

Edge computing research: a bibliometric analysis and JEC Volume 3 Issue 2 (2024) highlights

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Abstract. This editorial presents a bibliometric analysis of edge computing research published in IEEE Access from 2018 to 2023, followed by an overview and discussion of the papers featured in the current issue of the Journal of Edge Computing (JEC), Volume 3, Issue 2 (2024). The IEEE Access analysis reveals key trends and themes in edge computing research, including IoT integration, AI and machine learning applications, resource management, wireless networks, and security concerns. The most cited authors, countries, and collaboration patterns are also identified. The JEC papers align well with these findings, addressing challenges and proposing novel solutions in areas such as IoT interoperability, plant disease detection using deep learning, wireless technologies in IoT projects, efficient operating systems, and adaptive IoT honeypot frameworks. The research in both IEEE Access and JEC demonstrates the rapid advancements and growing importance of edge computing in various domains.

Keywords: edge computing, Internet of Things (IoT), artificial intelligence, machine learning, resource management, wireless networks, security, bibliometric analysis, research trends, IEEE Access, Journal of Edge Computing


1. Introduction

Edge computing is an emerging technology that has gained significant attention recently. It is a distributed computing paradigm that enables data processing and storage closer to the source of data generation.

In recent years, the IT industry has been developing increasingly, and the new area of edge computing research has attracted the attention of many scientists worldwide. The problems associated with edge computing include several issues, including IoT, cloud computing, fog computing, networks, security, blockchain, intelligent cities and homes, distributed systems, etc. Due to the widespread use of IoT devices and sensors and the increasing amount of data being generated, collected, and processed, edge computing is becoming necessary to process this data at the source efficiently. This helps reduce data transmission delays to central data centres and increase productivity. In addition, edge computing allows for better reliability and security of systems by processing data at the source. This is especially important in critical applications such as autonomous vehicles, medical diagnostics, and manufacturing. Edge computing also

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saves network and computing resources, as data processing can be performed on local servers or embedded systems instead of sending all the data to a central data centre. In turn, the deployment of 5G technology creates favourable conditions for the development of edge computing, as it provides high speed and low latency in the network, which allows for the effective use of this technology for various applications. All these factors underline the importance of research and development in this area.

The purpose of this bibliometric analysis is to identify and analyze the new trends in edge computing.

2. Methods

The Scopus scientometric database was chosen for the search because it is known for its high data quality and peer-review system, ensuring that articles included in the database undergo a scientific review process. This ensures that search results will meet scientific standards. In addition, exported data from Scopus can be used in other services, such as VoSViewer, which provides a wide range of functions for analyzing scientific data, including determining the ranking of authors, institutions, and countries working on a given topic, or keyword co-occurrence and their dynamics over time. These tools can be useful for studying research trends. The search was conducted using the following keywords: “edge computing”, “fog computing”, “mobile edge computing”, “cloudlet”, “edge analytics”, “edge intelligence”, “edge caching”, and “edge security”. We retrieved 36,360 documents. We included studies published between 2018 and 2023 that focused on the new trends in edge computing, resulting in 32,592 publications. We excluded studies not written in English or did not meet our inclusion criteria, resulting in 31,824 documents. We extracted data from the included studies and analyzed it using a thematic synthesis approach.

Next, we limited the sample to the IEEE Access source. This is an authoritative open-access journal from the Institute of Electrical and Electronics Engineers (IEEE). It publishes high-quality research on various electrical engineering, computer science, and related fields. Thus, by focusing on this journal, we increase the likelihood of finding relevant and effective research in the field of edge computing.

By limiting our search, we get a more manageable set of results relevant to our interests in edge computing. As a result, we received 1,163 publications.

3. Results

3.1. Statistics by year

According to an analysis of scientific sources from 2018 to 2023, this topic was most prevalent among scholars in 2020 (figure 1). It is worth noting that the decline in popularity since 2021 could have been caused by factors such as the quarantine caused by the pandemic, military operations, etc.

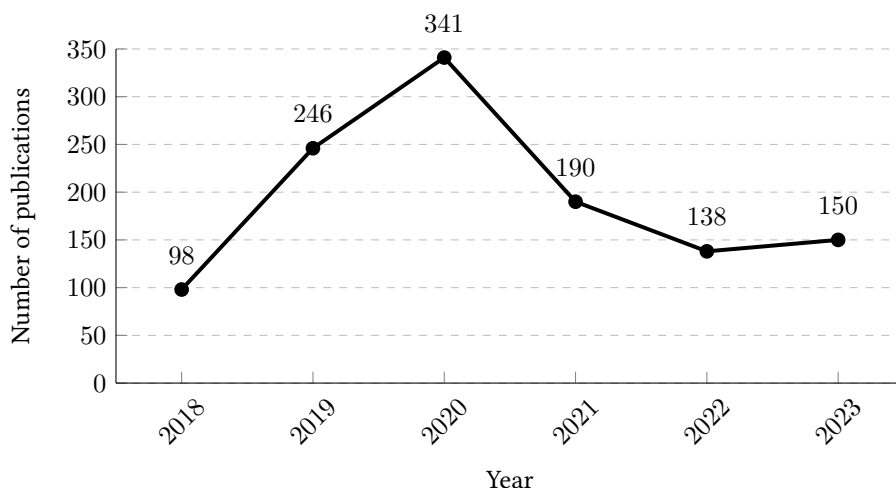


Figure 1: Statistics by year.

3.2. The most cited authors

To begin with, we identified the most cited authors and research groups on the subject. The limit was set at a minimum of 5 publications and ten citations. Thus, out of 4275 authors, 31 were identified as having met these conditions.

Based on the table 2, here's an analysis of the most cited authors and research groups in the field of edge computing and related topics:

The top 4 most cited authors, namely Paula Fraga-Lamas [4, 8, 9, 11–13], Quoc-Viet Pham [14, 14, 25, 27–30], Mohsen Guizani [1, 10, 21, 32, 33, 38], and M. Shamim Hossain [2, 7, 17, 18, 23, 32] have garnered a significantly high number of citations, ranging from 633 to 1304. This indicates their substantial contributions and influential work in the field.

The citation counts vary considerably, from 67 (Wei Zhao [6, 22, 47–49]) to 1304 (Paula Fraga-Lamas [4, 8, 9, 11–13]), suggesting a wide range of influence and impact among the authors.

Authors like Joelj P. C. Rodrigues (5 publications [19, 26, 31, 35, 36, 46], 386 citations) and Mark A. Gregory (5 publications, 219 citations) has relatively fewer publications but high citation counts, indicating the potential significance and influence of their work.

The figure 2 visualises co-authorship networks or collaboration patterns among researchers or authors working on a particular topic or field of study. Each green circle or node represents an individual author; their names are displayed within the nodes.

The visualization uses a force-directed graph layout, where closely connected nodes (authors who have co-authored papers together) are positioned closer, and those with fewer or no direct collaborations are pushed further apart. The size or intensity of the nodes may indicate the author's productivity or centrality within the network.

In figure 2, clusters of authors have intensively collaborated, forming dense subgroups or communities within a larger network. For example, the group around “Zhang, Jie” [5, 37, 40, 42, 44, 45] and “Wang, Wei” [16, 20, 41, 43, 50] seems to represent a tightly-knit collaboration

Table 1

Authors with the highest citations.

Rank	Author	Documents	Citations
1	Fraga-Lamas, Paula	6	1304
2	Pham, Quoc-Viet	7	806
3	Guizani, Mohsen	6	727
4	Hossain, M. Shamim	6	633
5	Han, Zhu	6	392
6	Rodrigues, Joelj P. C.	6	386
7	Wu, Celimuge	5	315
8	Zhang, Qi	5	307
9	Kim, Byung-Seo	6	305
10	Hong, Choong Seon	8	274
11	Zhang, Jie	6	269
12	Al-turjman, Fadi	7	255
13	Reisslein, Martin	5	248
14	Hassan, Mohammad Mehedi	5	247
15	Gregory, Mark A.	5	219
16	Li, Shuo	5	219
17	Wan, Jian	5	204
18	Fitzek, Frank H. P.	5	201
19	Harjula, Erkki	7	168
20	Lin, Fuhong	5	150
21	Ylianttila, Mika	5	143
22	Ahmad, Ijaz	5	135
23	Alharbi, Hatem A.	5	133
24	Wang, Jin	6	132
25	Xia, Junjuan	6	131
26	Wang, Tian	5	123
27	Wang, Wei	5	93
28	Abdullah, Saima	5	88
29	Huh, Eui-Nam	5	77
30	Zhang, Peiying	5	73
31	Zhao, Wei	5	67

cluster.

It's also possible to identify potential research collaborations or connections between authors from different sub-groups based on their proximity in the visualization. The visualization provides an overview of the research community's structure, collaboration patterns, and potential for future collaborations on the given topic. The figure 2 also suggests that no large, stable teams are working closely together on this topic.

3.3. The most cited countries

Next, the statistics among countries were determined. The limit was set at a minimum of 10 publications and 10 citations. Thus, out of 84 countries, 30 were identified as having met these

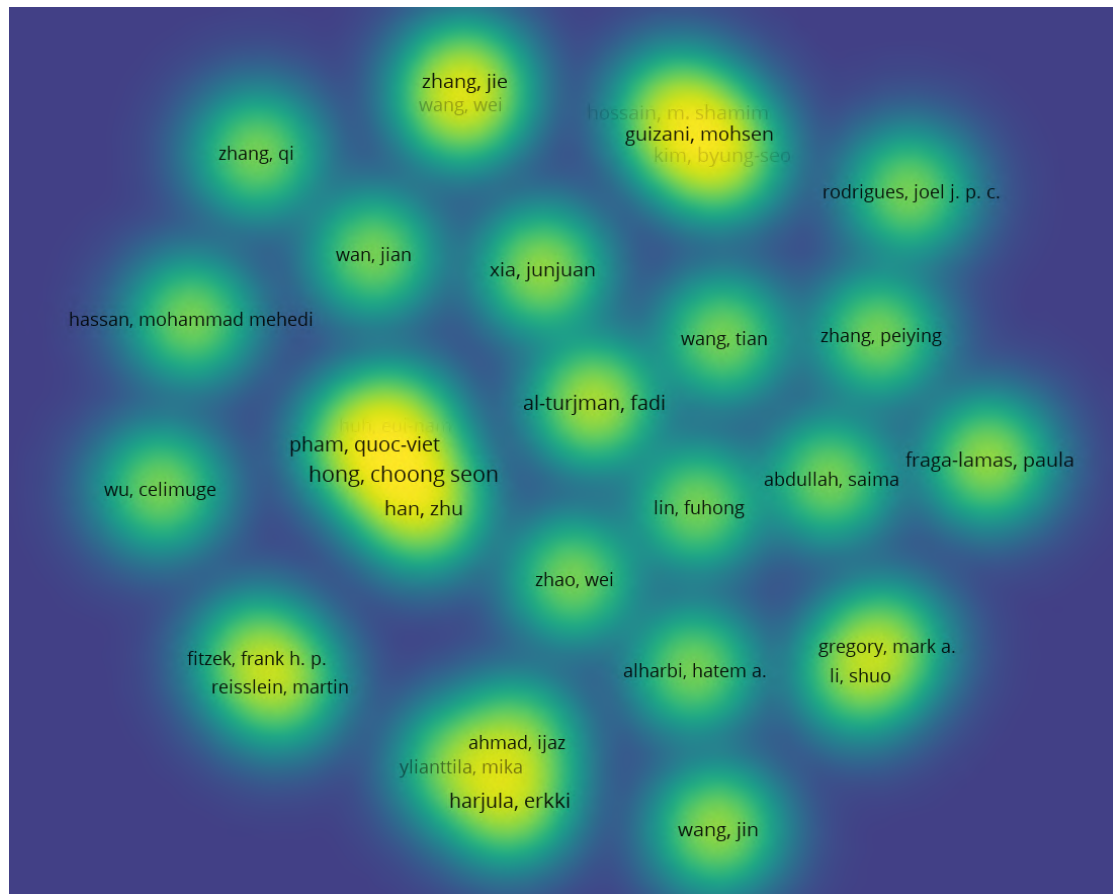


Figure 2: The most cited authors.

conditions (table 2).

Here are the key observations from the data. China has the highest number of documents (534) and citations (15,138), indicating its significant contribution and impact in this research area.

The United States (4,517 citations), South Korea (4,390 citations), and the United Kingdom (4,253 citations) follow China as the countries with the highest number of citations, despite having fewer documents.

Several countries from the Middle East and Asia, such as Saudi Arabia, Pakistan, India, and Malaysia, rank highly in terms of both documents and citations, suggesting their active involvement in this research field.

European countries like Spain, Italy, Denmark, Portugal, Finland, Sweden, and Germany are among the top 30 countries, demonstrating their contributions to this research area.

Australia, Canada, and Brazil are non-European countries that have made notable contributions, as evidenced by their presence in the top rankings.

The data highlights the global nature of research in this field, with countries from various

Table 2

Countries with the highest citations.

Rank	Country	Documents	Citations
1	China	534	15138
2	United States	132	4517
3	South Korea	129	4390
4	United Kingdom	99	4253
5	Saudi Arabia	78	3637
6	Pakistan	69	2609
7	India	53	2595
8	Australia	52	2430
9	Spain	42	2062
10	Malaysia	38	1793
11	Canada	42	1691
12	Taiwan	42	1443
13	Italy	40	961
14	Egypt	24	921
15	Denmark	14	794
16	Japan	36	735
17	Brazil	23	683
18	Portugal	18	674
19	Vietnam	16	662
20	United Arab Emirates	17	592
21	Finland	25	482
22	Sweden	15	466
23	Iran	15	394
24	Hong Kong	15	380
25	Germany	24	365
26	Turkey	18	363
27	Ireland	14	273
28	France	19	248
29	Greece	12	184
30	Poland	10	172

regions in the top 30.

The figure 3 appears to be a network visualization showing co-authorship connections between countries in a specific research area.

Some key observations from the network visualization:

1. China is prominently positioned at the centre of the network, represented by the largest purple node, indicating its significant role and extensive collaborations with other countries in this research area.
2. The United States is also a central node, closely connected to China, suggesting strong research collaborations between these two countries.
3. Countries like Saudi Arabia, Pakistan, Egypt, and Malaysia form a distinct cluster, potentially indicating a regional collaboration network in this research field.

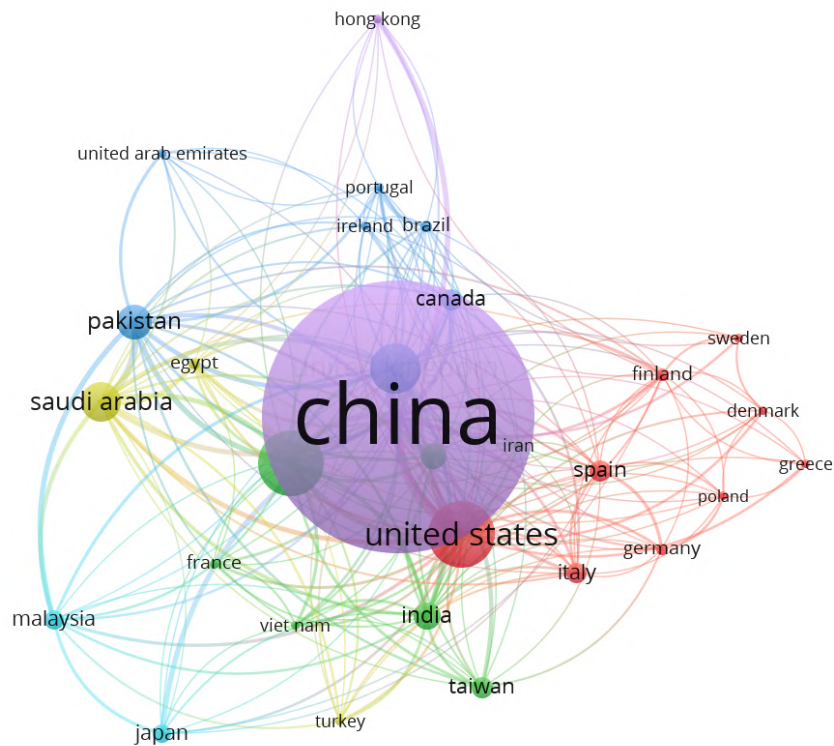


Figure 3: The most cited authors.

4. European countries such as the United Kingdom, Spain, Germany, Italy, Denmark, Finland, and Sweden are well-connected within the network, suggesting active research collaborations among them and other countries.
5. Certain countries, like Portugal, Ireland, Brazil, and Canada, appear to have connections bridging different clusters or regions, potentially facilitating international collaborations.
6. The density and patterns of connections between countries provide insights into the strength and nature of research collaborations within this specific field.
7. The network also represents countries like Hong Kong, the United Arab Emirates, Vietnam, and Taiwan, indicating their involvement and contributions to this research area.

4. Keyword analysis

A limit of at least 15 occurrences was set to analyze keywords and identify relationships. This condition was met by 34 words. Subsequently, the following repetitions were removed from the list: Internet of Things (IoT), IoT, MEC, mobile edge computing (MEC), multi-access edge computing (MEC), and reinforcement learning. Thus, the final list includes 28 keywords (figure 4).

Analyzing the figure 4, the following conclusions can be deduced.

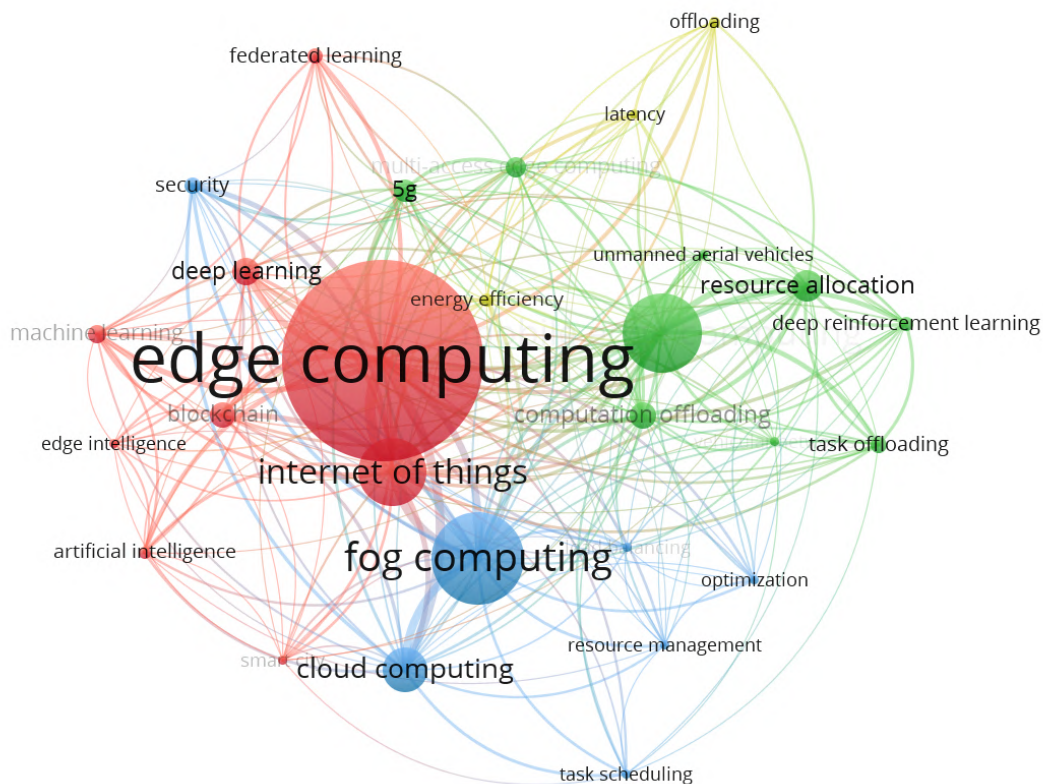


Figure 4: Keywords clusters.

Cluster 1 (red colour): artificial intelligence, blockchain, deep learning, edge computing, edge intelligence, federated learning, the Internet of Things, machine learning, and smart cities. This cluster appears to encompass the broad areas of artificial intelligence (AI) and machine learning (ML) and their applications in edge computing environments. It includes specific techniques like deep learning, federated learning (a collaborative ML approach), and the integration of edge computing with the Internet of Things (IoT) and smart city initiatives. The presence of blockchain in this cluster suggests the exploration of decentralized and distributed architectures in edge computing scenarios.

Cluster 2 (green colour): computation offloading, deep reinforcement learning, mobile edge computing, multi-access edge computing, resource allocation, task offloading, unmanned aerial vehicles, and vehicular networks. This cluster focuses on the practical aspects of edge computing, particularly in the context of mobile and multi-access edge computing (MEC). It covers concepts like computation offloading, task offloading, and resource allocation, which are essential for optimizing the performance and efficiency of edge computing systems. Including unmanned aerial vehicles (UAVs) and vehicular networks indicates the application of edge computing in transportation and mobility domains. Deep reinforcement learning, a branch of ML, is also included, suggesting advanced AI techniques for decision-making and optimization in edge

computing environments.

Cluster 3 (blue colour): cloud computing, fog computing, load balancing, optimization, resource management, security, and task scheduling. This cluster represents the infrastructure and management aspects of edge computing systems. It includes concepts like cloud computing, fog computing (an extension of cloud computing to the edge), load balancing, resource management, task scheduling, and optimization techniques. Security in this cluster highlights the importance of addressing security concerns in edge computing deployments.

Cluster 4 (yellow colour): energy efficiency, latency, offloading. This cluster focuses on edge computing systems' key performance metrics and objectives. It includes energy efficiency, latency, and offloading, which are critical factors in designing and optimizing edge computing solutions. The emphasis on these metrics suggests the need for efficient resource utilization, low-latency communication, and effective workload distribution between edge devices and the cloud.

The figure 5 shows overlay visualization, illustrating trends in keyword usage over time.

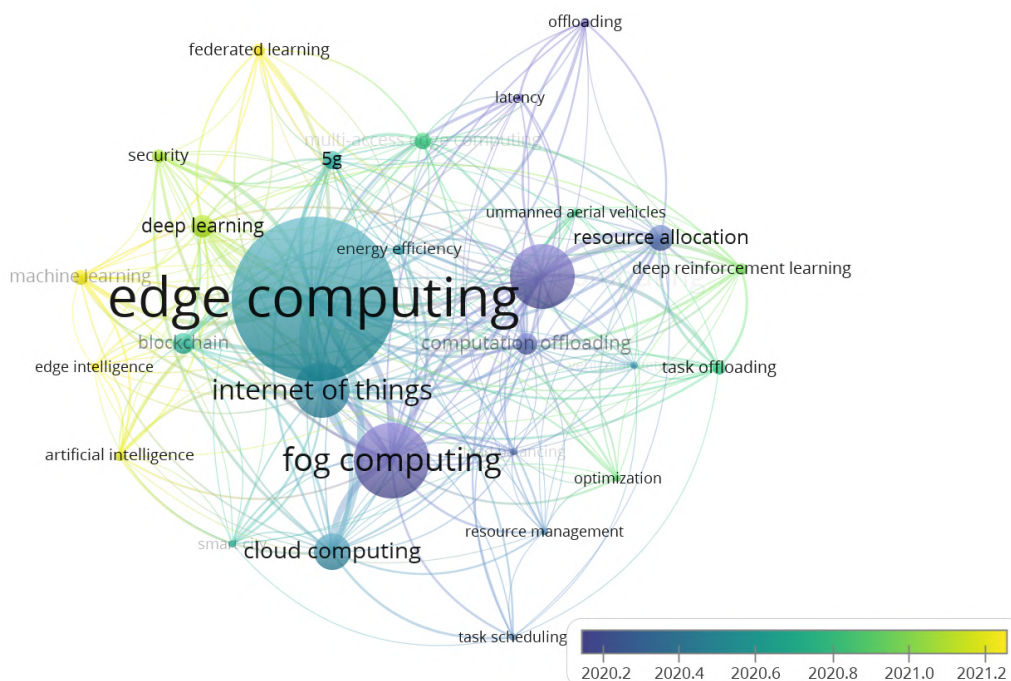


Figure 5: Keywords by the years.

5. An overview of the JEC Volume 3 Issue 2 (2024)

Continuing our exploration of the field of edge computing, we present the research reviewed in the current issue of the Journal of Edge Computing.

Shvaika, Shvaika and Artemchuk [34] examines the advancement of IoT interoperability through dynamic data serialization using ThingsBoard, comparing JSON with Protocol Buffers (Protobuf) and addressing the challenges of integrating Protobuf-compatible devices into IoT platforms. The research proposes a dynamic method for automating Protobuf schema compilation in ThingsBoard, allowing real-time device integration without system downtime. However, the current implementation has some limitations regarding Protobuf features. The study concludes that this approach significantly enhances IoT platforms' flexibility and scalability, with the potential for further development in edge computing applications.

Hamim and Jony [15] presents a modified MobileNet architecture for detecting plant diseases in chilli plants, achieving 97.18% diagnostic accuracy through advanced deep learning techniques and data augmentation. The research addresses the limitations of conventional diagnostic tools by combining sophisticated optimization models with reliable training procedures, making it more efficient for real-time disease diagnosis in agricultural settings. The study emphasizes the importance of high-quality image data and comprehensive training datasets while highlighting the need for further evaluation across various environmental conditions to ensure the model's robustness and adaptability in precision farming applications.

Vakaliuk et al. [39] explores the implementation of wireless technologies in IoT projects, focusing on how edge computing reduces system response delays and increases network throughput in both short-range and long-range sensor networks. The research examines various wireless data transmission methods, including ESP-NOW technology, nRF24L01 radio modules, and local Wi-Fi access points, while also providing practical examples of IoT applications such as air quality monitoring systems and blood oxygen saturation measurement devices. The study demonstrates how short-range sensor networks can operate locally without internet access, while long-range networks typically require internet connectivity and utilize both edge and cloud computing, with a detailed analysis of the LoRa radio line's range using the Okumura-Hata propagation model.

Bakir et al. [3] introduces Ambience, a novel operating system specifically designed to support IoT applications structured as microservices across heterogeneous devices, from resource-constrained microcontrollers to cloud servers. The operating system's unique features include deployment-time determination of isolation boundaries, asynchronous computational models, typed system calls, automatic network overlay generation, and capability-based access control, enabling efficient resource use and optimization across different scales. Through empirical evaluation, the research demonstrates that Ambience is often one to three orders of magnitude more efficient than commercial IoT frameworks and current state-of-the-art systems while allowing unmodified microservices to be deployed at different scales without code modifications.

Morozov et al. [24] presents an adaptive IoT honeypot framework that dynamically adjusts its behaviour based on observed attack patterns. The authors propose a comprehensive evaluation framework with quantitative metrics to assess IoT honeypot effectiveness and integrate software-defined networking (SDN) to create device-group-specific deceptive views.

6. Discussion

The research articles published in this issue of the *Journal of Edge Computing* align well with the findings from the bibliometric analysis of IEEE Access articles on edge computing. The keywords and themes identified in the IEEE Access analysis, such as IoT, resource management, wireless networks, and machine learning, are prominently featured in the JEC papers.

The study by Shvaika, Shvaika and Artemchuk [34] on advancing IoT interoperability through dynamic data serialization using ThingsBoard aligns with the IoT and edge computing integration theme identified in the keyword analysis. Their approach to automating Protobuf schema compilation addresses scalability and flexibility challenges, which are crucial for edge computing deployments.

The study by Hamim and Jony [15] on plant disease detection using a modified MobileNet architecture showcases the application of deep learning techniques in edge computing environments. This resonates with the presence of keywords like deep learning, machine learning, and edge intelligence in the IEEE Access analysis.

The exploration of wireless technologies in IoT projects by Vakaliuk et al. [39], focusing on edge computing's role in reducing response delays and increasing network throughput, aligns with the themes of resource allocation, task offloading, and vehicular networks identified in the keyword analysis.

The Ambience operating system introduced by Bakir et al. [3] addresses the infrastructure and management aspects of edge computing systems, which is a prominent cluster in the keyword analysis. The system's features, such as deployment-time determination of isolation boundaries and capability-based access control, contribute to efficient resource use and optimization across different scales.

Finally, the adaptive IoT honeypot framework by Morozov et al. [24] tackles the critical issue of security in edge computing deployments, which is highlighted as a key concern in the keyword analysis.

The geographic distribution of authors in the JEC papers also reflects the global nature of edge computing research, with contributions from various regions, including Europe, Asia, and North America. This aligns with the findings from the country-level analysis of IEEE Access articles.

Therefore, the research presented in this issue of the *Journal of Edge Computing* builds upon and extends the trends and themes identified in the IEEE Access bibliometric analysis. The JEC papers provide novel solutions and insights that address the challenges and opportunities in edge computing, contributing to the advancement of this rapidly evolving field.

7. Conclusions

This editorial presented a bibliometric analysis of edge computing research published in IEEE Access from 2018 to 2023, followed by an overview and discussion of the papers featured in the current issue of the *Journal of Edge Computing* (JEC), Volume 3, Issue 2 (2024).

The IEEE Access analysis revealed key trends and themes in edge computing research, including the integration of IoT and edge computing, the application of AI and machine learning

techniques, resource management and optimization, wireless networks, and security concerns. The most cited authors, countries, and collaboration patterns were also identified, highlighting the global nature of edge-computing research and the diverse range of contributors.

The JEC papers in this issue align well with the findings from the IEEE Access analysis. They address challenges and propose novel solutions in areas such as IoT interoperability, plant disease detection using deep learning, wireless technologies in IoT projects, efficient operating systems for edge computing, and adaptive IoT honeypot frameworks for security.

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