introduction

Edge computing has emerged as a transformative technology enabling computation close to data sources and end users. According to the Cogent Infotech [9], by 2025, there will be a significant shift from cloud computing to edge computing, driven by dissatisfaction with the cost, complexity, and lack of control in cloud services:

1. Many organisations will adopt private cloud infrastructure and focus on deploying appliances at the edge.
2. The global edge computing market is expected to grow substantially, reaching $139.58 billion by 2030, up from $15.96 billion in 2023.
3. With reduced size, increased speed, and expanded storage capacity, technological advancements in servers will facilitate the transition to edge computing by allowing cost-effective deployment across distributed sites.
4. Industries like retail and convenience stores are expected to shift to edge computing to handle the large volumes of data generated at each location more efficiently and cost-effectively, especially with the growth of AI applications.

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Key trends shaping edge computing in 2024 include:

- increased integration of Artificial Intelligence (AI) at the edge for local data processing;
- adoption of automation to streamline operations and management of edge devices;
- heightened focus on security and privacy measures at the edge;
- rise of edge containers for flexible deployment of applications;
- widespread adoption of 5G networks for low-latency connectivity to support edge computing.

In this context, the Edge Computing Workshop (doors) is a forum for researchers to share advances and applications of edge computing. doors is a peer-reviewed international Computer Science workshop that covers diverse edge computing topics, including algorithms and techniques for machine learning and AI, cellular infrastructure, blockchain, data storage and databases, heterogeneous architectures, fault-tolerance, IoT data processing, resource management and Quality of Service, security and privacy, and more [52, 67, 68].

The 4th edition of Doors was held in Zhytomyr, Ukraine, on April 05, 2024. This report summarises the organisation and outcomes of Doors 2024, with a focus on the technical papers presented. The next section provides an overview of the workshop organising and program committees. Section 3 describes the accepted papers and their contributions. The report concludes with reflections and future directions.

2. doors 2024 organizers

The 4th edition of the doors (previous editions are [52, 67]) was organised jointly by the Zhytomyr Polytechnic State University and the Academy of Cognitive and Natural Sciences (ACNS). ACNS, a non-governmental organisation, is committed to developing researchers' cognitive and natural sciences knowledge. Their mission involves advancing research, protecting individual rights and freedoms, and addressing professional, scientific, and social needs.

One of ACNS's noteworthy publications is the Journal of Edge Computing (JEC), a peer-reviewed journal that delves into the realms of the Internet of Things (IoT), distributed systems, and edge computing. JEC focuses on scientific research on the use and implementation of edge computing across diverse domains such as education, science, medicine, and architecture.

ACNS also publishes such journals as Educational Dimension (ED), Educational Technology Quarterly (ETQ), and CTE Workshop Proceedings. Notably, JEC, ED, ETQ, and CTE cover a broad range of topics aligned with doors topics of interest:

- machine learning, deep learning and AI [5, 30, 44, 66];
- edge computing and edge devices [19, 20, 37, 62, 66];
- distributed systems [61];
- fault-tolerant computing [47, 66];
- UAV [42];
- IoT [5, 18, 20, 29, 39, 56, 62, 66];
- cloud and fog computing [50];
- SMART houses [5];

Figure 1: Workshop highlights, part 1.

Figure 2: Workshop highlights, part 2.

Figure 3: Workshop highlights, part 3.

- automated intelligent robotic platforms [62];
- biomedical systems [20, 37, 39];
- GRID systems [63].

The call for papers solicited original submissions across the full range of edge computing research and applications. At least three Program Committee members reviewed each paper for technical quality, originality, and alignment with the workshop scope. Nineteen papers were submitted, spanning short papers to full research articles. After a rigorous review process, nine papers were accepted, for an acceptance rate of 47%.

Program committee co-chairs

- *Tetiana A. Vakaliuk*, Zhytomyr State Polytechnic University, Ukraine [64, 69]
- *Serhiy O. Semerikov*, Kryvyi Rih State Pedagogical University, Ukraine [11, 17]

Program committee

- *Aleksandr Cariow*, West Pomeranian University of Technology, Poland [6, 7]

Figure 4: Workshop highlights, part 4.

- *Attila Kertesz*, University of Szeged, Hungary [16, 32]
- *Nagender Kumar Suryadevara*, University of Hyderabad, India [59, 60]
- *Gyu Myoung Lee*, Liverpool John Moores University, United Kingdom [3, 12]
- *BongKyo Moon*, Dongguk University, South Korea [4, 26]
- *Michael J. O'Grady*, University College Dublin, Ireland [35, 71]
- *Pedro Valderas*, Universitat Politècnica de València, Spain [53, 54]
- *Xianzhi Wang*, University of Technology Sydney, Australia [8, 13]
- *Eiko Yoneki*, University of Cambridge, United Kingdom [21, 72]
- *Alejandro Zunino*, ISISTAN Research Institute, UNCPBA & CONICET, Argentina [10, 73]

Additional reviewers

- *Olexander Barmak*, Khmelnytskyi National University, Ukraine [22, 23]
- *Akinul Islam Jony*, American International University-Bangladesh, Bangladesh [2, 55]
- *Valerii Kontsedailo*, Inner Circle, Netherlands [45, 46]
- *Vyacheslav Kryzhanivskyy*, R&D Seco Tools AB, Sweden [15, 33]
- *Nadiia Lobanchykova*, Zhytomyr Polytechnic State University, Ukraine [27, 28]
- *Mykhailo Medvediev*, ADA University, Azerbaijan [24, 34]
- *Franco Milano*, University of Florence, Italy [31, 40]

- *Tetiana Nikitchuk*, Zhytomyr Polytechnic State University, Ukraine [36, 38]
- *Etibar Seyidzade*, Baku Engineering University, Azerbaijan [1, 14]
- *Andrii Striuk*, Kryvyi Rih National University, Ukraine [51, 52]

Organizing committee

- *Tetiana Nikitchuk*, Zhytomyr Polytechnic State University, Ukraine
- *Andrii Morozov*, Zhytomyr Polytechnic State University, Ukraine
- *Serhiy Semerikov*, Kryvyi Rih State Pedagogical University, Ukraine
- *Andrii Striuk*, Kryvyi Rih National University, Ukraine
- *Tetiana Vakaliuk*, Zhytomyr Polytechnic State University, Ukraine

3. Accepted papers

The nine accepted papers covered a range of innovative applications and approaches to advance edge computing research and practice.

The paper "Wireless technologies in IoT projects with distributed computing" [65] examines the many choices for wireless data transfer that may be used while implementing short- and long-range Internet of Things applications. Examples demonstrate how ESP-NOW technology, nRF24L01 radio modules, and setting up a local Wi-Fi access point can be used to transfer data over short distances. The realistic range of sensor data transfer between microcontrollers is calculated for every choice. When using the LoRa physical interface, the data transmission range is computed at a certain speed. This demonstrates the fundamentals of edge computing by combining digital and analogue sensor technologies (figure 6).

The paper "Edge computing applications: using a linear MEMS microphone array for UAV position detection through sound source localisation" [48] investigates the application of a microphone array to determine the position of an unmanned aerial vehicle (UAV) solely based on the sound emitted by its engines. The study also delves into a mathematical model for pulse density modulation in a digital MEMS microphone. It illustrates how the efficiency of a differential array composed of first-order microphones varies with frequency. Considering this frequency-dependent directivity and the instability model of microphone parameters, a reasonable operational frequency range can be established for the normal functioning of the microphone array. Additionally, the study proposes a linear microphone array model utilising MEMS omnidirectional microphones (figure 7).

The paper "Search and classification of objects in the zone of reservoirs and coastal zones" [58] indicates that the system effectively detects objects on the water surface. However, the classification of these objects needs to be revised. Several reasons contribute to this issue, including errors in dataset labelling and the small dataset size. One potential use case for the built model is collecting general information about the reservoir, regardless of the classification output (figure 8).

In the paper "An analysis of approach to the features of satellites classification determining based on modeling of linguistic variables and membership functions" [43], the study examines

Figure 5: Workshop opening.

contemporary methods for classifying satellites. It highlights the relevance of employing fuzzy logic tools and outlines the primary steps for addressing the specified problem using the theory of fuzzy sets. The study identifies the features relevant to satellite classification, which can be derived from both a priori and a posteriori information about satellites. These features may be numerical, categorical, or linguistic data (figure 9).

The paper “Advanced software framework for comparing balancing strategies in container orchestration systems" [70] presents an intricate software design for assessing scheduling strategies within container orchestration systems. It emphasises software architecture and delves into the diverse elements, including dynamic cluster topology, container configuration streams, cluster packing algorithms, metric collectors, and a state machine for monitoring

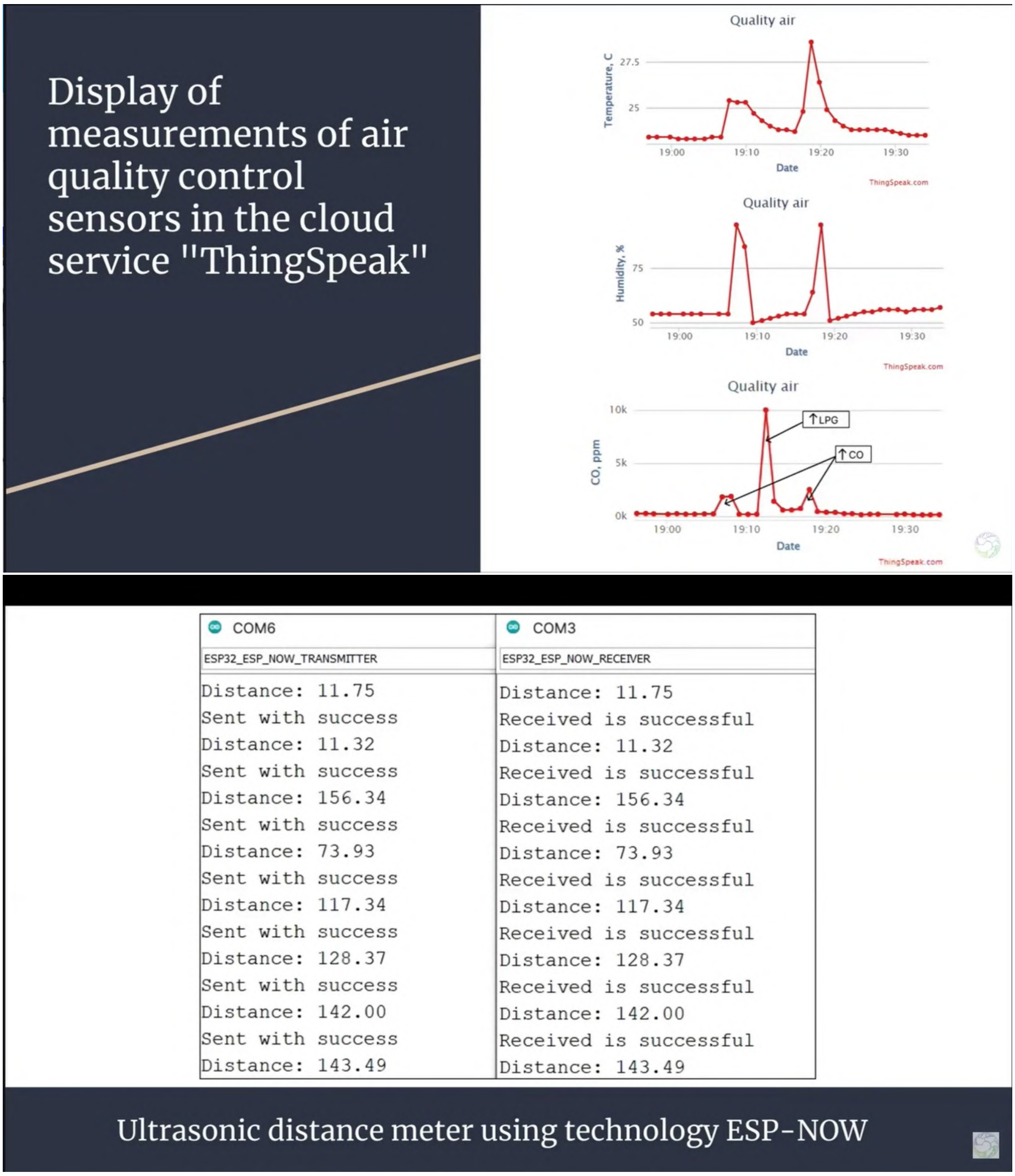

Figure 6: Presentation of the article [65].

experiment progress. The system also encompasses malfunction scenarios, evaluating the robustness of various strategies. Furthermore, it is intentionally designed to be adaptable and extensible, allowing for the incorporation of new key performance indicators and test scenarios (figure 10).

In the paper "Data serialisation protocols in IoT: problems and solutions using the ThingsBoard

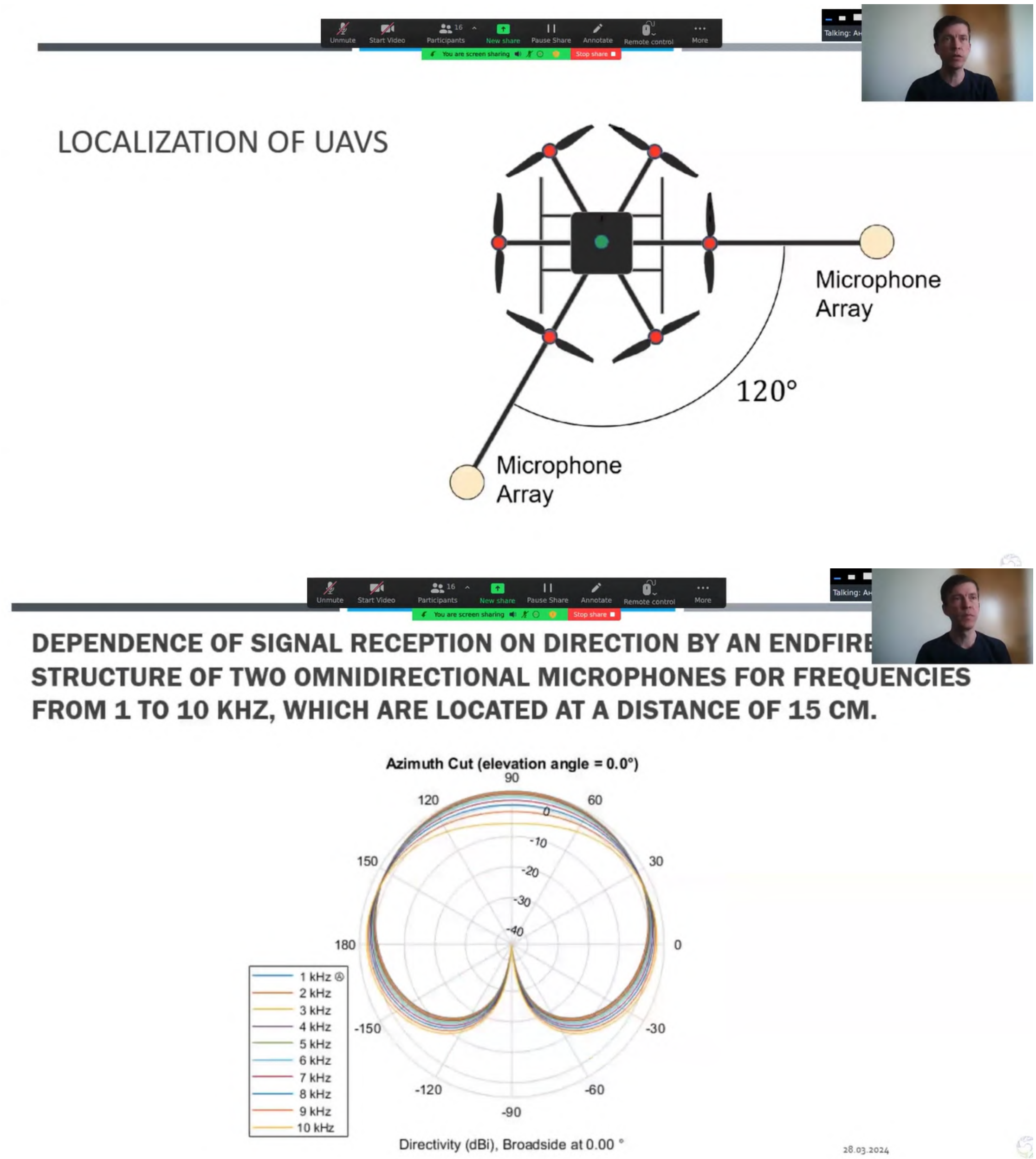

Figure 7: Presentation of the article [48].

platform as an example" [57], the authors explore the challenges and advancements related to data serialisation protocols in the Internet of Things (IoT) context. Specifically, they focus on dynamic schema compilation within ThingsBoard. The authors highlight the limitations of static schema compilation using Protobuf and propose an innovative approach for real-time schema compilation driven by users. This approach enhances flexibility, scalability, and performance in

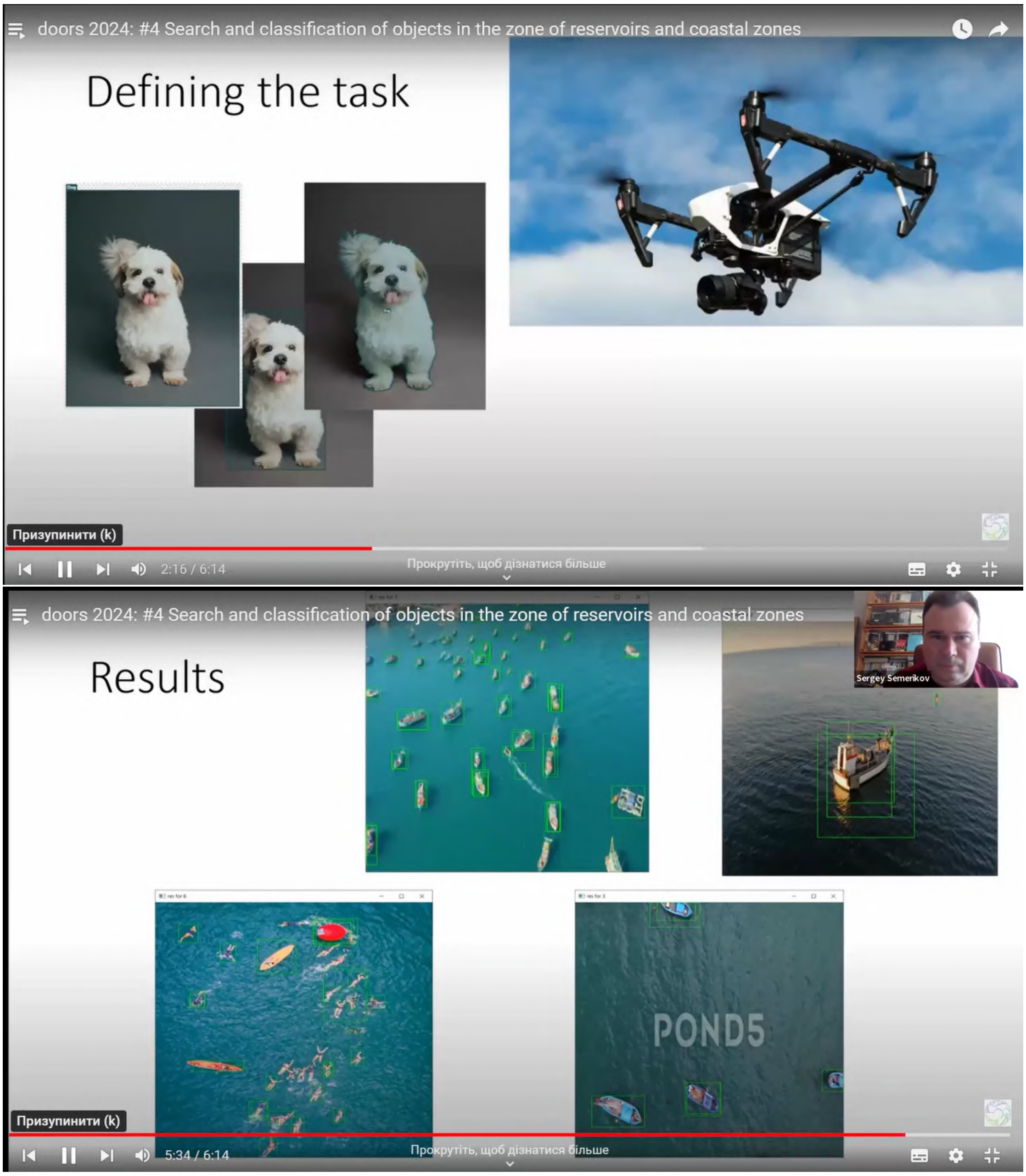

Figure 8: Presentation of the article [58].

IoT platforms. Their solution addresses critical adaptability issues by enabling seamless device communication and integration using compact Protobuf formats. Additionally, they emphasise this solution's potential impact on edge computing and suggest avenues for further research to extend the applicability of dynamic serialisation across diverse IoT solutions (figure 11).

In the paper "Test platform for Simulation-In-Hardware of unmanned aerial vehicle on-board

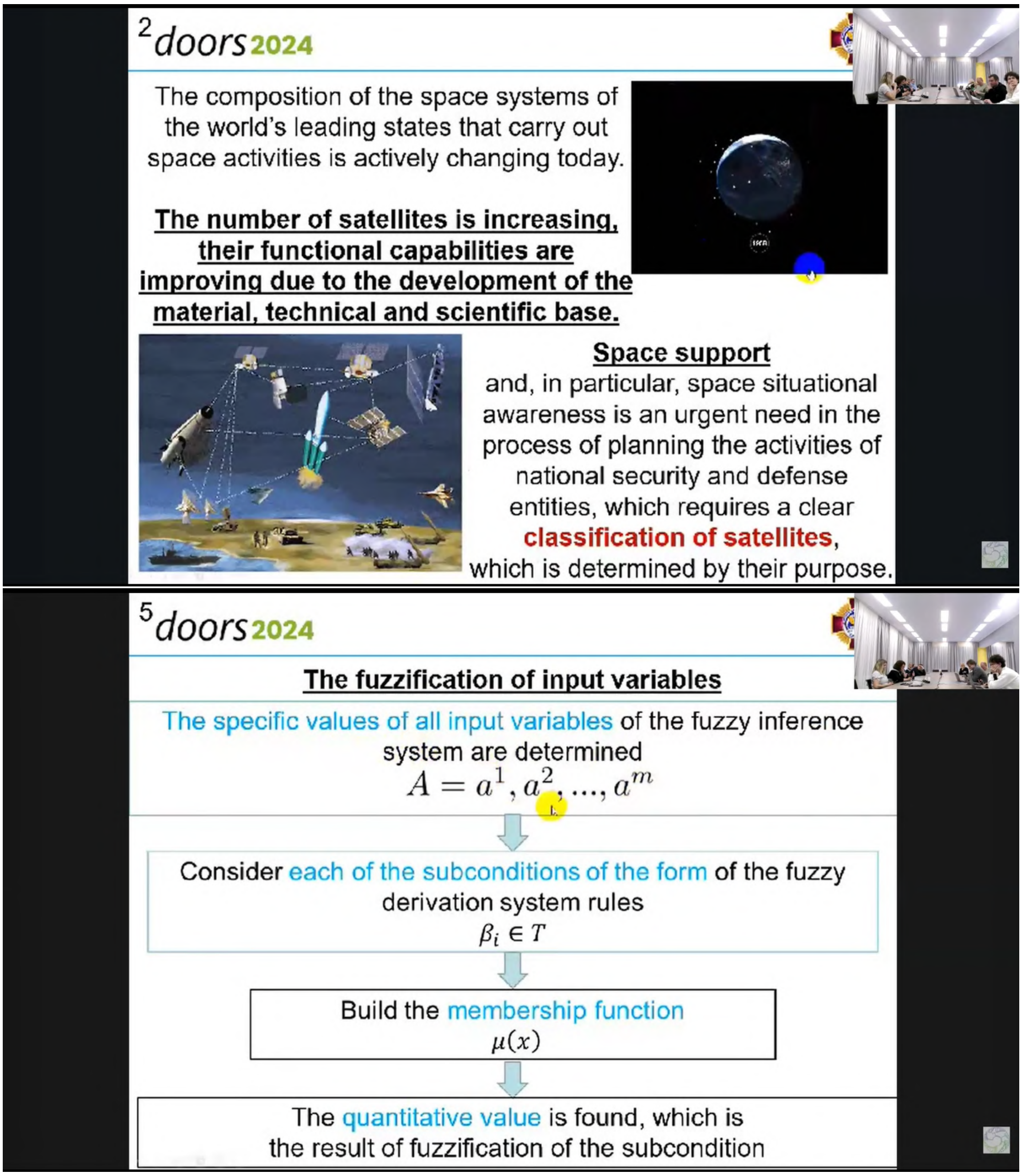

Figure 9: Presentation of the article [43].

computer" [41], the authors assert that the most effective way to implement the test platform involves utilising SIH-simulation. Their proposed method represents an enhanced iteration of SIH simulation. This approach centres around a sensor and actuator simulator, ensuring the original firmware's proper functioning in an unmanned aerial vehicle. Additionally, it facilitates seamless communication between on-board systems and personal computers. To validate their

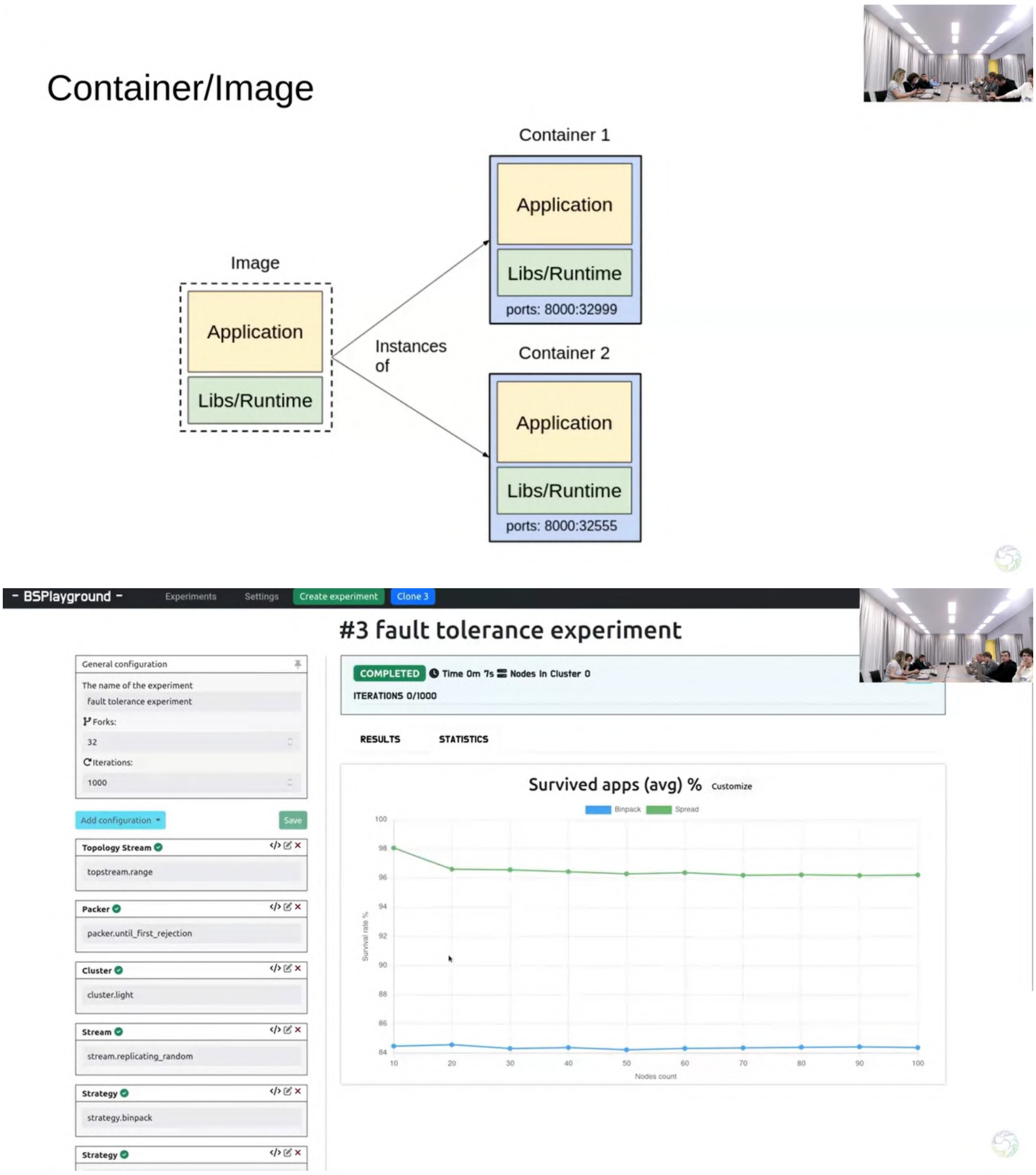

Figure 10: Presentation of the article [70].

concept, the authors practically implemented the test platform. Furthermore, they developed a configuration utility specifically for the simulator of sensors and actuators (figure 12).

The paper "Data security of IoT devices with limited resources: challenges and potential solutions" [49] emphasises the need for adaptive security mechanisms that can effectively respond to changing operational conditions and resource limitations. It underscores the importance of regularly updating security measures to address new and evolving cyber threats. Beyond technical considerations, the article highlights the significance of strategic planning and inno-

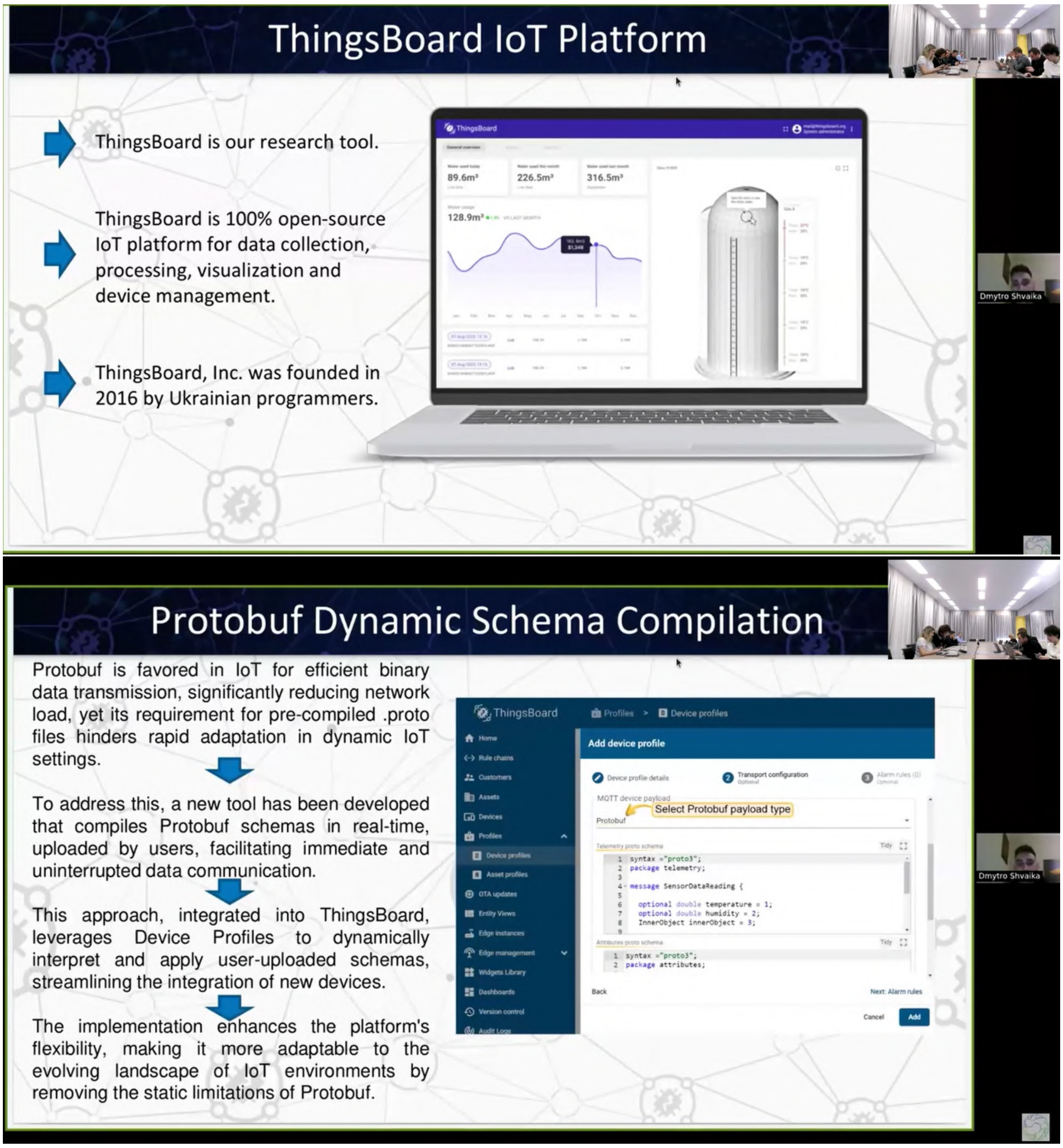

Figure 11: Presentation of the article [57].

vation in IoT security. Furthermore, the authors recommend integrated solutions that combine hardware, software, and management aspects to enhance overall efficiency and security in IoT systems. This contribution addresses security challenges faced by IoT devices operating under resource constraints, providing an overview of existing issues and suggesting avenues for future research and development in this dynamic field (figure 13).

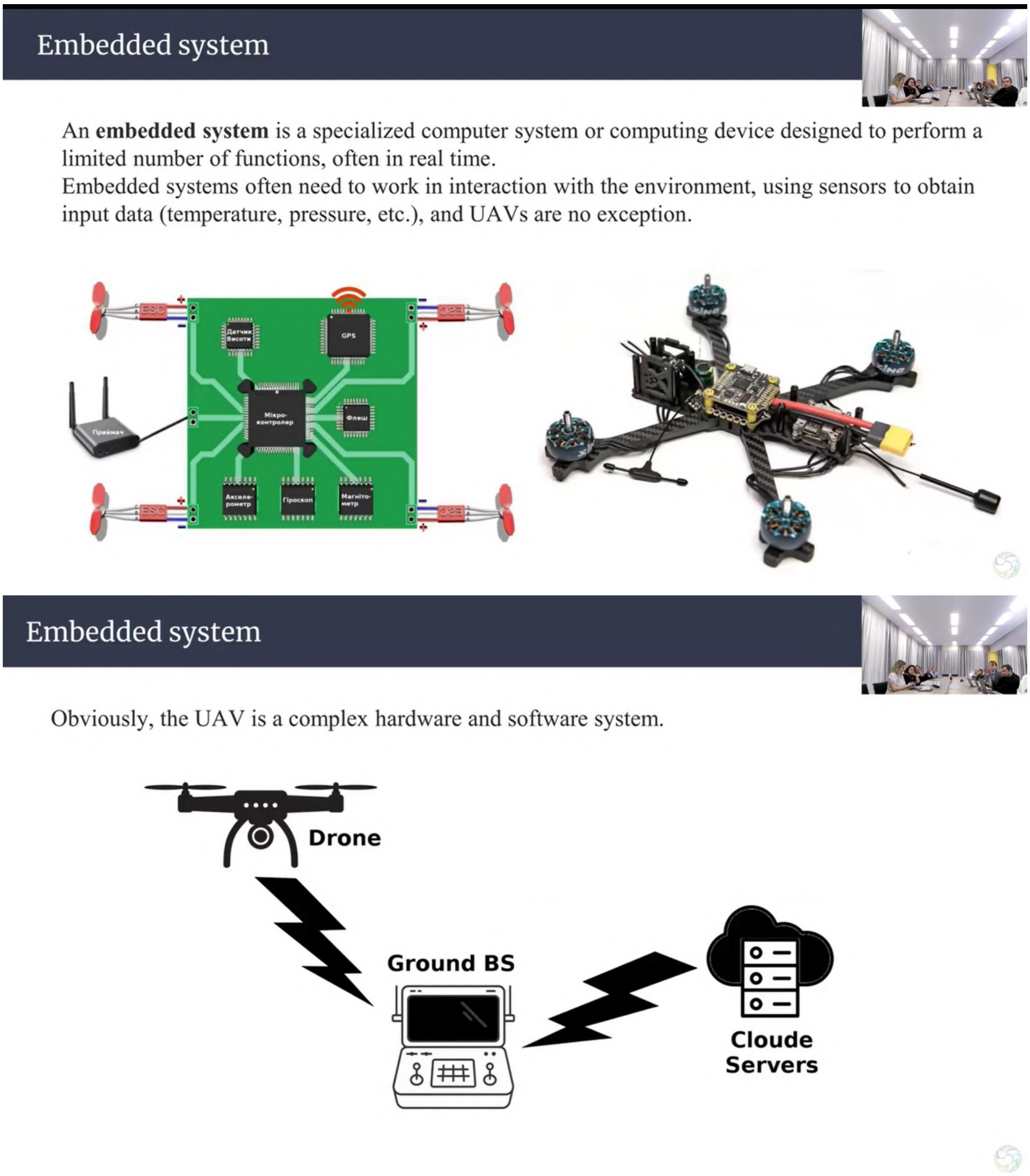

Figure 12: Presentation of the article [41].

The paper "Automated Internet of Things system for monitoring indoor air quality" [25] investigates how IoT technologies can be harnessed to develop a comprehensive air quality monitoring system, mainly focusing on indoor environments. The primary objective is to enhance the performance of energy devices and safeguard the environment by maintaining optimal air conditions. The study underscores the significance of embedded sensors in establishing a

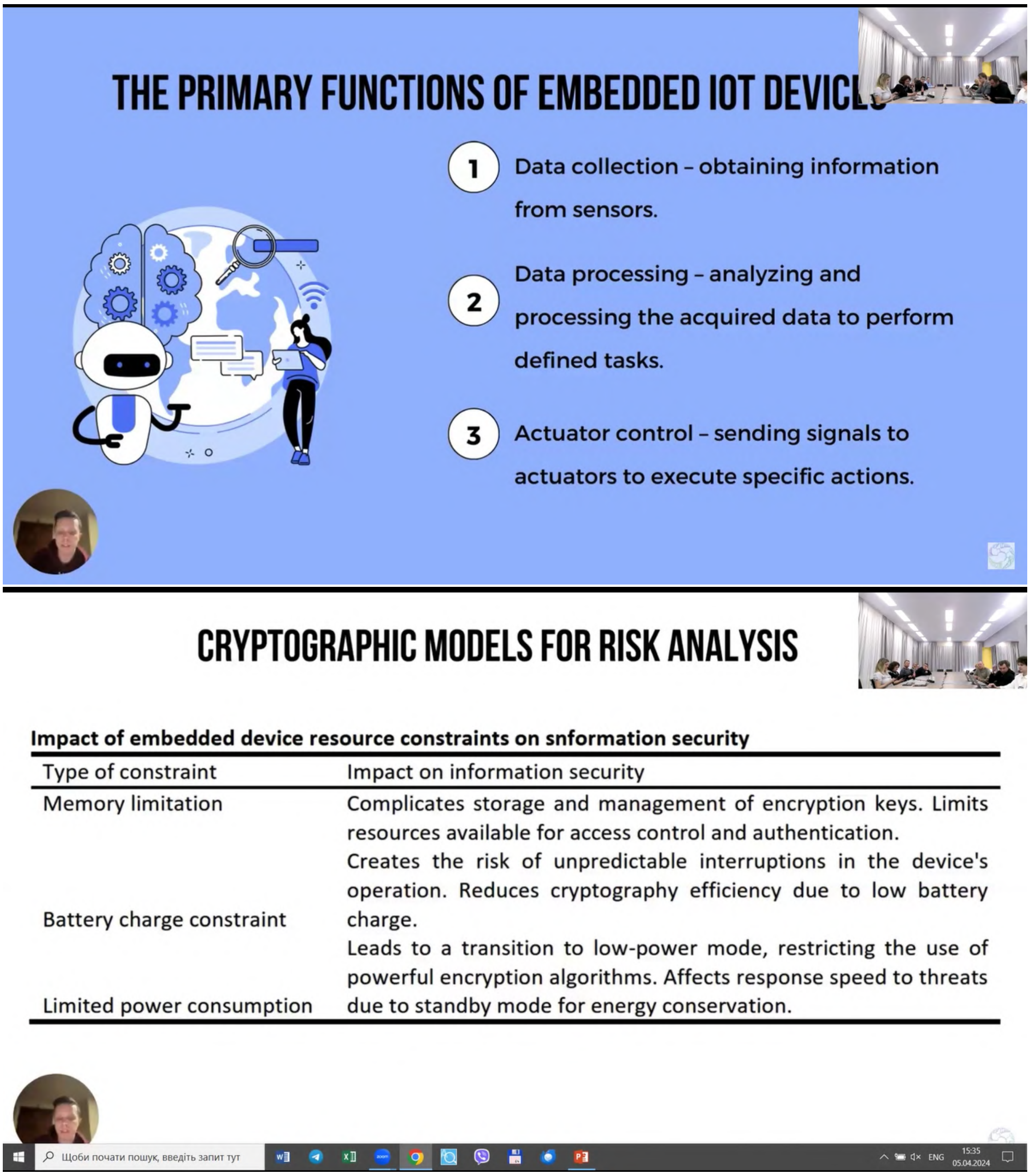

Figure 13: Presentation of the article [49].

versatile IoT-based monitoring system that adapts to different control parameters while filtering out irrelevant data (figure 14).

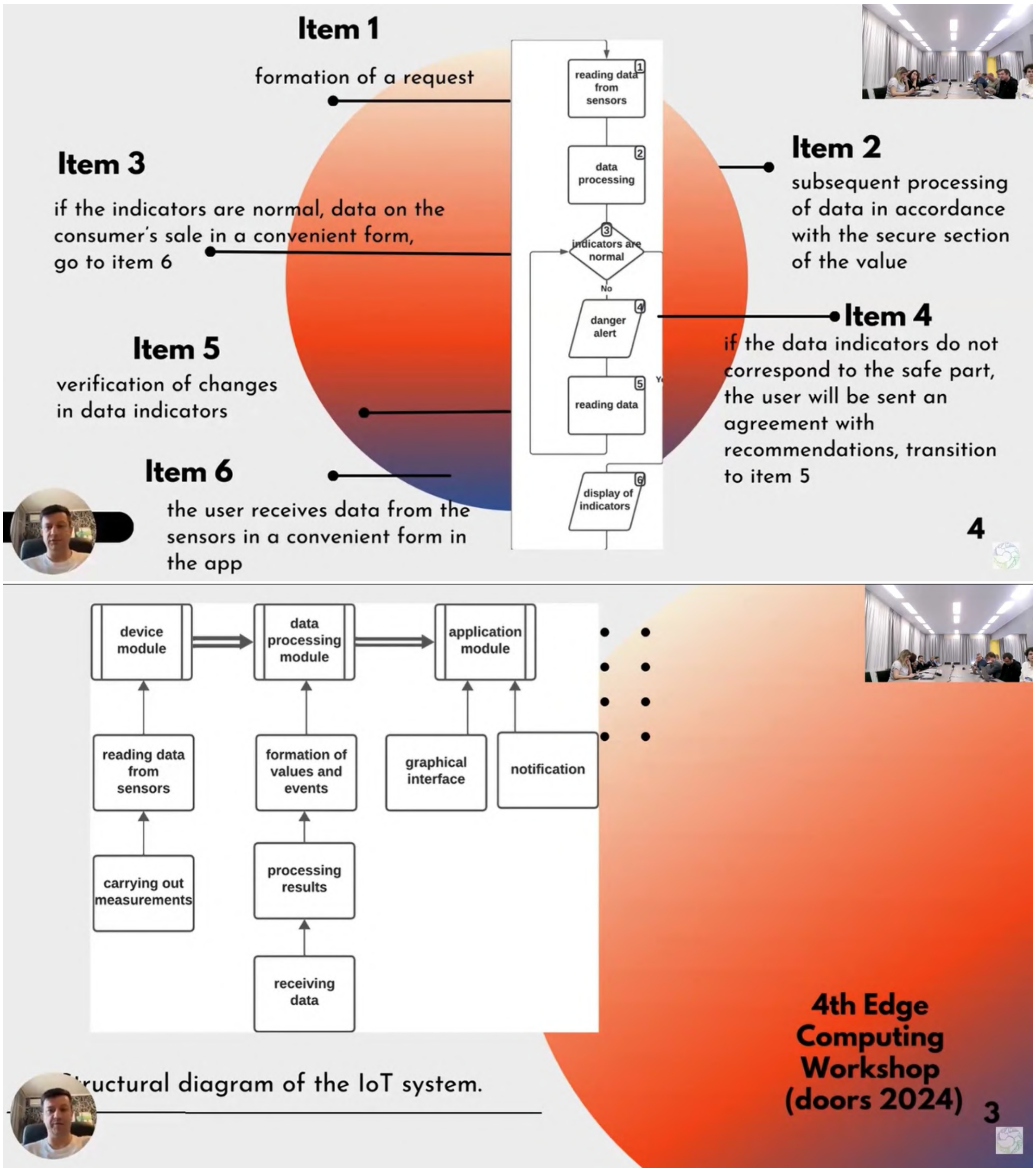

Figure 14: Presentation of the article [25].

4. Conclusions and future directions

Doors 2024 brought together researchers and practitioners to share cutting-edge research and applications in edge computing. The accepted papers spanned novel wireless communication techniques, sensing and analytics applications, performance optimisation, and security. Collectively, the papers show both the breadth of edge computing use cases and the continued need for innovative solutions to make edge practical and efficient.

Key themes that emerged across the workshop include:

- leveraging edge computing to enable new IoT applications, from environmental monitoring to UAV sensing;
- advancing wireless communication technologies to connect edge devices robustly;
- developing software frameworks and methodologies to evaluate edge system performance;
- designing adaptive security measures to protect resource-constrained edge devices.

Attendees valued the focused technical presentations and ample time for discussion. To broaden participation, the organisers will consider adding tutorials, panels, and student research competitions for future iterations. The workshop's growth and co-location with major conferences could increase its impact.

Edge computing will continue to be an important growth area as computation moves closer to data sources and end users. doors will continue to play a crucial role in advancing research and practice in this exciting field.

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