Cloud Broker: A Systematic Mapping Study

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Abstract—In a cloud environment, a cloud broker plays a vital role as an intermediary between cloud customers and providers, resolving issues and facilitating negotiations to balance customer preferences and provider profits. Over the past few years, numerous research articles have either directly or indirectly examined this area. Conducting a Systematic Mapping Study (SMS) on cloud brokerage is highly motivating as it offers a high-level overview of the research landscape, identifying trends, topics, gaps, and patterns within this dynamic and crucial field. This article presents an SMS conducted to categorize existing research, highlight underexplored areas, and map out the evolution and current state of cloud brokerage, providing valuable insights for researchers and practitioners. The SMS identified 91 relevant and reputable search spaces (journals and conferences) and 634 high-quality articles published from 2009 to 2022. Furthermore, we formulated and addressed eight significant research questions to clarify various aspects of the cloud broker field. The extracted information from the selected articles is included in a supplementary file, available online, offering valuable insights for research teams and developers interested in this domain.

Index Terms—Cloud broker, service composition, service selection, systematic mapping study (SMS), systematic review.

I. INTRODUCTION

As the adoption of cloud computing continues to grow, businesses are increasingly looking for ways to optimize their cloud environments and manage the complexities of multiple cloud services. This is where cloud brokers come into play [1], [2]. The market for cloud services consists of a vast number of offerings, many of which share similar functionalities but differ in quality [3]. Consequently, cloud customers face significant challenges when selecting appropriate services based on their preferences. A broker plays a vital role in overcoming this challenge by negotiating between Cloud Service Providers (CSPs) and Cloud Service Users (CSUs) to find the most suitable services that align with customer preferences and provider profits [2], [4]. The National Institute of Standards and Technology (NIST) defines a broker as an entity that manages the use, performance, and delivery of cloud services and negotiates relationships between cloud providers and consumers [5].

Although a cloud broker can negotiate between CSUs and a single CSP, its role becomes even more critical in an inter-cloud environment, where CSUs obtain their required services from multiple CSPs [6]. In such an environment, the cloud broker assists CSUs with service discovery, service selection, service negotiation, service composition, and resource management. Additionally, brokers assist CSUs in avoiding vendor lock-in, which occurs when a CSU becomes dependent on a particular CSP and cannot easily switch between CSPs without incurring extra costs. Consequently, cloud brokerage has become an essential service, aiding organizations in navigating the complexities of inter-cloud environments to achieve optimal performance and cost-efficiency.

Given the crucial role of brokers, the past decade has witnessed considerable research aimed at examining their diverse responsibilities [3], [7]. For a better understanding of the research trends and topics in the field of cloud brokerage, a comprehensive and systematic review is essential. It can serve as a guideline for researchers and enthusiasts, providing a deeper understanding of the challenges and issues that need to be addressed. Employing an accurate methodology is essential for covering and reviewing all relevant, high-quality research studies. However, there are few studies that systematically investigate and analyze cloud brokerage.

Systematic Literature Review (SLR) and Systematic Mapping Study (SMS) are established methodologies in evidence-based software engineering aimed at systematic research review [8]. While both follow similar procedures for searching and analyzing research, they have distinct objectives. The primary difference lies in the type of Research Questions (RQs) they address [9], [10]. SMS focuses on broader RQs to identify research trends and topics across a wide field, while SLR targets specific RQs related to particular procedures, technologies, methods, or tools, synthesizing information from primary studies. Consequently, an SMS usually covers a wide-ranging topic, such as cloud brokerage, and includes a large number of primary studies, whereas an SLR focuses on a more detailed topic, such as service selection in cloud computing, involving fewer studies (typically under 100) [10]. The result of an SMS is a comprehensive inventory of papers classified by publication details (like authors, affiliations, source, type, and date of publication) [8]. In contrast, an SLR offers a detailed analysis of research from the primary studies. Thus, conducting an SMS on a broad subject can serve...
as a preliminary stage, paving the way for multiple SLRs on more specific sub-topics.

To comprehensively cover research studies in the field of cloud brokerage, a systematic methodology is crucial for exploring all relevant sources, including journals and conferences. This systematic review builds on the authors’ previous works [11], [12], [13] and employs a two-tier search strategy involving a manual search and backward snowballing. In each phase of searching for new studies, papers are assessed for quality, and only those meeting the required criteria are included. By integrating both search strategies, 634 papers are selected based on specific inclusion and exclusion criteria. These papers are then analyzed to answer eight research questions, serving as a valuable resource for research teams and developers in the field.

All included papers and the extracted information for answering the research questions are available in an Excel supplementary file, available online. The main contributions of this paper can be summarized as follows:

- Compiling a list of top-quality studies in the field of cloud brokerage and making it accessible to other researchers as an open dataset.
- Identifying research trends in cloud brokerage from its inception in 2009 to the end of 2022.
- Highlighting the most active researchers, venues, and countries in the field of cloud brokerage.
- Determining the core research topics and techniques used in cloud brokerage, as well as their publication trends.
- Examining research gaps and suggesting future directions within the domain of cloud brokerage.

The structure of this paper is as follows: Section II explains the concept of cloud brokerage. Section III describes the research methodology used in this SMS. Section IV presents the results which were categorized based on eight research questions derived from the systematic study. Section V analyzes the findings discussed in Section IV. Section VI discusses the implications of the SMS findings for researchers, stakeholders, practitioners, and educators. Lastly, Section VII summarizes the conclusions of the study.

II. CLOUD BROKERAGE

As cloud computing continues to dominate the technological landscape, the complexity of managing cloud services has increased significantly. Cloud brokerage has emerged as a crucial function in this environment, providing a strategic approach to managing cloud resources and services. Instead of directly contacting a CSP, a CSU can engage a cloud broker to manage cloud services on their behalf. The cloud broker may create a new service either by combining multiple services or enhancing an existing one. Acting as intermediaries between CSPs and CSUs, cloud brokers simplify the processes of service discovery, service selection, service negotiation, service composition, and resource management.

One of the primary duties of a cloud broker is service discovery. The broker maintains an up-to-date catalog of services, ensuring that CSUs can easily find the resources they need. Another critical role performed by a cloud broker is service selection. The broker evaluates and compares the offerings of CSPs, considering performance metrics, compliance standards, and cost structures. By aligning these evaluations with a CSU’s specific needs, the cloud broker helps in selecting the most suitable services. Once the services are chosen, the cloud broker engages in service negotiation. Acting as an intermediary, the broker negotiates terms and conditions with CSPs to secure favorable agreements for their clients. This includes negotiating pricing, Service Level Agreements (SLAs), and other contractual terms.

Service composition is another crucial responsibility of a cloud broker. This involves integrating diverse cloud services into a unified, functional environment, ensuring interoperability and seamless operation. The task includes orchestrating different services to work together synchronously, thereby enhancing the overall efficiency and effectiveness of cloud deployments. Additionally, the broker aids CSUs in resource management by provisioning necessary resources and scheduling applications on them. In some cases, the broker creates its own pool of resources by leasing lower-cost options, such as spot and reserved instances from the CSP, and allocates them to the CSUs as needed. This approach helps reduce the cost of resources for the CSUs [14], [15].

Although the roles of a cloud broker are valuable even when dealing with a single CSP, their importance significantly increases when managing multiple CSPs simultaneously, a scenario known as inter-cloud [6], [16]. Relying on a single CSP can result in a problem called vendor lock-in, where a CSU faces difficulties and high costs when trying to switch CSPs [7]. This problem stems from the lack of standardized interfaces in the cloud industry, with each CSP offering services through its proprietary interfaces. Consequently, if a CSU decides to switch CSPs, it must adapt its applications to the new provider’s interfaces and services [3]. A cloud broker mitigates this problem by offering a unified, CSP-independent interface and services to CSUs, translating their requirements into compatible formats for various CSPs. Additionally, working with multiple CSPs allows the broker to better serve CSUs’ interests by negotiating with several providers to select the best services at the lowest prices. The broker can also compose and orchestrate services from multiple CSPs to deliver a unified solution for CSUs.

Inter-cloud can be categorized into two main types: multi-cloud and cloud federation [6]. In a multi-cloud environment, the CSU, usually through a cloud broker, uses services and resources from multiple independent clouds in aggregation. This scenario presents significant challenges for service discovery and selection due to the vast number of similar services provided by many CSPs. Without a broker, managing this complexity becomes not only extremely difficult, but almost impossible for CSUs. Therefore, it is common for CSUs to rely on a cloud broker in a multi-cloud environment. Sometimes, CSPs also delegate some of their duties to the broker in a multi-cloud setup. A typical example is when CSPs offer their services to CSUs through an auction mechanism. In such cases, the cloud broker can act as an auctioneer, handling resource management and pricing duties on behalf of the CSPs.

On the other hand, a cloud federation consists of CSPs voluntarily collaborating to achieve high availability and scalability. In a cloud federation, a marketplace is created for CSPs to share...
their computational resources with each other. When a CSP encounters a resource shortage due to a spike in user demand, it can request resources from other CSPs with excess capacity. This marketplace is typically managed by a central broker, which regulates the relationships between CSPs, including resource pricing and allocation. However, communication between CSPs can also be managed in a distributed manner, where each CSP has its own broker that negotiates with brokers from other CSPs. Once again, auction mechanisms are popular for resource pricing and trading between CSPs.

Recently, a new concept in inter-cloud has emerged called sky computing, envisioned as the future of cloud computing [17], [18]. Sky computing aims to achieve interoperability and compatibility between CSPs, enabling cloud applications to be executed on any CSP. Instead of relying on universally adopted comprehensive standards, sky computing uses inter-cloud brokers to achieve this vision. In this model, CSUs send their job requirements, including multiple aspects of the job and oversees its execution. While multi-cloud computing involves running different applications on different cloud platforms, sky computing takes this a step further by distributing different parts of the same application across multiple CSPs using inter-cloud brokers. The CSPs that run the application remain transparent to the CSUs. Sky computing highlights the crucial role of brokers in the future of cloud computing and has recently garnered significant attention [19], [20].

According to the role of a cloud broker in a cloud environment, NIST classifies cloud brokers into three categories [5]:

- **Service Intermediation:** This involves the broker enhancing an existing service by improving certain capabilities and providing additional value-added services to CSUs, such as identity management and performance monitoring.
- **Service Aggregation:** The broker combines and integrates multiple (static) services into one or more new services. It facilitates data integration and ensures secure data transfer between the cloud consumer and various cloud providers.
- **Service Arbitrage:** This category goes beyond service aggregation by offering flexibility in service selection. The broker can dynamically choose services from different CSPs.

Although other organizations, such as Gartner, have their own classifications, we have used the NIST classification of cloud brokers in this SMS due to its high citation and recognition in the field of cloud computing.

### III. Research Methodology

There are several established works on conducting an SMS and developing a unique research methodology [21], [22]. One of the most notable methodologies was developed by Peterson et al. [22]. The methodology for the current study, incorporating some updates and enhancements in certain phases, is adapted from the SMSs performed by Peterson et al. [21], Ramaki et al. [12], and Sakhdari et al. [13]. Given the timeline of research, it is important to note that the concept of the cloud broker emerged in 2009. Thus, this study’s SMS covers all research articles published from 2009 to 2022, focusing on those relevant to the field of cloud brokerage for a comprehensive review. It is important to note that security is considered a distinct research domain due to its extensive scope. Consequently, security-related articles were excluded from the study’s search criteria. The SMS presented in this study consists of two main stages: planning the mapping study and conducting the mapping study, which are briefly outlined below.

#### A. Planning the Mapping Study

The planning stage involves five key phases: specifying the scope and research questions, planning the search process, planning the study selection process, specifying the evaluation strategy for the search space and study selection, and planning the data extraction and classification process. Each of these phases will be discussed separately in the following sections.

1) **Specifying the Scope and Research Questions:** Defining Research Questions (RQs) is a critical step in conducting review research. In the proposed SMS, eight comprehensive and distinct RQs have been formulated. These questions encompass a broad spectrum of aspects, ensuring that all study objectives are met. Table I details these RQs and explains the rationale behind each one.

To thoroughly address the research questions outlined earlier, it is vital for the scope of this paper to encompass all published works in the field. Our review covers a period of 13 years, beginning with the emergence of cloud brokers in 2009 and extending through to the end of 2022.

2) **Planning the Search Process:** This phase involves specifying three key factors: search strategy, search space, and search string. In this SMS, we employed two distinct search strategies: manual search and backward snowballing. Manual search entails using a search string to locate relevant papers in designated search spaces, such as journals and conferences. Conversely, backward snowballing involves reviewing the reference lists of already included papers to identify additional related papers and search spaces. The proposed search strategy includes five main steps:

1) The initial set of included papers is gathered from relevant secondary studies (i.e., surveys and reviews) by examining the cited papers within them.
2) The search space of each included paper, referring to the journal or conference where the paper was published, is identified and recorded.
3) The set of identified search spaces is evaluated against predefined quality criteria. Only those search spaces meeting these criteria are included in the review. For these selected search spaces, manual searches are conducted using the specified search string.
4) The study selection process is applied. If the paper is included, the process moves to step 5; If the paper results from backward snowballing, the process returns to step 2.
5) Backward snowballing is performed on papers not previously snowballed. This involves reviewing the reference...
lists of the included papers to identify additional relevant papers. If a new paper is found through this process, the search process continues to step 4; Otherwise, the process concludes.

The next step is to define the search space, which includes journals and conferences where relevant studies have been published. Initially, the search space set is empty. To populate this set, we begin by selecting a group of secondary studies (such as surveys and reviews), as shown in Table II. We extract relevant articles cited in the reference sections of these secondary studies and add their publication venues to the search space set. This search space set will expand as the search continues. The final step in this phase is defining the search string to use when searching within the identified search spaces for studies related to the cloud broker field. Based on the authors’ experience and the definition and duties of a cloud broker (see Section II), related keywords are combined to form four queries. Table III presents the queries used in the proposed SMS to search the defined search spaces.

3) Planning the Study Selection Process: This phase consists of three steps. The first step is to establish the inclusion/exclusion criteria for the search spaces to ensure the identification of high-quality and relevant venues. Tables IV and V detail the

| No. | Research Questions | Rationale |
|-----|-------------------|-----------|
| 1   | How active is the field of brokering and how is the distribution of selected studies by type over publication year (journal and conference)? | This will help to detect the current volume of researches and primary trends in order to better discernment the attraction of the field. |
| 2   | Which researchers and research venues are more active in this field and how are the active researchers distributed geographically? | The demographics of broker technology techniques research provide a useful starting point for interested researchers by identifying active scholars, venues, and countries. |
| 3   | What are the core research topics in the field of brokering? | This will help the researchers to determine the significance of different areas within the domain of cloud brokering and unravel the research tree within the brokering field. |
| 4   | Which broker topics have the least/most corresponding attention and what is the publication trend and distribution for each topic? | This will help researchers identify which topics have received more attention and thus have more maturity, as well as which areas need more focus from the scientific community. |
| 5   | Which forms of empirical evaluation have been used? Which techniques are more used in the field? | The empirical evaluation determines the evaluation environment, which can be real, simulated, or a testbed. Techniques specify the methods used to address the problem, such as heuristic, metaheuristic, game theory, etc. |
| 6   | What is the relation between topics and broker roles in NIST category? Which NIST roles have the least/most corresponding attention? | It specifies the relationship between the proposed topics and NIST roles and also indicates which NIST roles have received more attention from researchers. |
| 7   | In which service layer is the broker mostly considered? | It shows which service layers (IaaS, PaaS, SaaS, and XaaS) cloud brokers are mostly designed for and identifies which layers need more attention. |
| 8   | What is the most common broker control topology? | Which control topologies (centralized and distributed) are mostly used by researchers, and what are the pros and cons of each? |

| No. | Secondary Study Title | Year | Ref. |
|-----|----------------------|------|------|
| 1   | Brokering in Interconnected Cloud Computing Environments: A Survey | 2018 | [3] |
| 2   | A Review on Service Broker Algorithms in Cloud Computing | 2017 | [23] |
| 3   | A Comprehensive Study on Cloud Service Brokering Architecture | 2017 | [24] |
| 4   | Cloud Services Recommendation Reviewing the Recent Advances and Suggesting the Future Research Direction | 2017 | [25] |
| 5   | Service Provisioning in Cloud: A Systematic Survey | 2017 | [26] |
| 6   | A Survey on Various Cloud Aspects | 2016 | [27] |
| 7   | A Classification and Comparison Framework for Cloud Service Brokerage Architectures | 2016 | [22] |
| 8   | A Review on Broker Based Cloud Service Model | 2016 | [21] |
| 9   | Cloud Service Brokerage: A Systematic Literature Review using a Software Development Lifecycle | 2016 | [28] |
| 10  | Resource Provision Algorithms in Cloud Computing: A Survey | 2016 | [29] |
| 11  | Towards a Holistic Multi-Cloud Brokerage System: Taxonomy, Survey and Future Directions | 2015 | [30] |
| 12  | A survey on SLA-based Brokering for Inter-Cloud Computing | 2015 | [31] |
| 13  | Cloud Services Brokerage: A Survey and Research Roadmap | 2015 | [32] |
| 14  | Cloud Service Selection: State-of-the-art on Future Research Directions | 2014 | [27] |
| 15  | Cloud Computing Service Composition: A Systematic Literature Review | 2014 | [33] |
| 16  | A Review of Literature on Cloud Brokerage Services | 2014 | [34] |
| 17  | A Literature Review on Cloud Computing Adoption Issues in Enterprises | 2014 | [35] |
| 18  | A Survey on Needs and Issues of Cloud Broker for Cloud Environment | 2014 | [36] |
| 19  | Survey on important Cloud Service Provider attributes using SMI Framework | 2013 | [37] |
| 20  | A Comparison Framework and Review of Service Brokerage Solutions for Cloud Architectures | 2013 | [38] |
| 21  | A Survey on Interoperability in the Cloud Computing Environments | 2013 | [39] |
| 22  | Inter-Cloud Architectures and Application Brokerage: Taxonomy and Survey | 2012 | [6] |

| No. | Query |
|-----|-------|
| 1   | Cloud AND Broker |
| 2   | Cloud AND Service AND (Arbitration OR Intermediation OR Aggregation OR Integration OR Customization OR Orchestration) |
| 3   | (Multi cloud) OR (Federat* AND Cloud) OR (Cross cloud) OR (Inter cloud) OR (Sky Computing) OR (Third party AND Cloud) OR (Auction AND Cloud) |
| 4   | Cloud AND Service AND (Composition OR Selection OR Negotiation OR Management OR Pricing) |

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exclusion criteria for journals and conferences, respectively. For this purpose, we have utilized the JCR metric for journals and the Qualis, ERA, and H5-Index metrics for conferences. The second step is to specify the inclusion/exclusion criteria for the studies to determine which extracted papers should be included in the SMS. Table VI outlines the exclusion criteria for the extracted studies.

Finally, the third step involves defining the study selection strategy. Initially, the relevance of a paper is evaluated by reviewing its title, abstract, and keywords. If these elements do not provide sufficient information to make a definitive decision about its relevance, the full text of the paper is reviewed. If uncertainty about the paper’s relevance persists, a third-party is consulted to assist in the evaluation.

4) Specifying the Evaluation Strategy for the Search Space and Study Selection: The objective of this phase is to assess the thoroughness of the search strategies used to locate relevant studies. To ensure a more objective evaluation, the sensitivity metric is chosen to measure the effectiveness of the search and study selection. The sensitivity metric is calculated using the following formula:

\[
\text{Sensitivity} = \frac{\text{Number of studies in the SMS}}{\text{Number of studies overall}} \times 100 \quad (1)
\]

Given that the exact number of relevant studies is unknown, we have adopted the Quasi-Gold Standard (QGS) metric. This metric involves compiling a set of studies from reputable sources within the research community. To create this set, a separate team, known as the shadow team, reviewed the home pages of active researchers in the field of cloud computing and extracted papers related to cloud brokering. By applying the inclusion and exclusion criteria, a collection of papers, referred to as the QGS, was established.

We used the QGS to determine the quasi-sensitivity by dividing the number of papers included in our SMS that were also present in the QGS by the total number of papers in the QGS. If this result falls below a predefined threshold, it indicates the need to repeat the search and study selection process using the QGS. According to [25], an acceptable threshold range is between 70% and 80%, and we set our predefined threshold at 80%.

5) Planning the Data Extraction and Classification Process: This phase involved defining data extraction forms and establishing the extraction strategy. After identifying the studies to be included, various parts of the articles (such as the title, abstract, keywords, and main text) are reviewed to gather the necessary information for subsequent analysis. The extracted data is organized into tables and used to answer the RQs of the SMS. This information is accessible in the provided supplementary file, available online.

B. Conducting the Mapping Study

After establishing the strategies and protocols in the planning stage, we can proceed with our mapping study by implementing these strategies. This stage consists of several phases: conducting the search and study selection, evaluating the search and study selection, extracting data, and applying the analysis and classification process. The first phase was completed using the procedure described in Section III-A2, along with the inclusion/exclusion criteria defined in Section III-A3. As a result, this phase identified 91 search spaces and included 634 studies, which are detailed in the provided supplementary file, available online.

The evaluation phase was conducted following the guidelines in Section III-A4. During this phase, the shadow team identified a total of 32 articles, of which 28 had already been included. This resulted in a quasi-sensitivity of approximately 88%, surpassing the predefined threshold. Consequently, it can be concluded that the results obtained from the proposed review have satisfactory accuracy and validity. The next phase is data extraction, where relevant information from each study is extracted and categorized according to predefined criteria. It is important to note that disagreements may occur during the data extraction process. To resolve these disagreements, discussions were held among the team members involved in the study, leading to a consensus on the appropriate extraction and classification of the data.

The final phase involves analyzing and classifying the data to address the research questions of the SMS. One of the main objectives of this SMS is to identify the primary topics and sub-topics in the field of cloud brokerage. To determine these topics and sub-topics, a clustering technique proposed by researchers [40] was employed. This technique uses a co-occurrence matrix of keywords to group them into clusters based on their similarities. By analyzing the co-occurrence patterns, related topics and sub-topics can be identified, taking into account their similar cognitive orientations. The outcome of this process is a research tree, a multilevel tree structure that represents the main topics and sub-topics in the field of cloud brokerage. The resulting research tree is illustrated in Fig. 1.

The process of constructing the research tree starts with extracting keywords from the included papers. These keywords are either directly obtained from the papers or manually extracted by an expert when unavailable. The most frequent keywords,
exceeding a certain threshold, are then selected. For this SMS, the threshold value of 9 was determined through trial and error, resulting in 70 distinct keywords.

A co-occurrence matrix is then constructed based on these selected keywords. In this matrix, each cell $c_{ij}$ indicates the number of times the keyword from the $i$th row appears together with the keyword from the $j$th column in the same paper. An iterative procedure is employed to classify the keywords. During each iteration, the two keywords with the highest co-occurrence count are selected and merged to form a new combined subject. This process continues until no new co-occurrences are found in the matrix. After 27 iterations, a final set of 18 topics is obtained. Through expert review and consolidation of related topics, 11 main topics are identified as the first-level topics of the research tree.

Finally, these 11 topics are categorized into two groups: client-centric and provider-centric, as determined by a team of experts. Client-centric topics involve activities the cloud broker undertakes in response to user requests, such as service discovery, service selection, and service composition. Provider-centric topics encompass activities performed at the provider’s request, such as pricing, resource management, or energy management. Fig. 1 illustrates the research tree developed in this SMS, displaying the percentage of included papers for each topic. It is important to note that the total percentage may exceed 100 because some articles address multiple topics simultaneously.

IV. RESULTS OF THE STUDY

The previous sections provide a detailed explanation of the process for identifying search spaces and studies. This section will analyze the studies and address the RQs presented in Section III, following the arrangement outlined in Table I.

A. How Active Is the Field of Brokering and How Is the Distribution of Selected Studies by Type and Publication Year? (RQ1)

One of the primary RQs investigates the frequency of published papers in the field of cloud brokerage from its inception in 2009 through 2022. This analysis reflects the acceptance level and progress of cloud broker research during this period. The current study highlights the level of interest from academic communities and its evolution over the years. Fig. 2 illustrates the final results. As depicted, the field of cloud brokerage has shown an upward trend since its inception in 2009, peaking in 2019. A significant increase is observed in 2012, primarily due to the emergence of inter-cloud and multi-cloud environments and related articles. In the last three years, from 2020 to 2022, the number of articles has stabilized.

B. Which Researchers and Research Venues Are More Active in This Field and How Are the Active Researchers Distributed Geographically? (RQ2)

Identifying the active researchers in the field of cloud brokers is beneficial for those conducting research and working in this area. The data extracted during the data extraction phase, detailed in the Authors and Countries tab of the supplementary file, available online, was used to determine the active researchers and their associated countries. Fig. 3 displays the active researchers, ranked by the number of publications in each topic. The researchers are arranged in descending order based on their publication count, from left to right. For instance, Rajkumar Buyya, with 21 publications in this field, is at the top of the list. The size of the bubbles represents the number of publications, with larger bubbles indicating a higher number of publications. Please note that the total number of publications listed for each topic by an author may reach unprecedented levels compared to their overall number of published papers, as a single paper can address multiple topics.

Another type of analysis in the proposed SMS examines the number of publications based on geographical distribution. This analysis can identify significant institutes and countries that have a major impact on the advancement of the cloud broker field. Please note that when a single study has multiple authors with different affiliations, all affiliations are taken into account for that paper. Fig. 4 shows the geographical distribution of publications in this research area. A segment labeled Others aggregates the frequency of all countries with fewer than 30 publications. According to this figure, China has the largest share...
of total publications, followed by the United States. Researchers in these countries have been more active in this field, likely due to the availability of necessary platforms for cloud and brokerage infrastructure in research projects and implementations. This activity can also be attributed to generous research funding and technological advancements. Additionally, the presence of suitable infrastructures, such as cloud data centers, in these countries has drawn more attention to cloud brokerage.

Another useful analysis involves identifying the active search spaces within the field to help researchers become familiar with the most popular venues. This knowledge enables them to follow the publications of leading search spaces to gain more information on their topics of interest. Figs. 5 and 6 show the 10 most active journals and conferences in the field of cloud brokerage, respectively. It is evident that the journals *Future Generation Computer Systems*, *IEEE Transactions on Cloud Computing*, and *IEEE Transactions on Services Computing* have a significant lead over other journals in this field. Among conferences, the *IEEE/ACM International Conference on Utility and Cloud Computing* is a particularly popular venue in the realm of cloud brokerage.

C. What Are the Core Research Topics in the Field of Brokering? (RQ3)

Main research topics are identified through a topic detection process that involves clustering keywords and conducting expert analysis, as detailed in Section III-B. This process resulted in a research tree that highlights the main topics of cloud brokerage, shown in Fig. 1. Below, we provide a detailed description of each topic.

1) **Resource management (client-side):** Involves efficiently managing and maintaining the pool of resources leased from one or multiple CSPs (i.e., resource provisioning), as well as scheduling CSUs’ tasks and applications on these resources to maximize resource utilization [41].

2) **Service composition and integration:** Entails selecting suitable candidate services based on the CSU’s objectives, preferences, and constraints (on QoS attributes) to create a value-added composite service [42]. This process integrates various software components, resources, and functionalities from one or multiple CSPs to deliver a cohesive and unified solution.

3) **Service selection:** refers to the process of evaluating and choosing the most appropriate available services or combination of services for the CSUs, according to their requirements and objectives [43]. It involves evaluating
4) Service discovery: refers to the automatic detection of services and resources offered by CSPs, which meet the specific functionality or requirements of the CSUs [16]. Since different CSPs use different terms for describing their offered services, a common language is needed to describe them to avoid disputes. Semantic technologies such as Resource Description Framework (RDF) and Web Ontology Language (OWL) are commonly used to achieve this.

5) Service recommendation: Involves using recommendation algorithms (such as Collaborative Filtering) to help a CSU select the optimal services from various CSPs that match its requirements. This process ranks available services based on the CSU’s preferences, the QoS properties of the services, along with user ratings, and presents the results to assist the CSU in choosing the most appropriate service [44].

6) Resource management (provider-side): Resource management on the provider side is often discussed in the context of a cloud federation, which is a marketplace where a group of CSPs share their computational resources with each other [45]. Resource management in a cloud federation involves a set of policies that determine how resources from CSPs with excess capacity are allocated to CSPs experiencing resource shortages.

7) Pricing: Refers to the mechanism of determining the value of services or resources provided by a single CSP or a group of CSPs to ensure their profitability [46]. As auctioning is a common pricing mechanism, the broker can act as a trusted auctioneer between CSPs and CSUs. Additionally, in a cloud federation, the broker...
can implement dynamic pricing schemes based on the demand and supply of resources to encourage CSPs to offer their excess resources in the federation market [45].

8) Monitoring: Refers to the process of measuring and reporting parameters related to cloud infrastructure and resources (e.g., CPU, RAM), as well as specific parameters of applications and services [16]. Monitoring is crucial for CSPs to ensure efficient resource utilization and compliance with SLAs, and for CSUs to verify that the promised service levels are met [47]. In an inter-cloud environment, a broker can provide a centralized monitoring platform that aggregates data from multiple CSPs and presents it in a unified dashboard. Additionally, cloud brokers can offer customized monitoring services tailored to the specific needs of CSUs.

9) SLA management: Involves the processes of negotiating, establishing, monitoring, reporting, and ensuring compliance with the agreed-upon service levels between CSPs and CSUs [48]. Cloud brokers play a crucial role as a trusted third party in SLA monitoring, reporting, issue resolution, and escalation.

10) Energy management: Focuses on deploying energy-efficient technologies in cloud data centers to reduce CSPs’ operational costs and promote environmental sustainability [49]. Cloud brokers can support energy management through energy-aware resource allocation and task scheduling algorithms.

11) Big data: Involves the storage, processing, and analysis of large and complex datasets using cloud resources [50]. Although many CSPs offer Big Data storage and processing services, cloud brokers can provide additional analytic services needed by CSUs, known as Analytics as a Service (AaaS). Furthermore, brokers can offer inter-cloud services for running Big Data applications by provisioning the significant processing power and storage these applications require [51].

D. Which Broker Topics Have the Least/Most Corresponding Attention and What Is the Publication Trend and Distribution for Each Topic? (RQ4)

To address the first part of RQ4, we computed the percentage of publications per topic, as shown in Fig. 7. This figure displays the proportion of each topic in all cloud brokerage publications. It’s important to note that the percentages in this figure differ from those in the research tree. In this figure, the percentage of each topic is calculated by dividing the total number of papers related to that topic by the sum of papers related to all other topics. In other words, unlike the research tree, the sum of percentages in this figure equals 100.

As illustrated, the topics Resource Management (Client-Centric), Service Composition, and Service Discovery have a higher frequency in the included studies compared to other topics. This indicates that most studies consider a cloud broker primarily as a client-centric entity focused on meeting clients’ needs and interests. We believe the reason for the greater attention to resource management, service composition, and service selection is that these are the core services of cloud brokers, according to the NIST definition. Moreover, some topics are more technical and less scientific, such as service discovery and monitoring, and thus have received less attention from the scientific community. Higher-level services such as pricing and recommendation have not garnered as much attention but are expected to become more significant to broker system researchers in the future. Supporting the information in Fig. 7, Figs. 8 and 9 illustrate the progression of both client-centric and provider-centric topics over time, respectively.
E. Which Forms of Empirical Evaluation Have Been Used? What Are the Tools Available to Support Field Approaches? Which Techniques Are Used More in the Field? (RQ5)

Additional valuable insights gleaned from the mentioned SMS focus on exploring the popularity of evaluation methods in cloud brokerage. The empirical evaluation encompasses three main approaches: real world, testbed, and simulation. Real world implementation refers to deploying solutions in commercial cloud settings. Testbed involves setting up scaled-down versions of real clouds using management software like OpenStack. Simulation entails creating mathematical models of real-world cloud environments using simulators such as CloudSim [52] or developing custom solutions in languages like Java and Python.

Fig. 10 illustrates the prevalence of these evaluation methods in reviewed studies. Simulation emerges as the most favored method among researchers for evaluating their approaches. This preference is largely due to the high costs associated with conducting experiments in actual cloud environments. In contrast, testbed experiments are limited in scalability and can only support small-scale setups with limited resources, raising doubts about the scalability of proposed methods. Additionally, simulations offer the advantage of reproducibility, allowing other researchers to replicate experiments under similar conditions, thereby boosting confidence in experimental outcomes.

Additional pertinent information concerns the scientific techniques employed by researchers to address ongoing challenges in cloud brokerage. Fig. 11 delineates the diverse methodologies utilized by brokers. The term “technique” here refers to specific methodologies, algorithms, models, or tools systematically employed to tackle research problems. Notably, heuristic algorithms are the most commonly used, followed by the development of architectures or frameworks for managing brokerage tasks. Meta-heuristic algorithms like Genetic Algorithms rank third in popularity. Appendix A, available online, provides further details on these techniques, including their definitions and applications.

F. What Is the Relation Between Topics and Broker Roles in the NIST Category? Which NIST Roles Have the Least/Most Corresponding Attention? (RQ6)

Fig. 12 depicts the distribution of NIST roles across the reviewed papers. A significant portion, approximately 45%, focuses on arbitration. This emphasis is driven by extensive research in inter-cloud environments (such as multi-cloud and cloud federation), where brokers negotiate with multiple CSPs to integrate and select optimal services at competitive prices. Conversely, aggregation, which involves consolidating fixed services from various CSPs, garners less attention due to perceived lower efficiency compared to arbitration. Intermediation, considered the simplest and currently most functional broker type, receives substantial attention, encompassing about 42% of all studies. However, as broker capabilities evolve, it is anticipated that arbitrage and aggregation concepts will be increasingly explored over intermediation.

Fig. 13 provides an overview of how each NIST role is distributed across different paper topics. As expected, papers focusing on composition and integration predominantly address aggregation and arbitrage roles. In contrast, studies in selection and monitoring topics primarily concentrate on the intermediation role.

G. In Which Service Layer Is the Broker Mostly Considered? (RQ7)

During the systematic review of the broker field, a crucial aspect of analysis involves examining the service layers at which brokers operate. This study categorizes cloud service layers into five distinct categories: Infrastructure as a Service (IaaS), which also includes Container as a Service (CaaS); Platform as a Service (PaaS); Software as a Service (SaaS); and anything as a Service (XaaS). Given that the majority of commercial cloud services fall within the IaaS layers, the findings presented in Fig. 14 are both predictable and reasonable. It is important to note that when a specific type of cloud service is not explicitly mentioned in the reviewed studies, this study categorizes it under XaaS, which broadly encompasses any type of cloud service.

H. What Is the Broker Control Topology? (RQ8)

In this RQ, the study investigates the role of brokers from two perspectives: a centralized topology and a distributed (or peer-to-peer) topology. In the centralized model, a single broker entity manages all brokerage tasks. In contrast, the distributed model involves multiple brokers collaborating to execute brokerage tasks collectively. The centralized model is simpler to implement, with decision-making centralized and streamlined due to consolidated information. However, challenges include obtaining accurate real-time data and potential reluctance from participants, such as CSPs in federations, to share information with a centralized entity. In contrast, the distributed model addresses privacy concerns as each CSP manages its own broker, though decision-making relies on local information, potentially limiting insight from other brokers. Fig. 15 illustrates the distribution of papers across these control topologies, highlighting a significant preference for centralized topology in showcasing cloud broker capabilities.

V. DISCUSSION ON THE RESULTS

This section includes our analyses and discussions regarding the results presented in Section IV. It begins with a comparison
between our proposed SMS and other review articles in the field, followed by an exploration of trends and demographics. We then discuss research efforts concerning the evaluation, usage, and development of cloud brokers. Finally, we conclude by outlining future directions for further research in this area.

A. Comparison Between the Proposed SMS and Other Reviews

The primary aim of this section is to compare the proposed SMS with other relevant reviews. Four previous studies have been selected for detailed analysis due to their close alignment with our research focus and comprehensive scope. These selected surveys are Fowley et al. [33], Chauhan et al. [28], Elhabbash et al. [7], and Li et al. [41]. As illustrated in Table VII, the proposed SMS (represented in the last row) examines a larger set of related papers for comparative purposes with other review studies. Unlike the proposed SMS, most previous reviews lack a systematic process for reviewing articles on cloud brokerage. Furthermore, these studies have reviewed only a limited number of papers within the domain of cloud brokering, with a relatively small selection of high-quality works. Additionally, Table VIII provides a comparison between the proposed SMS and other reviews in terms of the topics covered in each study.

B. The Trends and Demographics and Active Search Spaces in Cloud Broker Research (RQ1, RQ2, RQ3, and RQ4)

Analyzing the demographics of cloud broker research highlights their importance in studies conducted within cloud environments. The upward trend shown in the bar charts of Fig. 2 (RQ1) up to 2019 indicates that the concept of cloud brokering has gained widespread acceptance as a promising solution. Despite a decline in the number of published papers in recent years (after 2020), this topic continues to attract significant attention from the research community. The present study has identified key researchers and research venues in the field of cloud brokering, which can serve as valuable references for those interested in conducting research in this area. A comprehensive list of researchers and research venues is available in the supplementary file under Authors, Journals, and Conferences tabs.

Fig. 7 illustrates a clear correlation between the volume of research conducted in cloud brokerage and specific topics such as service composition, service selection, and resource management. These topics have consistently garnered the highest number of research studies and publications up to 2022 compared to other aspects related to brokers. This trend indicates a shift among researchers towards exploring more complex services that involve multiple cloud services, moving beyond simple single-service compositions. Consequently, it is expected that cloud brokers will evolve to provide increasingly sophisticated services, integrating multiple cloud services sourced potentially from various providers in the future.

Given the expanding landscape of cloud environments, numerous commercial companies vie to market their cloud resources and attract customers. Within this vast array of cloud services, identifying the most suitable service tailored to user needs has become a significant challenge. Cloud brokers have assumed a pivotal role in tackling this challenge, carving out a
specialized niche within the cloud ecosystem. Referring to the findings presented in Fig. 7, 18% of the included studies have proposed solutions focused on selecting the optimal service that aligns with the preferences of cloud customers. Additionally, resource management, which spans both client and provider sides, has consistently emerged as a prominent research area. This domain encompasses critical tasks such as VM task scheduling (client side) and VM allocation on physical machines (provider side). These activities are crucial for achieving optimal resource utilization in cloud environments, prompting extensive research efforts aimed at advancing these capabilities.

As a guideline for researchers interested in brokerage, it can then be said that, according to the analysis of the included studies, resource management, composition and integration, and service selection are the more outstanding and active topics in this field. Among the three main roles introduced by NIST, the largest number of research studies published from 2009 to 2022 were on arbitration (RQ6).

### C. Research Efforts Toward Cloud Broker Evaluation (RQ5)

The results of RQ5 indicate that the majority of studies (69%) have utilized simulations to evaluate their methods, while a smaller proportion have employed testbed (10%) and real-world methods (10%). It is noteworthy that 11% of the research studies did not specify the type of evaluation method used. Real-world methods typically offer advantages due to their accuracy and reduced susceptibility to bias and parameter manipulation. They can provide valuable insights into actual conditions within cloud environments. However, implementing real-world methods for
testing and evaluating proposed solutions can be challenging and costly due to the dynamic nature of execution time conditions.

These challenges have led to the widespread adoption of simulation methods, such as CloudSim [52], for evaluating research approaches. Nonetheless, simulation methods have limitations as they may not fully replicate real-world execution conditions, potentially creating a gap between simulated evaluations and actual environments. Researchers employing simulation methods should strive to ensure the objectivity and quality of their proposed approaches by validating them with industry experts. This validation helps bridge the gap between simulated evaluations and real-world applicability, thereby enhancing the relevance and reliability of their findings.

D. Research Efforts Towards Cloud Broker Usage (RQ3, RQ4, and RQ6)

Based on the findings of RQ3, the main responsibilities and components of a cloud broker are crucial for meeting the needs of both cloud providers and clients. The research tree depicted in Fig. 1 outlines eleven primary tasks that are integral to a current cloud broker, as identified in the analysis of included studies. Furthermore, RQ4 emphasizes the importance of each component. For instance, as shown in Fig. 7, resource management emerges as one of the most critical tasks for cloud brokers, with 25% of research studies focusing on this area. Following closely are service composition and integration, and service selection, which are also pivotal components.

According to RQ6, the arbitration role stands out as the most significant for cloud brokers, with a majority of previous studies concentrating on this specific role. This suggests that the majority of existing real cloud brokers likely already support arbitration. Overall, understanding these key components and roles is essential for researchers aiming to develop effective cloud brokerage solutions that meet the diverse needs of stakeholders in cloud environments.

E. Research Efforts Towards Cloud Broker Development (RQ7 and RQ8)

Based on the findings of RQ7, a majority of previous research has concentrated on proposing cloud brokers specifically tailored for the IaaS environment. This focus is understandable, given that most cloud users historically have predominantly utilized IaaS services. In the early stages, IaaS provided a straightforward and widely accepted service model. However, with the evolution of the cloud landscape, more advanced services such as serverless computing (also known as Function as a Service or FaaS) have emerged, offering complex and sophisticated functionalities. As users increasingly explore and adopt these newer cloud services, it is expected that future research will shift towards designing cloud brokers for other service layers, particularly for emerging models like FaaS. This indicates a trend towards enhancing the capabilities of cloud brokers to effectively manage and optimize the usage of these advanced cloud service models.

Another significant aspect highlighted by RQ8 is the centralization or distribution of brokers within cloud environments. Currently, centralized brokers have received the majority of attention, accounting for 83% of previous studies, as depicted in Fig. 15. Centralized brokers are straightforward and foundational in nature. However, there is growing recognition of the advantages associated with distributed broker architectures. Distributed approaches offer potential benefits and represent a future trend in the design and development of cloud brokers.

| References | [7] | [22] | [3] | [33] | [21] | [6] | [16] | Our SMS |
|------------|-----|-----|-----|-----|-----|-----|-----|--------|
| Composition| ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Discovery  | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| RM (client)| ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Energy Mgmt. | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Selection  | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| RM (provider)| ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Pricing    | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Monitoring | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Recommendation | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| SLA Mgmt.  | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| Big data   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
aiming to enhance scalability, fault tolerance, and performance in complex cloud environments.

F. Future Directions (RQ4, RQ6, RQ7, and RQ8)

Considering the various RQs and their corresponding findings, it is possible to identify areas that have received less attention and could serve as potential directions for future research. For example, based on the results of RQ4, two promising topics for further investigation are pricing strategies and Big Data. Big data, being a relatively new research area, holds significant potential for cloud brokers to introduce novel services to users. Additionally, areas such as service recommendation and energy management could be of interest to researchers. Specifically, energy management can be further explored within the context of green computing, which aims to minimize the environmental impact of cloud computing by adopting environmentally-friendly practices and technologies.

Building on the findings of RQ6, focusing research efforts on advancing the arbitration and aggregation roles within cloud brokerage appears to be a promising path. While cloud brokers have predominantly concentrated on basic intermediation services so far, it is clear that they are evolving towards a more comprehensive approach that combines services and offers more intricate solutions. Therefore, researchers should prioritize investigating and further understanding these two roles, as they have significant potential to shape the future landscape of cloud brokerage.

RQ7 emphasizes the importance of exploring alternative service models beyond IaaS, particularly focusing on the emerging serverless computing models like FaaS. Recently, serverless computing has garnered significant attention from both academia and industry [53]. In this paradigm, the cloud provider manages and dynamically allocates computing resources to execute individual functions on-demand. This allows developers to focus on writing and deploying functions without dealing with the complexities of managing the underlying infrastructure. Cloud brokers can play a crucial role in resource management and delivering serverless services to users, especially in inter-cloud environments. They can facilitate the effective allocation and utilization of resources in a serverless context, ensuring optimal performance and cost efficiency.

As previously mentioned in Section II, the concept of sky computing has recently emerged as the future of cloud computing [17, 18]. Sky computing introduces the concept of inter-cloud brokers, which enable the execution of CSUs’ jobs across multiple clouds based on their preferences and optimization metrics. This vision enhances the role of cloud brokers in the future of cloud computing, particularly with the introduction of brokers such as SkyPilot [19]. The new paradigm of serverless sky computing has been recently proposed to extend this vision into the realm of serverless computing [54, 55], opening new horizons for cloud brokerage.

VI. IMPLICATIONS OF THE FINDINGS

The present study has conducted a systematic review of cloud broker research to guide researchers, stakeholders, and educators interested in this field. Given the extensive scope of the search spaces reviewed, the results and discussions presented in Sections IV and V offer valuable insights for diverse research audiences. Each result highlighted in the previous sections can significantly assist various audiences within this research domain. This section outlines the implications of the proposed SMS for researchers, stakeholders, and educators.

A. Implications for Researchers

There are notable variations in the number of studies conducted in different countries (RQ2). China (with 119 studies), the United States (with 101 studies), India (with 92 studies), and Australia (with 79 studies) stand out as highly active contributors in this research field. The findings suggest that the high research output in these countries can be attributed to their advanced technological industries and the strong collaboration between academic institutions and industry. As a country’s technology and industry continue to advance, it becomes crucial to support academic research endeavors that aim to develop efficient methods and cater to industry needs. The level of progress a national industry achieves in utilizing cloud technologies to meet user requirements directly influences the motivation and acceptance of researchers within that country. Additionally, the high number of publications in China and India can be partly attributed to their larger populations, resulting in more researchers and scholars.

On the other hand, for researchers to develop efficient methods for cloud brokering, it is crucial to use appropriate platforms to evaluate these approaches before implementing them in an industrial context. A vital step towards this objective is allocating budgets to provide the necessary infrastructure for evaluating academic research aimed at advancing industry goals. As revealed by RQ5, countries equipped with robust infrastructure, such as cloud data centers, are better positioned to support and implement research efforts within the industry. Additionally, the presence of dedicated research laboratories focused on cloud computing, such as the CLOUDS Laboratory managed by Rajkumar Buyya, has significantly influenced advancements and fostered innovation in the field of cloud computing.

The combination of cloud services to fulfill users’ complex requirements is achievable in both single-cloud and inter-cloud environments. However, in inter-cloud environments, the conditions during the broker’s implementation tend to be more diverse and unpredictable compared to single-cloud environments. Consequently, when a broker acts as an orchestrator, its role extends beyond service selection to effectively combine services, thereby enhancing resilience against failures.

Given the extensive adoption of cloud services by both established customers and startups, along with the broker’s essential role in combining services to deliver enhanced offerings, it is crucial to effectively manage failures during the broker’s execution. This is especially critical in the service combination process, as the failure of even a single service can disrupt the entire broker operation. Therefore, as a valuable guideline for researchers and individuals interested in the field of brokerage, it is essential to prioritize the development of robust mechanisms.
for failure management and detection during the implementation of web service composition.

B. Implications for Stakeholders and Practitioners

The findings of RQ1 reveal that brokers have been integral to cloud computing since 2009 and are set to become key components in negotiating cloud services and facilitating business-to-market interactions. Stakeholders should leverage the accumulated experience from solutions widely employed in recent decades to enhance the quality and performance of cloud-based services.

Currently, research on the development and utilization of cloud brokers remains predominantly theoretical and academic. The practical application of solutions proposed in academic studies is not commonly observed in the industry. Therefore, it is essential for cloud practitioners and stakeholders to play a pivotal role in improving existing technology in cloud computing. Practitioners specializing in cloud computing, particularly in brokering, should actively participate in reputable academic conferences dedicated to this subject (RQ1). By sharing their perspectives and preferences regarding current and future research approaches, they can significantly contribute to the advancement of cloud computing within the industry. The presence of these stakeholders and practitioners at such events will substantially influence the direction of algorithms presented by researchers, ensuring alignment with the dynamic and real-world conditions of cloud environments. Additionally, the experience of practitioners can profoundly affect the construction methods employed for brokers (RQ2). In turn, practitioners can benefit from fruitful collaborations with researchers in academia, fostering a mutually beneficial relationship.

Currently, the majority of solutions proposed in broker research demonstrate satisfactory quality for application in real-world environments (RQ1, RQ6). However, there is still a lack of empirical evidence from industry settings. To bridge this gap, it is essential for industry experts (practitioners) and stakeholders to collaborate with researchers. This collaboration should focus on expanding the academic perspective to include metrics that align more closely with industry requirements and standards. By fostering this collaboration, a broader and more industry-friendly approach can be achieved, ensuring that the research outcomes are better suited for practical implementation.

C. Implications for Educators and Teachers

With more than 10 years of experience, cloud brokers have emerged as one of the most promising solutions for facilitating trade in complex cloud environments (RQ1). These brokers have been developed through the dedicated efforts of renowned researchers and pioneers in the field of cloud brokering. Leveraging academic expertise in constructing industry-friendly brokers offers the advantage of transferring valuable knowledge to aspiring developers.

As a recommendation, the findings of the proposed SMS suggest that instructors of courses related to cloud computing and distributed systems should incorporate the topic of cloud brokers into their syllabi as an important component of cloud environments. The extensive research conducted in the field of brokers can serve as a valuable educational resource for those teaching cloud computing, enriching the curriculum and providing students with a comprehensive understanding of cloud brokerage.

VII. Conclusion and Future Work

The present study focuses on conducting an SMS on cloud brokers, specifically covering the period from 2009 to 2022. The SMS identified 91 related search spaces based on its search strategy. These search spaces were then scrutinized for relevant studies that met established quality criteria, resulting in the selection of 634 studies for further analysis. A key aspect of the proposed SMS is the utilization of a robust research methodology. This SMS incorporates a comprehensive two-tier search strategy, including a manual search strategy and backward snowballing. The accuracy of the search methodology was carefully examined to ensure the extraction of relevant studies and the collection of comprehensive and complete information.

The proposed SMS addresses a set of eight research questions, providing comprehensive responses. The first three research questions (RQ1, RQ2, and RQ3) focus on reviewing the amount of research conducted in the broker field from 2009 to 2022, identifying the key topics related to cloud brokerage, and introducing notable researchers and pioneers in this field along with the active countries in the broker domain. The following two questions, RQ4 and RQ5, investigate the research volume in each significant broker topic, the growth rate of research in these topics over time, the evaluation methods employed in research studies, and the techniques utilized for constructing cloud brokers.

In RQ6, the topics extracted from the included studies are analyzed based on the NIST definitions. RQ7 focuses on identifying the different layers of service for cloud brokers and determining the number of included studies pertaining to each layer. RQ8 explores two vital aspects of cloud brokers, namely centralized and distributed models, while analyzing broker studies according to two defined perspectives. Additionally, the present study compares the proposed SMS with other relevant reviews, assessing the depth of methodology, the number of studies examined, and the various aspects considered in each review. This comparison helps to highlight the strengths and areas of improvement for the proposed SMS, ensuring a thorough understanding of the cloud brokerage research landscape.

The proposed SMS reveals that the cloud broker field is dynamic and expanding across various geographical regions. It underscores the need for continuous development of cloud brokers in alignment with the latest research advancements. Researchers are encouraged to explore new domains in cloud brokerage, such as sky computing and serverless environments. Systematic mapping studies, like the proposed SMS, provide a foundation for conducting more focused and specific literature reviews. Future research can explore each topic identified in the
research tree in greater depth to address more specific research questions, thereby advancing the field of cloud brokerage further.

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