Bibliometric Overview of Internet-of-Things and Edge Computing Integration in Smart Healthcare Systems

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Abstract

This paper presents a comprehensive bibliometric analysis of research in Smart Healthcare Systems (SHS), focusing on the integration of Internet of Things (IoT) and edge computing technologies. The study aims to map the landscape of scholarly contributions, identify key trends, and highlight influential works within this growing field. Through the examination of keywords, publication frequency, and author networks, the analysis reveals significant patterns in the development of healthcare systems, underscoring the role of IoT and edge computing in enhancing healthcare system functionality. This bibliometric analysis aims to offer valuable insights into current research trajectories and potential future directions for smart healthcare innovation.

Keywords

Smart Healthcare Systems, Internet-of-Things, Edge Computing, Bibliometric Analysis

1. Introduction

The fusion of healthcare systems with IoT and edge computing technologies marks a significant stride in modern healthcare solutions, fundamentally transforming the way healthcare services are delivered and managed. By integrating a vast network of interconnected devices, such as sensors, wearable technologies, and medical equipment, Smart Healthcare Systems create an ecosystem capable of continuous data collection, real-time analysis, and autonomous decision-making [1, 2]. This integration allows healthcare providers to monitor patients remotely, process large volumes of data at the edge of the network, and take immediate actions without the need for centralized control. Consequently, these systems have the potential to significantly improve patient outcomes, particularly in critical and time-sensitive scenarios[3].

One of the key advantages of Smart Healthcare Systems is their ability to dynamically adjust to changing demands. In environments such as hospitals or emergency care units, where patient loads can fluctuate dramatically, the ability of these systems to adapt and scale in real-time is crucial. By leveraging edge computing, data processing can occur closer to where the data is generated, reducing latency and improving response times[4]. This is particularly important in resource-constrained settings, where system efficiency and the prioritization of critical tasks can directly impact patient care and resource allocation.

Current research in this field emphasizes improving the flexibility, scalability, and analytical capabilities of these systems. By enhancing data-driven decision-making processes and resource optimization, Smart Healthcare Systems aim to provide more personalized and effective treatments[5], reduce operational costs, and alleviate the burden on healthcare providers. Advanced analytics, powered by

TACC'2024: The 4th Tunisian-Algerian Conference on applied Computing, December 17-18, 2024, Constantine, Algeria
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machine learning, play a crucial role in this evolution, enabling predictive diagnostics, early detection of potential health risks, and automated care adjustments tailored to individual patients[6].

Despite these advancements, the development of smart healthcare systems presents significant challenges. One major issue is ensuring the interoperability of diverse systems and devices that must communicate and collaborate seamlessly across different platforms and networks[7]. Achieving robust security is another pressing concern, as sensitive medical data must be protected from cyber threats while still allowing for easy accessibility by authorized personnel[8]. Additionally, the complexity of ensuring dependable operation in an environment with so many interconnected components requires sophisticated fault-tolerant mechanisms and efficient lifecycle management.

This study offers a bibliometric analysis of recent developments in Smart Healthcare systems, focusing on the convergence of IoT and edge computing. The study uncovers key trends and areas that warrant further exploration, providing insights into the emerging technologies shaping the future of healthcare infrastructure. This paper is structured as follows: Section 2 described the adopted methodology used to undergo the analysis, Section 3 presents the results of the search and analyzes them after refinement, Section 4 discusses in light of the research questions laid out. Section 5 concludes the paper with recommendations and perspectives for the field of IoT integration in smart healthcare.

2. Methodology

The methods used in this paper are partially aligned with the methods used in [1] or in [9]. Such strategy consists of planning a focused search, then gathering and processing all relevant data in 6 basic steps (as in subsection 2.2).

2.1. Research Questions

Prior to this task, our study will be guided by 3 pertinent research questions we are poised to answer by analyzing the final results:

1. **RQ1:** *"What are the most frequently recurring keywords in Smart Healthcare Systems research, and what do they reveal about the main focus areas and trends?"*
2. **RQ2:** *"How has research on key topics such as "IoT," "Cloud/Fog/Edge Computing," and other Smart Healthcare-related technologies evolved over time?"*
3. **RQ3:** *"What relationships exist between recurring keywords in Smart Healthcare Systems research, and how do these relationships inform the interdisciplinary nature of the field?"*

2.2. Strategy

1. Planing a search query covering key aspects on topic.
2. Selecting relevant and reputable sources for material.
3. Determining significant analytical indicators that help reframe the resulting data into meaningful data.
4. Collecting data after applying the search on all established data sources while considering analysis metrics.
5. Screening the gathered data by filling incomplete information, discarding duplicates and formatting all the data.
6. Interpreting the processed data and visualizing it with graphs and tables.

2.3. Process

1. The search query that was conceived to bring out the most relevant and optimal results is the following: *("Smart Healthcare"* ***OR*** *"Healthcare System-of-Systems"* ***OR*** *"Healthcare SoS")* ***AND*** *("Internet of Things"* ***OR*** *"IoT")* ***AND*** *("Edge Computing"* ***OR*** *"Fog Computing"* ***OR*** *"Cloud Computing")*

2. **"IEEEXplore"** was selected as the main data source based on its reputation in Computer Science and Internet-of-Things circles.
3. Analytical indicators that are considered for this study pertain primarily to **citation count**, **contribution frequency** and **co-occurrence** relationships.
4. Upon executing the query in *October 16th, 2024 at 09:35 pm*, **568** papers were extracted from IEEEXplore.
5. We applied a filter on the set of results to exclude all duplicate entries, fortunately enough, none were removed. As for the publications, it terms of recency, all those published prior to 2019 were discarded resulting in a cull of **54** papers.
6. The final outset consists of **512** titles upon which we applied the analyses and visualized them into graphic and tabular forms.

3. Findings

This section is dedicated to the presentation of the results in coherent visualizations, divided in 3 parts pertaining to publication, author and keyword analyses, respectively.

3.1. Publication Trends

As shown in Figure 1, there appears to be a steady increase in research activity related to Smart Healthcare Systems as early as 2019, reflecting the growing recognition of IoT-intensive approaches in healthcare setups. The brief decline in the year 2024 can be attributed to the fact that the time this study is taking place corresponds to the same year and therefore; a good number of papers may still be undergoing review or await publication.

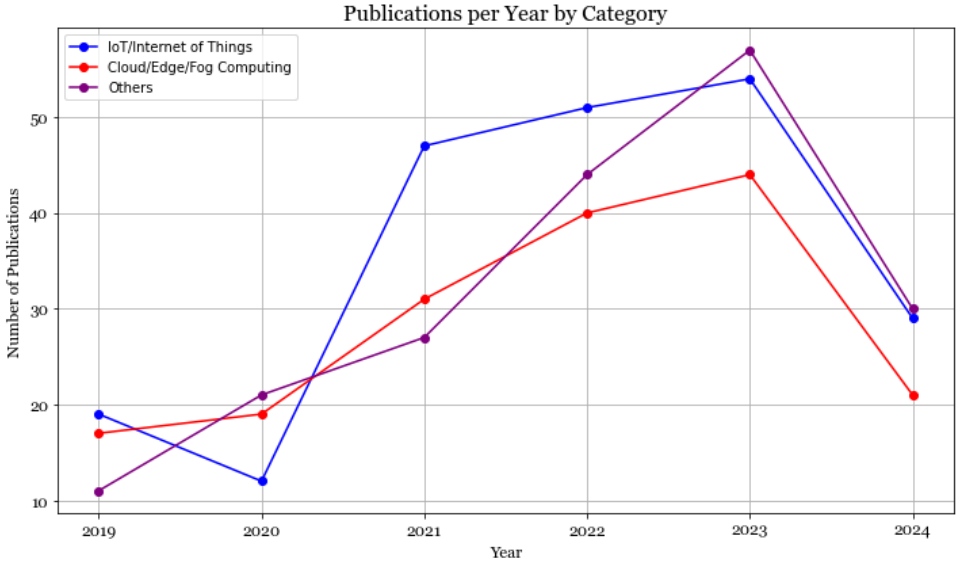

Figure 1: Publication Trends per Year Divided by Category

Table 1 presents the most relevant papers according to IEEEXplore's sorting algorithm. These papers were selected based on their relevance to the topic of Smart Healthcare Systems and the integration of IoT and edge computing, reflecting their significance in the current research landscape.

Whereas Table 2 highlights the most cited papers in this domain, ranked by their citation count. Supposedly, implying they have the greatest impact on the field in recent times. Naturally, all works with a high citation record are at least 3 years old. Newer works have a lesser chance of gaining attention in such a narrow window of time.

Table 1
Most Relevant Papers According to IEEEXplore Sorting Algorithm

N.	Reference	Citations	Year
1	[10]	4	2021
2	[11]	7	2022
3	[12]	3	2023
4	[13]	2	2022
5	[14]	253	2020
6	[15]	1	2022
7	[16]	127	2021
8	[17]	168	2021

Table 2
Most Cited Papers According to IEEEXplore Citation Count

N.	Reference	Citations	Year
1	[18]	542	2021
2	[19]	409	2019
3	[20]	320	2020
4	[21]	282	2019
5	[22]	282	2022
6	[23]	271	2020
7	[24]	253	2020
8	[25]	187	2019

3.2. Collaborative Authorships

Leading contributors include authors actively engaged in healthcare IoT research. This subsection provides an overview of the most active and most influential researchers in the field, based on contribution count and citation count, respectively. The bar chart in Figure 2 shows the most active researchers, ranked by the number of contributions they have made in the field of Smart Healthcare Systems.

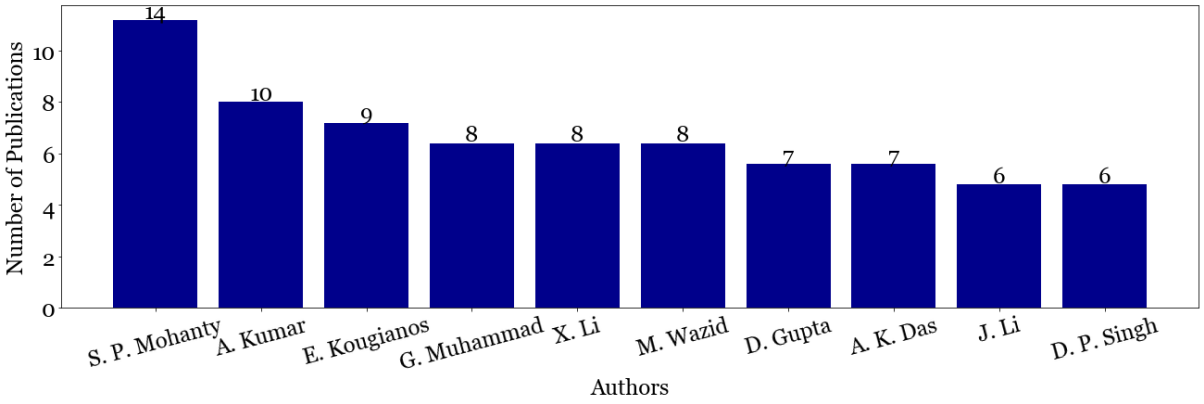

Figure 2: Most Active Researchers by Contribution Count

Leading with "S.P. Mohanty" with 14 contributions on the field, having produced an exceptionally high number of papers on the subjects of Fog Computing, IoT integration and Smart Healthcare in a diversity of works, of which we cite their most influential ones (see [26, 27, 28, 29, 30, 31, 32, 33]).

The bar chart in Figure 3 presents the most influential researchers whose works may have had on advancing the domain, based on the frequency of citations for their works.

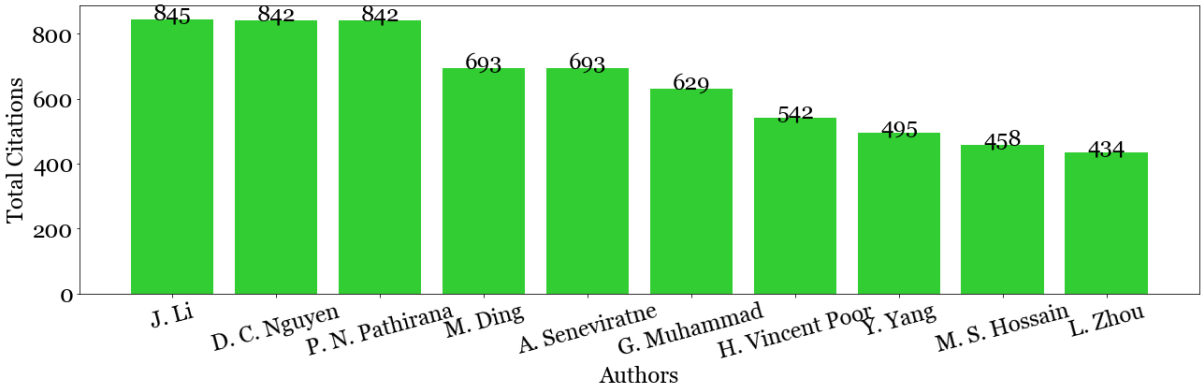

Figure 3: Most Influential Authors by Citation Count

Upon inspecting the figure in detail, authors "J. Li", closely followed by "D. C. Nguyen" and "P. N. Pathirana" have almost a matching number of citations suggesting they have collaborated extensively in recent works. Evidently, some of the most influential and relevant contributions on the subject have been authored by them [34, 35]

Figure 4 illustrates the full co-authorship network with all existing collaboration links.

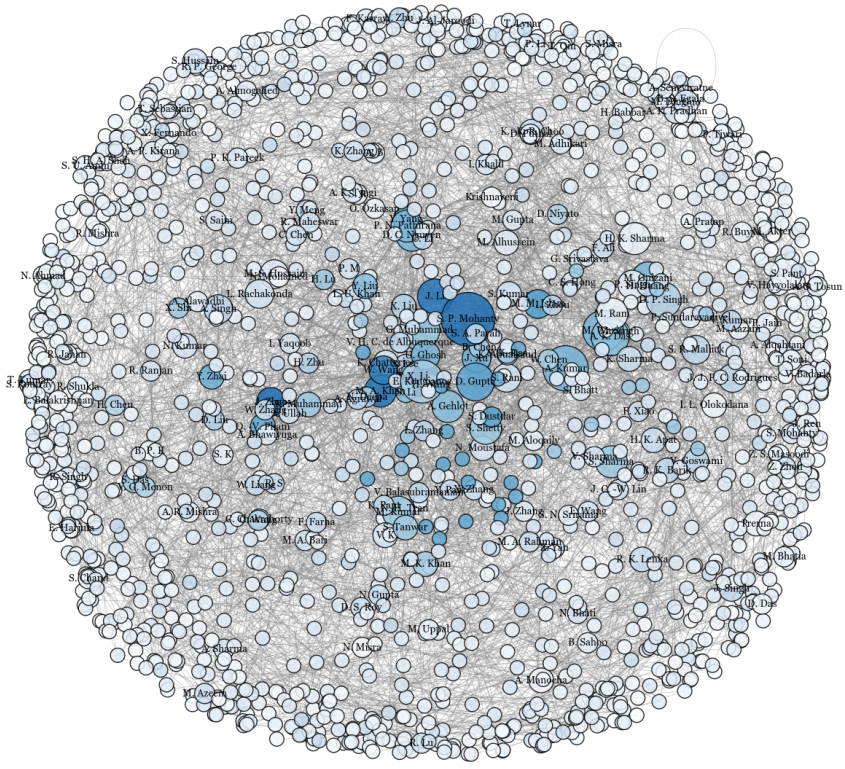

Figure 4: Co-Authorship Network Graph (unrefined)

Considering that such data clearly appears to be extremely convoluted. Enhancements were applied on the data to increase its readability in Figure 5, by plotting only the top 65 authors among 1632.

The screening criteria was based off the authors' total number of contributions (has to be over 3). To enhance readability, the nodes and edges were coded with additional information; Node color and size represent contribution frequency and activity, whereas edge width and the distance between connected nodes represent recurrence of co-authorships between the authors in question.

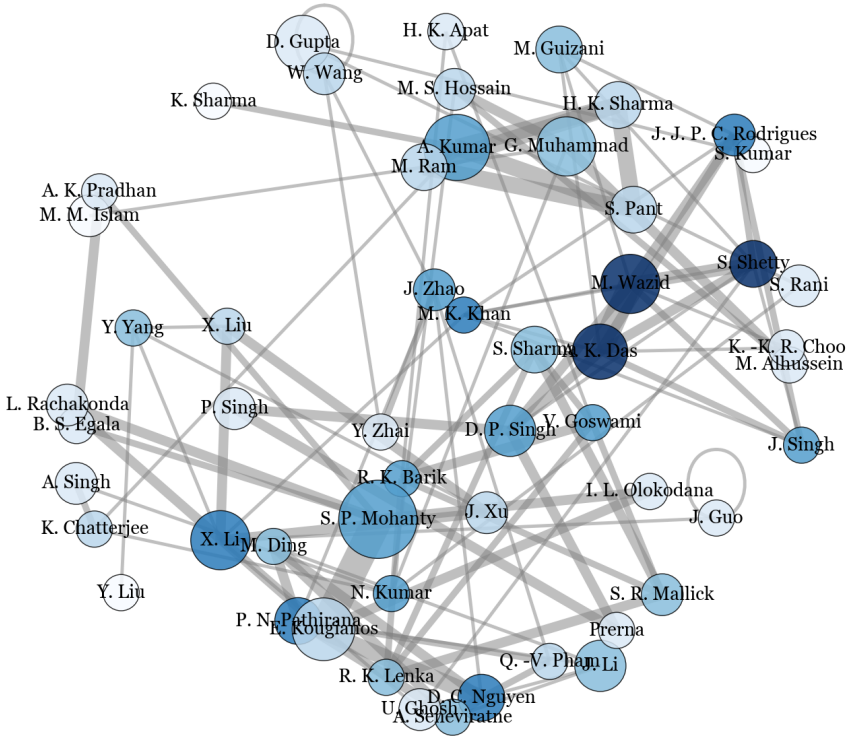

Figure 5: Refined Co-Authorship Network Graph

3.3. Keyword Analysis

Keyword analysis reveals the most frequently used terms in the literature, which indicates the dominant topics and areas of focus within the field of Smart Healthcare Systems, as shown in Table 3. This table lists the most cited keywords from IEEEXplore's IEEE Terms which provide insights into the primary focus areas within the research community, with topics like "Medical services," "Cloud computing," and "Internet of Things" emerging as the most frequent.

Table 3
Most Cited Keywords According to IEEEXplore's IEEE Terms

N.	Keyword	Mentions
1	Medical services	270
2	Cloud computing	215
3	Internet of Things	164
4	Real-time systems	93
5	Smart healthcare	92
6	Security	89
7	Computational modeling	66
8	Edge computing	51
9	Computer architecture	49
10	Servers	47

The co-occurrence network graph in Figure 6 illustrates the relationships between frequently mentioned keywords, depicts the most recurring keywords in the bibliometric data, as each node is coded with 2 pieces of information:

1. **Size:** reflects the amount of times it has been mentioned throughout the entire dataset.
2. **Color Intensity:** reflects how many times it has co-occurred with other terms in the paper

(purple for the least talked-about topics, green-ish and blue-ish for moderately frequent ones, and yellow being reserved for the most popular among the terms)

Similarly, the edges in-between the nodes have 2 other properties coded within them: **Width** and **Distance**. As it appears, the nodes in the graph are not scattered completely randomly. Closer the nodes are to each other the more times they have been associated with one another in the same paper. For better clarity, edge width and opacity also help visualize that same information.

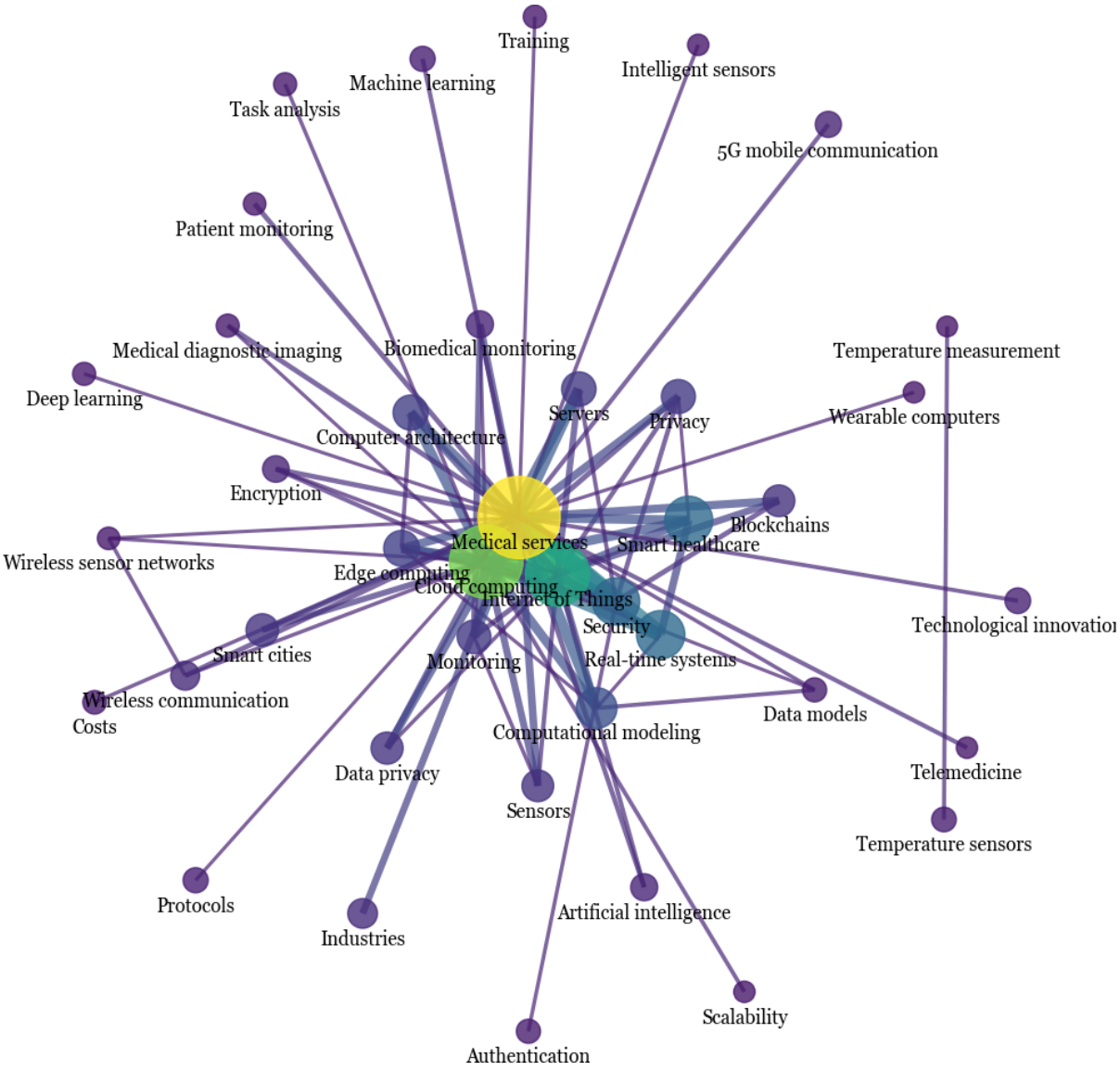

Figure 6: Keyword Co-Occurrences Network Graph

4. Discussion

In an attempt to find an adequate answer to the inquiries laid out in the beginning of this study, we explored each research question, individually:

RQ1: *"What are the most frequently recurring keywords in Smart Healthcare Systems research, and what do they reveal about the main focus areas and trends?"*

A1: The keyword analysis identified "Medical services" as the most frequently mentioned keyword with 270 occurrences, followed by "Cloud computing" with 215 mentions and "Internet of Things" with

164 mentions. Other significant terms include "Real-time systems" (93), "Smart healthcare" (92), and "Security" (89) (see Table 3). This shows that the core research areas are centered around medical services and the technological infrastructure (IoT, cloud, and edge computing) required to support real-time, secure healthcare solutions, therefore, placing the field's focus on developing scalable, responsive, and secure healthcare systems.

RQ2: *"How has research on key topics such as "IoT," "Cloud/Fog/Edge Computing," and other Smart Healthcare-related technologies evolved over time?"*

A2: The line graph in Figure 1 illustrates the publication trends from 2019 to 2024 for three categories: IoT/Internet of Things, Cloud/Edge/Fog Computing, and Other topics in Smart Healthcare Systems research. We observe a steady increase in publications for all categories, with IoT/Internet of Things experiencing significant growth, particularly between 2020 and 2023. Cloud/Edge/Fog Computing follows a similar upward trajectory, though at a slightly slower rate. Both categories witnessed a peak in 2023, followed by a slight decline in 2024. "Other" topics also surged, reflecting the expansion of diverse topics within this field. Upon comparing the lines for each category, we can surmise that the topics of interest in this paper share almost as much as 50% of the total papers associated with smart healthcare papers, suggesting its ever-growing relevance in recent literature.

RQ3: *"What relationships exist between recurring keywords in Smart Healthcare Systems research, and how do these relationships inform the interdisciplinary nature of the field?"*

A3: The co-occurrence network in Figure 6 provides insight into the relationships between key themes and concepts within Smart Healthcare Systems research. The most prominent keywords include "Medical services," "Cloud Computing," and "Internet of Things," indicating the central role of these technologies in modern healthcare. Other significant keywords, such as "Security," "Real-time systems," "Edge Computing," and "Smart Healthcare," reveal the focus on improving healthcare delivery, data protection, and integrating real-time emergency reponse. The dense interconnections among these terms highlight complex interdependencies among various technologies. For instance, Cloud and Edge computing are often mentioned alongside data privacy and computational modeling, reflecting their roles in enabling scalable and secure healthcare systems. Additionally, the frequent association with "Medical diagnostic imaging," "Biomedical monitoring," and "Telemedicine" suggests that these technologies are being applied across a wide range of healthcare services.

5. Limitations

A notable limitation of this study lies in the restricted scope of the database used for the literature search. Despite explicitly including keywords like "SoS" and "System of Systems" in the query, the search was confined to IEEE Xplore due to inaccessibility and technical barriers with other research databases. This constraint potentially excludes relevant publications from a broader range of sources, such as ACM Digital Library, ScienceDirect, and SpringerLink, which may contain critical studies in the field of Smart Healthcare SoS. As a result, the findings might not fully capture recent trends or contributions across the global research landscape, thereby limiting the quality of this analysis.

6. Conclusion

This bibliometric study delivers an analysis of the current state of Smart Healthcare Systems, underlining the critical role IoT and edge computing play in optimizing resource management and system responsiveness, especially in the case of emergencies. The findings emphasize that the key trends in Smart Healthcare Systems revolve around the integration of IoT, Edge/Fog Computing, and AI to enhance real-time decision-making, data processing, and security in healthcare environments. Studies that explore these intersections, particularly those addressing challenges like security and QoS management, are leading the way in current research. Moving forward, research should address the common challenges that designers face by developing resilient, self-configuring systems that ensure interoperability across diverse healthcare environments. This paper helped identify, partially, key

contributors and research trends, offering a foundation for future investigations aimed at advancing healthcare through the integration of novel technologies as it inspires researchers in this sense.

Acknowledgment

This work was partially supported by the LABEX-TA project MeFoGL: *"Méthodes Formelles pour le Génie Logiciel"*.

Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT for text generation in specific sections of the paper, including parts of the *Introduction* and *Conclusion*. The AI tool was employed to assist in drafting introductory explanations, as well as summarizing key takeaways in the conclusion. Additionally, minor grammar and style refinements were performed using ChatGPT.

All AI-generated content was carefully reviewed and revised by the authors to ensure accuracy, coherence, and alignment with the scientific objectives of this study. The authors assume full responsibility for the final content of this publication.

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