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RESEARCH ARTICLE

Cloud computing research productivity and collaboration: A scientometric perspective

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Abstract

Cloud computing has emerged as a transformative technology paradigm, revolutionizing the way organizations manage and deliver IT services. As the field continues to evolve, it is essential to understand the trajectory of research and development in the cloud computing environment. This scientometric analysis explores the landscape of cloud computing research, aiming to uncover trends, key contributors, and influential research themes. This work will employ a comprehensive dataset comprising academic publications, patents, and conference proceedings spanning the last five years of data. This research work will identify a significant increase in research output in the field of Cloud Computing over the last decade, indicative of its growing importance in both academia and industry. This work will identify key contributors and institutions that have played pivotal roles in shaping the landscape of cloud computing research. Through the trend topic approach, we categorize research themes within cloud computing, shedding light on emerging areas of interest and shifts in focus. Our analysis also examines the international collaboration network within cloud computing research, illustrating the global nature of this field. This scientometric analysis serves as a valuable resource for researchers, practitioners, and policymakers seeking to navigate the complex and dynamic world of cloud computing.

Keywords: Cloud computing, Trend topic, Co-occurrence, Co-citation network, Research production, Collaboration, Scientometric analysis.

Introduction

In the dynamic landscape of information technology, cloud computing has emerged as a transformative force over the past decade. The last five years, in particular, have witnessed remarkable advancements, reshaping the way organizations manage and utilize their digital resources. This introduction serves as a gateway to exploring the cutting-edge developments in cloud computing research, delving into its evolution and its impact on various sectors, Rosenberger, L. (2020); Dang, A., & Wang, F. (2021); Sunyaev, A., & Sunyaev, A. (2020).

Cloud computing is a model that offers on-demand access to a shared pool of computing resources, including servers, storage, databases, networking, software, and more, over the internet. It allows organizations to scale their operations, reduce infrastructure costs, enhance flexibility, and accelerate innovation. The journey of cloud computing over the last five years has been characterized by significant breakthroughs and paradigm shifts, Alam, T. (2020); Stoica, I., & Shenker, S. (2021, June).

One of the most prominent trends in recent cloud computing research is the rise of edge computing. Traditional cloud infrastructure was centralized, relying on data centers located in distant regions. However, as the demand for real-time data processing and low-latency applications surged, the need for decentralized computing closer to the data source became apparent. Edge computing brings computation and data storage closer to the data-generating devices, reducing latency and improving efficiency. Researchers have been working tirelessly to optimize edge computing architectures, making them more secure and scalable, Cao, K., Liu, Y., Meng, G., & Sun, Q. (2020), Alwakeel, A. M. (2021).

Security concerns have always been at the forefront of cloud computing discussions. Over the last five years, cloud

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security research has evolved significantly to address the ever-growing threats in the digital realm. Innovations in encryption, access control, and threat detection have played a pivotal role in making cloud environments safer for organizations. The last five years have also seen a proliferation of containerization technologies like Docker and Kubernetes. Containers allow developers to package applications and their dependencies into portable units, enabling seamless deployment and scaling across cloud environments. Researchers have been exploring novel container orchestration techniques, enhancing resource utilization, and optimizing container management in multi-cloud and hybrid cloud setups, Waranugraha, N., & Suryanegara, M. (2020, September), Sharma, S., & Sajid, M. (2021).

The environmental impact of cloud computing has come under scrutiny as the digital footprint of data centers grows. Researchers have been actively engaged in developing green cloud solutions, optimizing energy consumption, and exploring renewable energy sources to power data centers. Sustainable cloud computing is poised to become a critical area of research and development as environmental concerns intensify, Nazir, R., Ahmed, Z., Ahmad, Z., Shaikh, N. N., Laghari, A. A., & Kumar, K. (2020).

Furthermore, cloud-native development has become the norm in the software industry. The adoption of microservices, serverless computing, and DevOps practices have reshaped the way applications are designed, developed, and deployed in the cloud. Researchers have been at the forefront of this revolution, devising methodologies and tools to streamline the development lifecycle and ensure the reliability of cloud-native applications, Ogiela, L., & Ogiela, M. R. (2020), Sadeeq, M. M., Abdulkareem, N. M., Zeebaree, S. R., Ahmed, D. M., Sami, A. S., & Zebari, R. R. (2021).

The last five years have witnessed remarkable strides in cloud computing research, driven by the need for faster, more secure, and more sustainable digital infrastructure. The integration of edge computing, advancements in security, the synergy between AI/ML and cloud services, containerization, and the pursuit of environmentally conscious solutions have defined this era. As we delve deeper into the various dimensions of cloud computing research, it becomes evident that cloud technology will continue to be a dynamic force shaping the future of IT and business, Shetty, J. P., & Panda, R. (2021), Gourisaria, M. K., Samanta, A., Saha, A., Patra, S. S., & Khilar, P. M. (2020), Sunil, S. T., Khadri, S., & Sachin, K. T. (2020).

Materials

Data Collection Source

Many of the researchers can access databases such as Web of Science (WoS), Scopus, EBSCO, Google Scholar, and PubMed. Among these, WoS is considered for this study due to the consistent, standardized and widely utilized source for the scientometric study on the numerous disciplines. Furthermore, WoS, a platform managed by Clarivate Analytics (Formerly Thomson Reuters), is regarded as the most precise and complete source for scientific investigation and appraisal with the best quality indexing. It is also thought to be more relevant to the study scope and to evaluate the research output of various areas, authors, or organizations as well as to analyze the results. It includes over one billion searchable cited references as well as searches across major search databases, disciplines, and document kinds.

Data Collection Keywords and Query

The query ((“Cloud” or “Cloud Computing” or “Security” or “Encryption” or “Decryption” or “Access Control” or “Authentication” or “Cryptography” or “Elliptical Curve Cryptography” or “Attribute-based Access Control” or “Cloud Computing Environment” or “Cloud Security” or “Network Security” or “Cloud models” or “Intrusion Detection” or “Attacks” used to extract the publication data on the Cloud Computing of the WoS database from 2019 - 2023.

Overview Of The Cloud Computing Research Data

The Cloud Computing Web of Science is an overview of scientometric data spanning from 2019 to 2023, including various metrics related to sources, documents, authors, collaboration, document types, and document contents as shown in Figure 1.

Timespan (2019:2023)

The data covers a five-year period from 2019 to 2023.

Sources (Journals, Books, etc)

There are a total of 523 sources, which may include journals, books, and other publication types.

Documents

The dataset consists of 5,219 documents in total.

Annual Growth Rate %

The annual growth rate is negative at -7.34%, indicating a decrease in the number of documents over the specified period.

Document Average Age

The average age of the documents is 2.01 years, suggesting relatively recent research contributions.

Average Citations per Doc

On average, each document has received 13.77 citations, indicating a moderate level of scholarly impact.

Figure 1: Overview of the cloud computing scientometric data

References

The documents contain a total of 152,708 references to other works.

Document Contents

Keywords Plus (ID)

There are 2,746 instances of Keywords Plus (ID) used in the documents.

Author's Keywords (DE)

There are 11,151 instances of Author's Keywords (DE) used in the documents.

Authors

Authors

A total of 12,296 authors contributed to the documents.

Authors of Single-Authored Docs

173 authors have authored single-authored documents.

Authors Collaboration

Single-Authored Docs

There are 191 single-authored documents.

Co-Authors per Doc

On average, there are 4.19 co-authors per document, indicating a substantial level of collaboration.

International Co-Authorships %

Approximately 41.25% of collaborations involve international co-authors.

Document Types

The majority of documents are categorized as "article" (4,640), followed by "review" (301) and other types such as "editorial material" and "article; proceedings paper."

Cloud Computing Data Analysis Methodology

Most Productive and Influential Source on Cloud Computing (CC) Research

Figure 2 depicts the Source research productivity on CC for the years between 2019 to 2023. Figure 2 gives data presents a list of sources, which primarily appear to be academic journals or publications, along with the corresponding number of articles associated with each source. This data offers insights into the publication volume of various sources in a specific field, potentially related to computer science and information technology.

The following are the key observations from the given source research productivity on CC:

The data includes several notable journals, including "IEEE ACCESS," "IEEE INTERNET OF THINGS JOURNAL," and "SENSORS," which have a relatively high number of associated articles, indicating their significance and influence in the field. The number of articles varies significantly across the listed sources, with some journals having a substantial publication volume (e.g., "IEEE ACCESS" with 580 articles) while others have fewer articles (e.g., "CMC-COMPUTERS MATERIALS & CONTINUA" with 87 articles, and the "JOURNAL OF SUPERCOMPUTING" with 66 articles from 2019 to 2023). The sources likely cover a wide array of topics within the field, as indicated by their titles, including areas such as dependable and secure computing, industrial informatics, and network software tools and applications. Many of the listed sources are academic journals, suggesting that they primarily publish scholarly research contributions and play a significant role in advancing knowledge within the field.

Source Citation Productivity on Cloud Computing (CC)

Source citation productivity in the field of cloud computing has been a dynamic area of research and innovation. Cloud

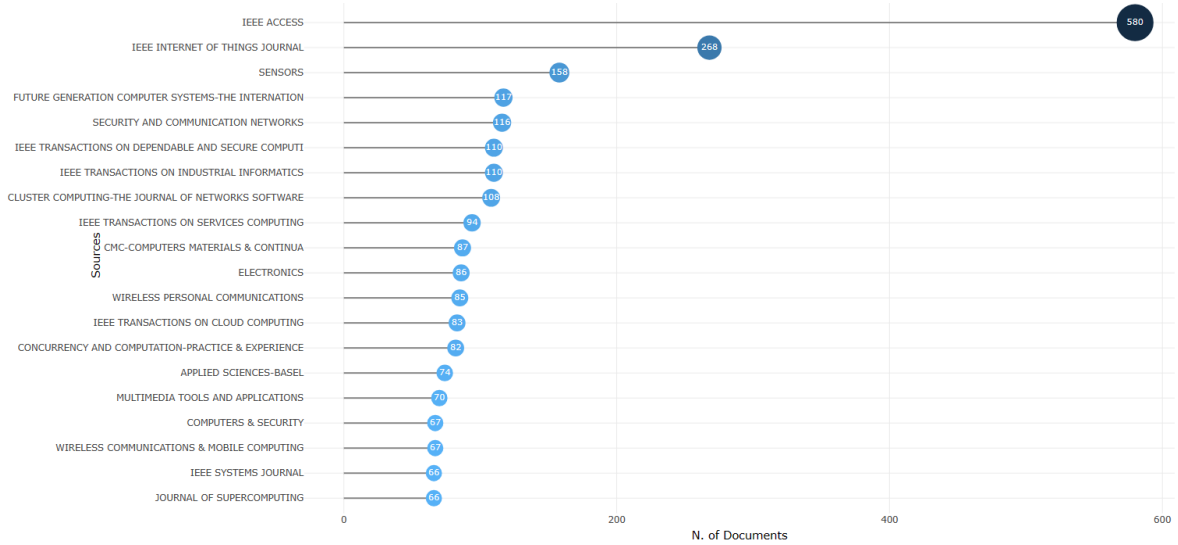

Figure 2: Source Research Productivity on Cloud Computing

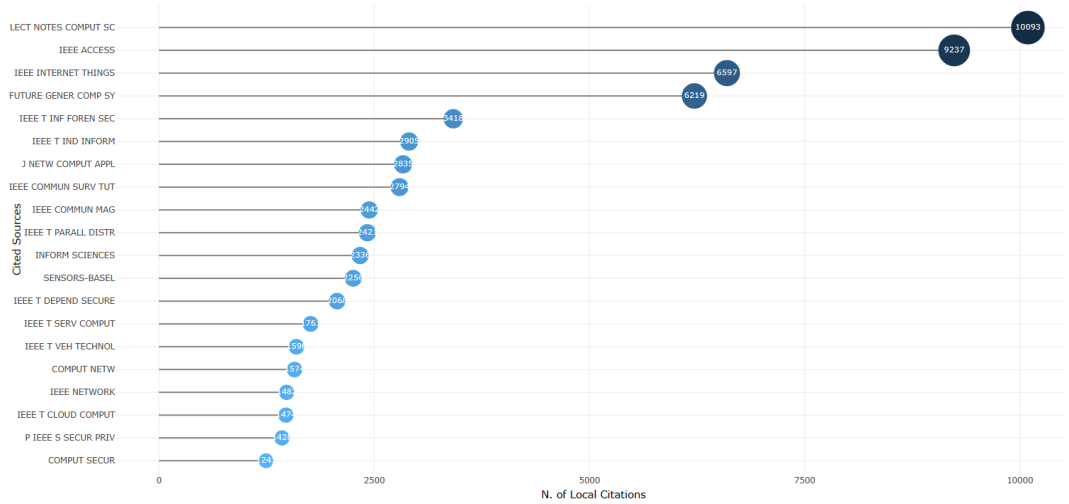

Figure 3: Source citation productivity on CC research

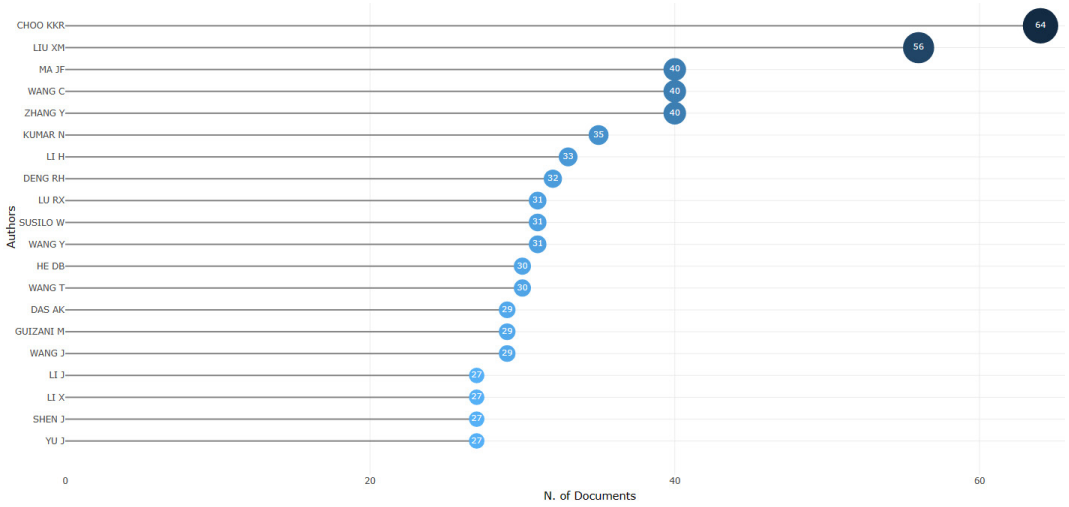

Figure 4: Authors productivity on cloud computing research

computing, with its transformative impact on various industries, has garnered significant scholarly attention. Researchers have actively contributed to this domain, leading to a substantial number of source citations. The prolific productivity in cloud computing citations reflects the rapid evolution of the technology, with studies spanning infrastructure, security, scalability, and application development. Prominent sources like "IEEE T CLOUD COMPUT" and "IEEE T CLOUD COMPUT MAG" have played pivotal roles in disseminating knowledge in this domain. This robust citation activity underscores the importance of cloud computing in shaping the future of information technology.

Figure 3 provides a summary of the number of local citations for various sources. The source "LECT NOTES COMPUT SC" has the highest number of local citations, with 10,093 citations, followed by "IEEE ACCESS" with 9,237 citations. "IEEE INTERNET THINGS" has 6,597 citations, while "FUTURE GENER COMP SY" has 6,219 citations. The source with the lowest number of local citations in the list is "IEEE SYST J" with 1,068 citations. Overall, this table presents data on the citation counts for different sources in a specific context.

Most Productive and Influential Authors on Cloud Computing (CC) Research

Author productivity in the field of cloud computing (CC) research has exhibited remarkable growth and diversity. CC has become a central focus of academia and industry, prompting prolific scholarly contributions. This productivity is reflected in the increasing number of research papers and publications from a wide array of authors worldwide. Esteemed researchers and institutions have played pivotal roles in shaping the CC landscape, resulting in influential and highly cited works. The collaborative nature of CC research has fostered interdisciplinary partnerships, enriching the field. As CC continues to evolve, the productivity of authors highlights the ongoing dedication to advancing this technology, driving innovation, and addressing critical challenges in the digital era.

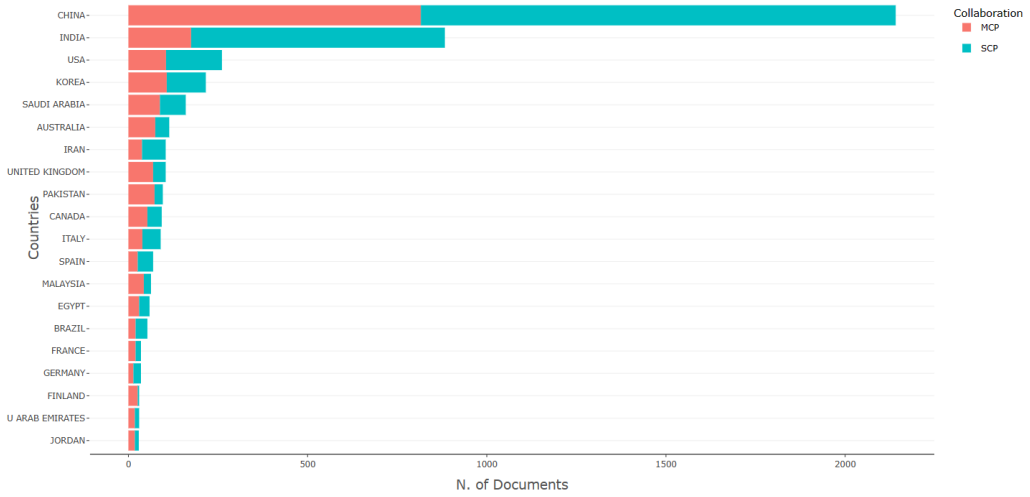

Figure 5: Corresponding author's country CC Research Productivity (SCP – Single Country Publication, MCP – Multi Country Publication)

Figure 4 depicts the author's productivity on CC research. The provided Figure 4 summarizes the productivity of various authors in terms of the number of articles they have contributed to. Choo KKR leads the list with 64 articles, followed closely by Liu XM with 56 articles. Ma JF, Wang C, and Zhang Y each have 40 articles to their names. Kumar N follows with 35 articles, while Li H, Deng RH, Lu RX, and Susilo W have 33, 32, 31, and 31 articles, respectively. These authors have made significant contributions to their respective fields, collectively generating a substantial body of research literature, likely in areas related to the data provided.

Most Productive and Influential Countries

Figure 5 depicts the scientific production of countries regarding publications and the multi-country collaboration in CC research based on the corresponding author's country. SCP is the abbreviation of Single Country Publications and MCP is Multiple Country Publications. Figure 5 provides a comparative overview of research productivity in the field of cloud computing across several countries, measured in terms of the number of articles published (Articles) and the distribution of these articles between SCP and MCP.

China leads in research productivity with the highest number of articles (2141), out of which 1325 are SCP and 816 are MCP. This indicates a strong presence in both single and collaborative research efforts in cloud computing. India follows with 883 articles, of which 708 are SCPs, and 175 are MCPs. While India has a significant number of articles, a larger proportion are single-authored, suggesting a potential for increased collaboration. The United States has 261 articles, with 156 SCPs and 105 MCPs. While the number of articles is lower than in some other countries, the proportion of MCPs is relatively high, indicating collaborative research efforts. Korea has 216 articles, with a nearly equal distribution between SCPs (109) and MCPs (107), showcasing balanced research contributions. Saudi Arabia contributes 160 articles, with a larger proportion being MCPs (88) compared to SCPs (72). Australia has 114 articles, with 39 SCPs and 75 MCPs. The majority of their contributions are in collaboration. Iran has 104 articles, with a significant number of SCPs (66) compared to MCPs (38), indicating a higher prevalence of single-authored work. The United Kingdom also has 104 articles, with 35 SCPs and 69 MCPs, demonstrating active collaborative research. Pakistan contributes 96 articles, with 23 SCPs and 73 MCPs, emphasizing a substantial focus on collaborative work. Canada has 93 articles, with a balanced distribution between SCPs (40) and MCPs (53), indicating active participation in both single and collaborative research.

Most Cited Countries

Figure 6 gives the most cited countries on the CC research. The table presents data on the total citations (TC) and the average number of citations per article for various countries in a CC research domain.

China leads in total citations with 27,584, indicating a significant impact in the research domain. On average, each article from China receives approximately 12.90 citations, demonstrating a substantial influence in the field. India has 7,955 total citations, with an average of 9.00 citations per article. While the total citation count is lower than some other countries, the average number of citations per article is respectable. The United States, despite having fewer total citations (6,974) than China and India, has the highest average article citations at 26.70. This suggests that research articles from the USA tend to be highly influential and widely cited. Australia has 2,943 total citations and an average of 25.80 citations per article, indicating a strong impact and high visibility of Australian research in the field. Korea has 2,827 total citations and an average of 13.10 citations per article, showing a moderate level of impact in the domain. Italy has 1,649 total citations and an average of 18.30

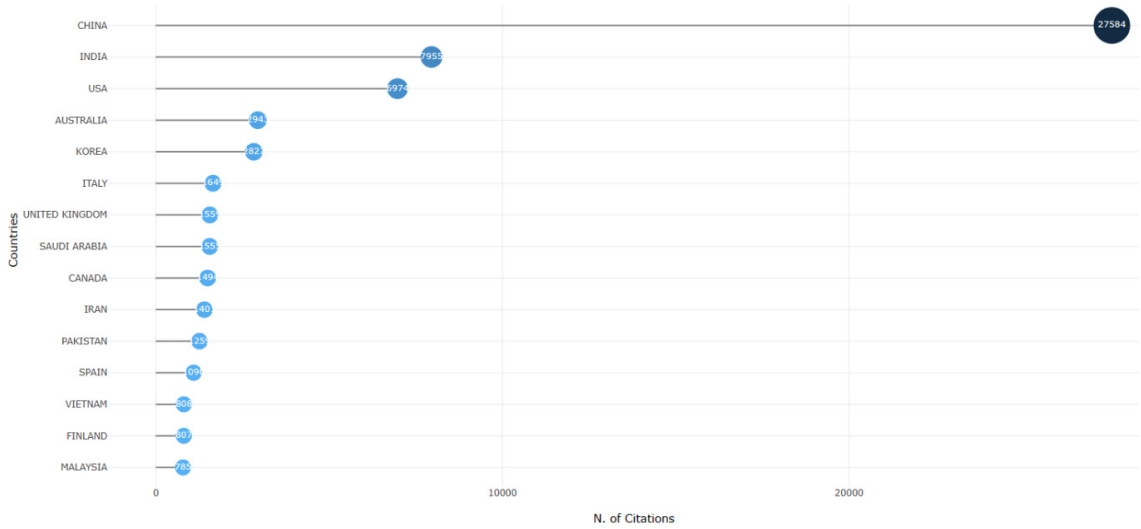

Figure 6: Most Cited Countries in CC Research

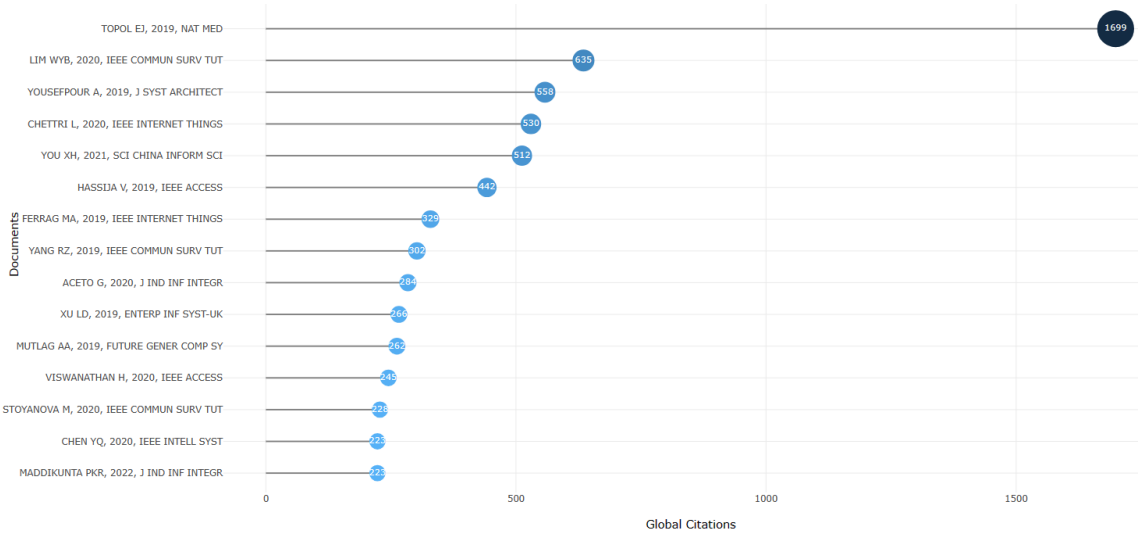

Figure 7: Most cited documents

citations per article, suggesting a good level of influence in the field relative to its citation count. The United Kingdom has 1,559 total citations and an average of 15.00 citations per article, indicating a solid presence in the research domain. Saudi Arabia has 1,555 total citations with an average of 9.70 citations per article. While the average citation count per article is moderate, there is room for growth in the total citation count. Canada has 1,494 total citations and an average of 16.10 citations per article, indicating a respectable level of impact in the field. Iran has 1,401 total citations and an average of 13.50 citations per article, showing a reasonable level of influence in the research domain.

Most Cited Articles (Documents)

Figure 7 provides information about research papers, their total citations (TC), and the average number of citations per year (TC per Year) in a CC academic field or domain.

TOPOL EJ, 2019, NAT MED: This paper has the highest total citations, with 1,699 citations. It also has an impressive average of 339.80 citations per year, indicating sustained and significant impact over time.

LIM WYB, 2020, IEEE COMMUN SURV TUT: Although this paper has fewer total citations (635) compared to the top-ranked paper, it still has a substantial average of 158.75 citations per year, suggesting ongoing relevance and influence. YOUSEFPOUR A, 2019, J SYST ARCHITECT: This paper has 558 total citations and an average of 111.60 citations per year, indicating a solid impact in its domain. CHETTRI L, 2020, IEEE INTERNET THINGS: With 530 total citations and an average of 132.50 citations per year, this paper demonstrates a strong presence in the field of Internet of Things research. YOU XH, 2021, SCI CHINA INFORM SCI: This paper has 512 total citations, and its average of 170.67 citations per year is notable, indicating rapid recognition

Figure 8: Word cloud for author keywords of CC research

and impact since its publication. HASSIJA V, 2019, IEEE ACCESS: While having 442 total citations, this paper has an average of 88.40 citations per year, reflecting a consistent but moderate influence in the field. FERRAG MA, 2019, IEEE INTERNET THINGS: This paper has 329 total citations and an average of 65.80 citations per year, showcasing a respectable level of impact in the Internet of Things domain. YANG RZ, 2019, IEEE COMMUN SURV TUT: With 302 total citations and an average of 60.40 citations per year, this paper contributes significantly to its research area. ACETO G, 2020, J IND INF INTEGR: This paper has 284 total citations and an average of 71.00 citations per year, indicating a strong presence in the field of industrial information integration. XU LD, 2019, ENTERP INF SYST-UK: Although having fewer total citations (266), this paper still maintains a respectable average of 53.20 citations per year, suggesting ongoing interest in its subject matter.

Science Mapping Results

In this section, the results from the science mapping analysis include topic and keywords trends, co-citation structure, and country collaboration patterns.

Authors Keywords Trend

Figure 8 presents a list of terms related to Cloud Computing and their respective frequencies in a dataset, reflecting the prevalence of these terms in the context of research, discussions, or content analysis.

Cloud Computing (Frequency: 2463)

"Cloud computing" is the most frequently occurring term in the dataset, indicating its central role in contemporary discussions and research related to information technology.

Security (Frequency: 1082)

"Security" is another prominent term, highlighting the significant focus on addressing security concerns in various IT contexts, including cloud computing.

Internet of Things (Frequency: 695)

The "Internet of Things" (IoT) is a widely discussed topic, with a substantial presence in the dataset, reflecting the growing interest in IoT technologies and applications.

Edge Computing (Frequency: 613)

"Edge computing" is a term that has gained relevance in discussions about distributed computing and processing data closer to the data source or edge devices.

Blockchain (Frequency: 560)

"Blockchain" signifies the interest in decentralized ledger technologies and their potential applications beyond cryptocurrencies.

Servers (Frequency: 446)

"Servers" are fundamental components of IT infrastructure, and their mention suggests discussions about server-related technologies and management.

Encryption (Frequency: 426)

"Encryption" is crucial for data security and privacy, and its presence reflects discussions on securing data in various IT environments.

Privacy (Frequency: 417)

"Privacy" is a critical concern in the digital age, and its frequency highlights ongoing discussions and research on privacy protection.

Fog Computing (Frequency: 401)

"Fog computing" is a term associated with extending cloud capabilities to the edge of the network, and its frequency indicates discussions about this emerging computing paradigm.

Authentication (Frequency: 319)

"Authentication" is essential for verifying user identities and

Figure 9: Most contributing subjects in cloud computing research

ensuring secure access to systems, making it a noteworthy term in IT discussions.

Most Contributing Subjects in CC Research

The Figure 9 presents a list of subject terms related to academic disciplines and their respective frequencies, indicating their contribution to research in the field of cloud computing. These subject terms reflect the interdisciplinary nature of cloud computing research and the variety of academic domains that contribute to it.

Computer Science Information Systems (Frequency: 2827)

"Computer Science Information Systems" is the most frequently occurring subject term, indicating the central role of computer science and information systems in cloud computing research.

Engineering Electrical & Electronic (Frequency: 2012)

"Engineering Electrical & Electronic" is the second most prominent subject, highlighting the significant contributions from electrical and electronic engineering disciplines to cloud computing.

Telecommunications (Frequency: 1940)

"Telecommunications" signifies the importance of communication technologies in cloud computing, including networking and data transmission.

Computer Science Theory & Methods (Frequency: 885)

"Computer Science Theory & Methods" represents the theoretical and methodological aspects of cloud computing research within the field of computer science.

Computer Science Software Engineering (Frequency: 747)

"Computer Science Software Engineering" indicates a substantial focus on software development and engineering practices in cloud computing.

Computer Science Hardware & Architecture (Frequency: 552)

"Computer Science Hardware & Architecture" emphasizes the hardware-related aspects of cloud computing, including server infrastructure and architecture.

Computer Science Artificial Intelligence (Frequency: 336)

"Computer Science Artificial Intelligence" suggests the application of AI techniques and technologies in cloud computing solutions and research.

Computer Science Interdisciplinary Applications (Frequency: 309)

"Computer Science Interdisciplinary Applications" reflects the interdisciplinary nature of cloud computing, where it intersects with various other fields.

Instruments & Instrumentation (Frequency: 186)

"Instruments & Instrumentation" may refer to the tools and equipment used in cloud computing research and experimentation.

Physics Applied (Frequency: 181)

"Physics Applied" indicates the application of physics principles in cloud computing, such as in the design of data centers and cooling systems.

Automation & Control Systems (Frequency: 176)

"Automation & Control Systems" suggests the use of automation technologies in managing cloud computing environments efficiently.

Materials Science Multidisciplinary (Frequency: 168)

"Materials Science Multidisciplinary" may relate to materials used in hardware components for cloud infrastructure.

Chemistry Analytical (Frequency: 159)

"Chemistry Analytical" could be relevant to chemical analysis techniques used in cloud computing research, particularly in data center maintenance.

Engineering Multidisciplinary (Frequency: 155)

"Engineering Multidisciplinary" reflects the diverse engineering disciplines that contribute to cloud computing advancements.

Engineering Industrial (Frequency: 147)

"Engineering Industrial" may refer to the industrial applications and practices related to cloud computing solutions.

Operations Research & Management Science (Frequency: 103)

"Operations Research & Management Science" points to the optimization and management aspects of cloud computing systems.

Figure 9 illustrates the multidisciplinary nature of cloud computing research, with contributions from various academic subjects and domains. It highlights the wide-ranging expertise required to advance the field and underscores the importance of collaboration between disciplines in cloud computing studies.

Topic trends in CC research from 2019 to 2023

Figure 10 provides insights into the evolving trends in cloud computing research by listing various research topics, their frequencies (freq), and the years when these topics gained prominence.

Vulnerability

This research topic had a frequency of 8 and was prominent in 2019, remaining relevant until 2020. It likely focused on identifying vulnerabilities in cloud computing environments.

Conjunctive Keyword Search

With a frequency of 7, this topic was notable in 2019, indicating interest in search algorithms and techniques in cloud computing.

Crowdsourcing

Crowdsourcing, with a frequency of 7, was also a significant research focus in 2019, potentially exploring collaborative approaches in cloud computing.

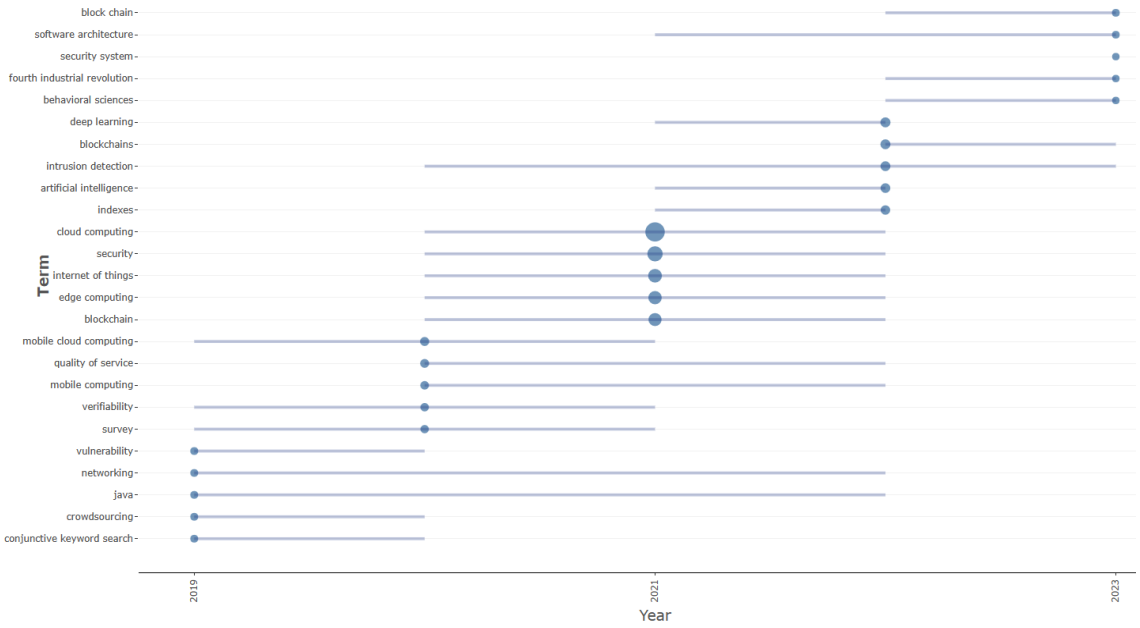

Figure 10: Trending topics in cloud computing research from 2019 – 2023

Mobile Cloud Computing

This topic had a substantial frequency of 53 in 2019, continued to gain attention in 2020, and remained relevant until 2021, reflecting the importance of mobile-centric cloud solutions.

Quality of Service

Research on quality of service (QoS) gained prominence in 2020 and remained relevant until 2022, with a frequency of 43. It likely addressed issues related to service performance and reliability in the cloud.

Mobile Computing

With a frequency of 30, mobile computing research was notable in 2020 and remained relevant until 2022, indicating the intersection of mobile technology and cloud computing.

Cloud Computing

"Cloud computing" itself had the highest frequency of 2,463 and was prominent in 2020, continuing to be a major research focus until 2022. It likely covered various aspects of cloud computing technology and applications.

Security

Research on cloud security had a substantial frequency of 1,082, gaining prominence in 2020 and remaining a critical topic until 2022. This reflects the ongoing concern for securing cloud-based systems and data.

Internet of Things (IoT)

IoT research, with a frequency of 695, gained prominence in 2020 and continued to be a significant focus until 2022, indicating the integration of IoT devices with cloud technologies.

Deep Learning

Deep learning research became prominent in 2021 and remained relevant until 2022, with a frequency of 127. It likely explored the application of deep learning techniques in cloud computing.

Blockchains

Blockchain research gained traction in 2022, with a frequency of 119, signifying the interest in using blockchain technology in cloud-based applications.

Intrusion Detection

This topic gained prominence in 2020 and continued to be relevant until 2023, with a frequency of 113. It likely addressed security measures to detect and prevent intrusions in cloud systems.

Block Chain

Although similar to "blockchains," "blockchain" became prominent in 2022 and was relevant until 2023, potentially focusing on specific blockchain implementations.

Software Architecture

Research on software architecture gained prominence in 2021 and continued until 2023, with a frequency of 6. It likely explored architectural design principles in cloud computing.

Behavioral Sciences

This research topic emerged in 2022 and remained relevant until 2023, suggesting a growing interest in understanding behavioral aspects in cloud computing contexts.

Keyword Plus Co-Occurrence Network of CC Research

Figure 11 presents a keyword plus co-occurrence network analysis in cloud computing research, where keywords are

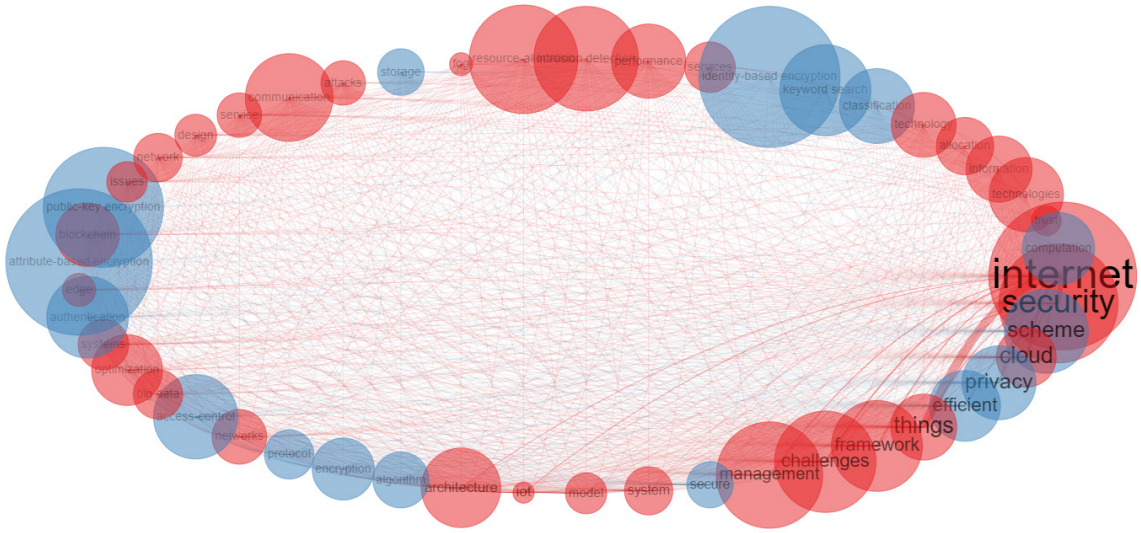

Figure 11: Cloud computing keyword plus co-occurrence network. Cluster 1 red in color, and cluster 2 is blue in color

represented as nodes in a network and various network centrality measures are calculated for each keyword.

Internet

This keyword is part of cluster 1 and has the highest betweenness centrality (79.14), indicating its importance as a bridge keyword connecting different topics in cloud computing research. It also has a high PageRank (0.095), suggesting significant influence.

Security

Also, in cluster 1, "security" is a central keyword with a substantial betweenness centrality (46.99) and PageRank (0.067). It highlights the critical role of security concerns in cloud computing.

Cloud

"Cloud" is a cluster 1 keyword with moderate betweenness centrality (21.28) and PageRank (0.046), reflecting its foundational role in the field of cloud computing.

Things (IoT)

This keyword is part of cluster 1 and has a notable betweenness centrality (10.51) and PageRank (0.049), signifying the intersection of the Internet of Things (IoT) with cloud computing research.

Framework

"Framework" is another cluster 1 keyword with moderate betweenness centrality (10.68) and PageRank (0.036), indicating its relevance in cloud computing research frameworks.

Challenges

Within cluster 1, "challenges" has a reasonable betweenness centrality (9.03) and PageRank (0.038), suggesting ongoing exploration of challenges in cloud computing.

Management

"Management" is a cluster 1 keyword with decent betweenness centrality (7.85) and PageRank (0.035), highlighting the management aspects in cloud computing.

System

"System" is a part of cluster 1 with moderate betweenness centrality (5.52) and PageRank (0.024), indicating its general relevance in the cloud computing context.

Model

Also in cluster 1, "model" has a moderate betweenness centrality (5.43) and PageRank (0.023), suggesting its importance in modeling cloud computing phenomena.

IoT (Internet of Things)

This keyword has a moderate betweenness centrality (2.90) and PageRank (0.028), indicating its connection to both cloud computing and IoT research.

Scheme

This keyword is part of cluster 2 and has a betweenness centrality of 26.02, indicating its importance as a bridging term connecting different topics within cluster 2. It also has a moderate PageRank (0.042), suggesting significant influence.

Privacy

Also in cluster 2, "privacy" is a central keyword with substantial betweenness centrality (25.24) and a significant PageRank (0.044). It highlights the critical role of privacy concerns in cloud computing.

Efficient

"Efficient" is another cluster 2 keyword with a decent betweenness centrality (20.28) and PageRank (0.036), indicating its relevance in discussions about efficiency in cloud computing.

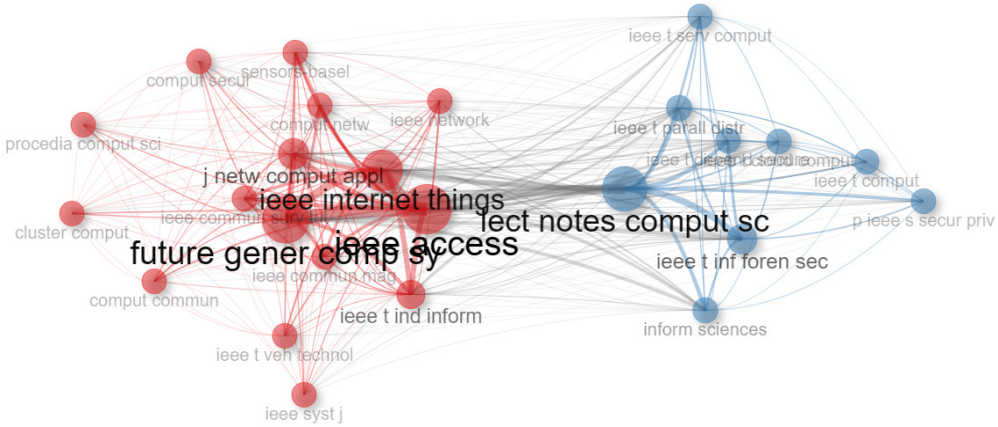

Figure 12: Co-Citation Network of Sources in CC Research

Secure

Within cluster 2, "secure" has a lower betweenness centrality (6.46) but a moderate PageRank (0.022), suggesting its importance in discussions about security measures in cloud computing.

Algorithm

This keyword is part of cluster 2 with low betweenness centrality (1.52) and PageRank (0.014), signifying its relevance but not as a central term in the cluster.

Encryption

"Encryption" has low betweenness centrality (0.92) and PageRank (0.012) within cluster 2, indicating its role in securing data in cloud computing.

Protocol

This keyword has a moderate betweenness centrality (1.02) and PageRank (0.017) within cluster 2, reflecting its significance in cloud computing protocol discussions.

Access-Control

"Access-control" has a decent betweenness centrality (2.70) and PageRank (0.016) in cluster 2, suggesting its importance in controlling access to cloud resources.

Authentication

Within cluster 2, "authentication" has moderate betweenness centrality (1.74) and PageRank (0.015), highlighting its role in verifying user identities.

Attribute-Based Encryption

This keyword has low betweenness centrality (0.18) and PageRank (0.010) within cluster 2, indicating its specific relevance in discussions about attribute-based encryption in the context of cloud computing.

Source Co-Citation Network on Cloud Computing Research

This Figure 12 presents a source co-citation network analysis in cloud computing research, where sources (publications, journals, conferences) are represented as nodes in a network, and various network centrality measures are calculated for each source.

IEEE Access

This source is part of cluster 1 and has a significant betweenness centrality (7.72), indicating its importance as a bridge source connecting different research in the cluster. It also has a high PageRank (0.076), suggesting substantial influence in the network.

IEEE Internet of Things

Also in cluster 1, "IEEE Internet of Things" has notable betweenness centrality (5.06) and PageRank (0.067), emphasizing its role in the IoT-related research within the cloud computing field.

Future Generation Computer Systems

"Future Gener Comp Sy" within cluster 1 has a substantial betweenness centrality (8.53) and PageRank (0.071), indicating its significance in discussions related to future computing systems.

IEEE Transactions on Industrial Informatics

"IEEE T Ind Inform" has moderate betweenness centrality (2.62) and PageRank (0.048) in cluster 1, suggesting its relevance in the industrial informatics aspects of cloud computing.

Journal of Network and Computer Applications

"J Netw Comput Appl" is another important source in cluster 1 with a moderate betweenness centrality (3.16) and PageRank (0.051), signifying its relevance in network and application-related research.

IEEE Communications Surveys and Tutorials

"IEEE Commun Surv Tut" has a reasonable betweenness centrality (1.16) and PageRank (0.044) within cluster 1, indicating its role in surveying and tutorial-based research.

IEEE Communications Magazine

"IEEE Commun Mag" is a source with low to moderate betweenness centrality (0.99) and PageRank (0.042)

within cluster 1, suggesting its relevance in the broader communication aspects of cloud computing.

Sensors-Basel

"Sensors-Basel" has low betweenness centrality (0.75) and PageRank (0.039) in cluster 1, indicating its role in sensor-related research within cloud computing.

IEEE Transactions on Vehicular Technology

"IEEE T Veh Technol" has low betweenness centrality (0.68) and PageRank (0.030) within cluster 1, suggesting its role in vehicular technology research in the context of cloud computing.

Computer Networks

"Comput Netw" has low betweenness centrality (0.95) and PageRank (0.039) within cluster 1, indicating its general relevance in network-related research.

Lecture Notes in Computer Science

"Lect Notes Comput Sc" is part of cluster 2 and has a high betweenness centrality (42.73) and PageRank (0.054), signifying its significance as a bridge source connecting different research within the cluster.

IEEE Transactions on Information Forensics and Security

"IEEE T Inf Foren Sec" in cluster 2 has notable betweenness centrality (15.82) and PageRank (0.042), indicating its importance in security-related research.

IEEE Transactions on Parallel and Distributed Systems

"IEEE T Parall Distr" within cluster 2 has substantial betweenness centrality (12.44) and PageRank (0.037), highlighting its role in parallel and distributed systems research.

Information Sciences

"Inform Sciences" has a significant betweenness centrality (13.91) and PageRank (0.035) in cluster 2, indicating its importance in the field of information sciences within cloud computing research.

IEEE Transactions on Dependable and Secure Computing

"IEEE T Depend Secure" in cluster 2 has a notable betweenness centrality (10.78) and PageRank (0.036), emphasizing its role in dependable and secure computing research.

IEEE Transactions on Services Computing

"IEEE T Serv Comput" has decent betweenness centrality (8.59) and PageRank (0.032) within cluster 2, indicating its relevance in services computing research.

IEEE Transactions on Cloud Computing

"IEEE T Cloud Comput" has moderate betweenness centrality (7.43) and PageRank (0.029) within cluster 2, highlighting its role in cloud computing research.

Proceedings - IEEE Symposium on Security and Privacy

"P IEEE S Secur Priv" within cluster 2 has moderate betweenness centrality (3.86) and PageRank (0.028), suggesting its importance in security and privacy research.

IEEE Transactions on Computers

"IEEE T Comput" in cluster 2 has moderate betweenness centrality (4.46) and PageRank (0.026), signifying its relevance in computer-related research.

This Figure 12 provides insights into the centrality and influence of specific sources in the field of cloud computing research. It emphasizes the significance of various journals, conferences, and publications in shaping the research landscape within clusters, with a focus on IoT, security, and various computing aspects.

Conclusion

This research analysis reveals several key insights into the landscape of cloud computing research, highlighting prominent sources, research clusters, and influential topics, and provides a temporal perspective on the popularity and evolution of various research topics in cloud computing from 2019 to 2023. It reflects the dynamic nature of the field and the shifting focus towards emerging technologies and security concerns. These findings shed light on the evolution of cloud computing as a multidisciplinary field. This work analyzed the influence of specific keywords of CC research. It highlights the significance of terms related to security, privacy, efficiency, and encryption in this specific context. The analysis highlights the significance of topics such as the internet, security, IoT, and management in the context of cloud computing. It highlights the wide-ranging expertise required to advance the field and underscores the importance of collaboration between disciplines in cloud computing studies.

This research analysis provides insights into the research impact of various countries in cloud Computing, considering both the total number of citations and the average citations per article. While China leads in total citations, the USA stands out for its high average article citations, emphasizing the importance of both quantity and quality of research output.

References

Alam, T. (2020). Cloud Computing and its role in the Information Technology. *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, 1(2), 108-115.

Alwakeel, A. M. (2021). An overview of fog computing and edge computing security and privacy issues. *Sensors*, 21(24), 8226.

Cao, K., Liu, Y., Meng, G., & Sun, Q. (2020). An overview on edge computing research. *IEEE access*, 8, 85714-85728.

Dang, A., & Wang, F. (2021). Information technology methods for locality preservation and inheritance of settlement cultural landscape. *Indoor and Built Environment*, 30(4), 437-441.

Gourisaria, M. K., Samanta, A., Saha, A., Patra, S. S., & Khilar, P. M. (2020). An extensive review on cloud computing. *Data Engineering and Communication Technology: Proceedings of 3rd ICDECT-2K19*, 53-78.

Nazir, R., Ahmed, Z., Ahmad, Z., Shaikh, N. N., Laghari, A. A., & Kumar, K. (2020). Cloud computing applications: a review. *EAI Endorsed Transactions on Cloud Systems*, 6(17), e5-e5.

Ogiela, L., & Ogiela, M. R. (2020). Cognitive security paradigm for cloud computing applications. *Concurrency and Computation: Practice and Experience*, 32(8), e5316.

Rosenberger, L. (2020). Making cyberspace safe for democracy. *Foreign Affairs*, 99(3), 146-159.

Sadeeq, M. M., Abdulkareem, N. M., Zeebaree, S. R., Ahmed, D. M., Sami, A. S., & Zebari, R. R. (2021). IoT and Cloud computing issues, challenges and opportunities: A review. *Qubahan Academic Journal*, 1(2), 1-7.

Sharma, S., & Sajid, M. (2021). Integrated fog and cloud computing issues and challenges. *International Journal of Cloud Applications and Computing (IJCAC)*, 11(4), 174-193.

Shetty, J. P., & Panda, R. (2021). An overview of cloud computing in SMEs. *Journal of Global Entrepreneurship Research*, 11(1), 175-188.

Stoica, I., & Shenker, S. (2021, June). From cloud computing to sky computing. *In Proceedings of the Workshop on Hot Topics in Operating Systems* (pp. 26-32).

Sunil, S. T., Khadri, S., & Sachin, K. T. (2020). Cloud Computing for Business Development. *International Journal of Research in Engineering, Science and Management*, 3.

Sunyaev, A., & Sunyaev, A. (2020). Cloud computing. *Internet computing: Principles of distributed systems and emerging internet-based technologies*, 195-236.

Waranugraha, N., & Suryanegara, M. (2020, September). The development of iot-smart basket: Performance comparison between edge computing and cloud computing system. *In 2020 3rd International Conference on Computer and Informatics Engineering (IC2IE)* (pp. 410-414). IEEE.