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Systematic Review

A Systematic Mapping Study of Cloud Resources Management and Scalability in Brokering, Scheduling, Capacity Planning and Elasticity

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Abstract

Cloud computing allows for resource management through various means. Some of these include brokering, scheduling, elasticity and capacity planning and these processes helps in facilitating service utilization. Determining a particular research area especially in terms of resources management and scalability in the cloud is usually a cumbersome process for a researcher, hence the need for reviews and paper surveys in identifying potential research gaps. The objective of this work was to carry out a systematic mapping study of resources management and scalability in the cloud. A systematic mapping study offers a summarized overview of studies that have been carried out in a particular area of interest. It then presents the results of such overviews graphically using a map. Although, the systematic mapping process requires less effort, the results are more coarse-grained. In this study, analysis of publications were done based on their topics, research type and contribution facets. These publications were on research works which focused on resource management, scheduling, capacity planning, scalability and elasticity. This study classified publications into research facets viz., evaluation, validation, solution, philosophical, option and experience and contribution facets based on metrics, tools, processes, models and methods used. Obtained results showed that 31.3% of the considered publications focused on evaluation based research, 19.85% on validation and 32% on processes. About 2.4% focused on metric for capacity planning, 5.6% focused on tools relating to resource management, while 5.6 and 8% of the publications were on model for capacity planning and scheduling method, respectively. Research works focusing on validating capacity planning and elasticity were the least at 2.29 and 0.76%, respectively. This study clearly identified gaps in the field of resources management and scalability in the cloud which should stimulate interest for further studies by both researchers and industry practitioners.

Key words: Cloud computing, elasticity, capacity planning, resource management, scalability, systematic mapping

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INTRODUCTION

Cloud is a parallel and distributed system that is made up of virtualized and interconnected computers which are actively provided and offered as one or several allied computing resources based on service level compliance among the cloud service providers and the users[1]. Resources offered to users must be effectively managed for optimum benefits of the cloud Service Provider (CSP) and the users alike. A broker[2] operates between the CSPs and the users and is responsible for balancing the needs of both parties. Users submit their requests to a broker, which in turn communicates and monitors the whole service exchanging procedures with the CSP[3]. Most cloud use a centralized brokering topology which enables the broker(s) to have a complete knowledge of the datacenter, its configuration and parameters as well as number of physical and virtual machines therein[3]. The process of elasticity[4] is used to match the user's workload with the provisions of the CSP. Cloud resources are often provided to numerous users using virtual systems[1] rather than physical/dedicated hardware. This way numerous users can share a single hardware resource. This is called multitenancy[5]. However, due to the sheer number of users, effective workflow allocation and scheduling schemes are paramount to allow for effective resource utilization and improved service quality. It is however, important to note that it is not all a bed of roses, as virtualization and multitenancy raise security related concerns[5,6]. Capacity planning is also important to both the user and the provider. These are three primary service models in cloud computing namely: Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). In SaaS, the CSP offers the user custom-built applications through a web browser over the Internet. The user is therefore not concerned with upgrades and/or licenses. In PaaS, the CSP provides the enabling underlying infrastructure that allows users to develop and deploy application. While in IaaS, the CSP among other services, provides storage, bandwidth and compute resource. However, the user has limited control over the CSP's infrastructure. Cloud computing is becoming very effective and services are improving and expanding on a regular basis because of the sound underlying architecture and applications running on the cloud[7,8]. The cloud consists of four developments models namely: public, private, community and hybrid cloud. Public clouds are services provided over the Internet by major CSPs who have massive cloud infrastructure spanning several geographical locations. Though CSPs strive to provide very efficient and reliable services, trust remains a major issues for users[9]. Private clouds on the other hand are hosted on-premises by organizations and are managed by in-house staff. They are sometimes considered as extensions of an organization's datacenter. Community cloud is used by organizations and institutions engaged in similar activities. Hybrid cloud enables organizations take advantage of the benefits available on both private and public cloud. Application scalability is one of the main advantage of moving to the cloud. This is because scalability allows real-time resources provisioning to meet application requirements[10]. The scheduling of resources is dependent on the user's needs. Some common scheduling algorithms include: First-come-first-serve, round-robin, min-min, max-max, most-fit-task scheduling and priority scheduling algorithms[10]. Resources have relationship that could be technical, dependent or limited in availability, hence, the need for proper planning[11]. Systems such as advanced planning and scheduling approaches, the theory of constraints and just-in-time approaches, have been proposed to enhance planning of resources utilization[12]. Resources management frame works are required to dynamically provision resources for the purpose of enabling scalability and seamless execution of workflows[13]. This is even more exaggerated in the computational cloud, where work flows are adapted to actively changing computing environments, while increasing the performance and simultaneously maintaining the required quality of service is paramount[12]. The core of virtual resource management and scheduling in cloud computing is load balancing[13].

In writing an article or embarking on research in general, a researcher must consider a technical area of interest. This involves a lot of studies in an attempt to understand the topic. It usually entails searching several conference proceedings, journals and even books. Additionally, there might be need to search through digital libraries, attend workshops, seminars and conferences to in order to identify a research focus. Also, observed phenomenon in an environment can serve as impetus for many researchers to pick interest in certain areas. From the foregoing, it is obvious that the process of determining a research topic can be cumbersome.

The areas covered by cloud resources management is diverse, consequently, a large volume of materials exist in this field of study. There is a possibility that research is focused on some specific areas, while others are neglected. It is therefore important to summarize publications in cloud management and obtain an overview of trends. This is where a systematic mapping comes in. A systematic mapping process allows for the categorization of reports using a scheme and structure based on frequencies of publications[14]. The summarized results of the scheme can then be presented in a visual manner using a map. The aim of this study is to perform a systematic mapping of cloud resources management and scalability. The categorization process used in this work was in three facets, which are the topic facet-where publications with topics discussing core issues in areas of resources management and scalability on the cloud were extracted; the research category-which examined the types of research undertaken and the contribution facets-which considered proposed method, model and tool used.

In Barros-Justo *et al*.[15], the planning phase of a systematic mapping study was explored. The work identified the software patterns as pertinent during the requirement engineering phase of projects. The study developed a protocol and highlighted basic steps needed for a systematic review. The authors adhered to the guidelines laid down in Petersen *et al*.[14] and the developed processes were benchmarked against those in related works. This comparison was used as confirmation of the validity of the research. The digital libraries used for the work are those of ACM DL, IEE Explore, SCOPUS and Web of Science.

The work in Kosar *et al*.[16] dwelt on the description of protocol for a systematic mapping study as it relates to domain-specific languages (DSL). The work is channeled towards an enhanced comprehension of the DSL domain of research with a focus on research trends and future direction. This work covered the period of July, 2013 to October, 2014 and leveraged on three guidelines for performing systematic review, namely; planning, conducting the review and reporting.

The systematic mapping study in Dos Santos *et al*.[17] was based on the analysis of the use of concept maps in Computer Science. This work delivered the result of a systematic mapping study that centered on collection and evaluation of existing research on concept maps in Computer Science. Five electronic databases were employed for the work. Backward snowballing and manual approaches were used in the searching process. The work shows massive interest and a rich investigation of concept maps, due to learning and teaching supports in that direction. The search strings of the work were applied on SCOPUS, Science Direct, Compedex, ACM and IEE Explore digital libraries.

In Souza *et al*.[18], a systematic mapping study was used to examine how game related techniques have been employed in software engineering education and how these techniques support specific software engineering knowledge domains, with research gaps and future direction identified. The primary studies of the work anchored on the use, evaluation of games and their elements on software engineering education. A total of 156 primary studies were identified in this study based on publications from 1974-2016. The mapping process of the work was done in line with Petersen *et al*.[14].

Fernandez-Blanco *et al*.[19] in their work performed a mapping of power system models. Their work was based on an overview of power system models and their applications in European organizations. They focused on the analysis of features in the various models as well as identification of modeling gaps. Though the authors sent out 228 surveys to power experts for information elicitation, only 82 completed questionnaires were used for the knowledge mapping.

In the work of Mernik[20], a systematic mapping study of domain-specific languages was done with the author's basic interest being on the type of contributions, type of researches done and the focus areas. The work featured a search from reputable sources from 2006 to 2012, with the systematic mapping study done based on defining research questions, conducting the search, screening, classifying and the data extraction. The research materials for the work included: Opinion papers, experience papers, philosophical or conceptual papers, solution proposal and validation research materials.

A systematic mapping of the literature on legal core ontologies was done by Griffo *et al*.[21]. The work based its search on "legal theory" and "legal concepts". The selected studies were categorized based on contribution with respect to language, tool, method and model. The authors also included phases for the identification of legal theories used in building core legal ontologies, recommendation for the use the proposed ontologies and finally the analysis of every chosen research for cogent deductions about legal and ontological research.

The work of Ahmad *et al*.[22] is a systematic mapping study that gave an overview of empirical research in software cloud-based testing in the process of building a classification scheme. Functional and non-functional testing methods were investigated. In addition, the applications of the methods and their peculiarities were examined. The work utilized 69 primary studies as discovered in 75 research publications. Only a fraction of the surveyed works considered rigorous statistical analysis with quantitative results. Majority of the studies however employed a singular experiment for the evaluation of their proposed solution.

From literature examined, there has been no work focused specifically on systematic mapping study of cloud resources management and scalability.

MATERIALS AND METHODS

A systematic mapping process offers a visual representation of results based on a vigorous review of publications in a field of study. This study was conducted using the formal guidelines for systematic mapping process as proposed in Kitchenham and Charters[23] and Mohammed and Mohammed[24]. The systematic mapping process is a repeatable procedure for extracting available material related to a research objective[22]. There are some pertinent steps in a systematic mapping study as discussed in Petersen *et al.*[14] and these steps are as elicited. The first step is the definition of research questions in which the scope of what is to be done in the particular field of study is outlined. Next is a search for primary studies conducted to find all relevant papers accessible in that field of study. The papers are later screened to select the ones that are applicable for the study. A classification scheme is usually designed by using the process of keywording on the abstracts of the relevant papers. The process is concluded by data extraction that leads to the creation of the systematic map. All these steps were applied in the creation of a systematic map of cloud resources management and scalability. In the context of paper selection criteria depicted by the research questions, the authors considered 131 articles to be incorporated in this study based on their applicability and direct relevance to the area of interest. These were selected out of a base interest consisting of 2,058 articles published between years 2000 and 2018. These 131 selected studies are listed on the Appendix.

Definition of research questions: Having an overview of research that has been done in a particular field of study is one of the major goals of systematic mapping. Knowing where the research has been published at times may also be necessary. Appropriate research questions to be applied for the study is determined by certain issues associated with the existing research that has been carried out. In this study, the research questions are as follows:

RQ1: What areas in resources management and scalability are dealt with and what is the number of articles covering the different areas?

RQ2: What evaluation and novelty do the published papers in the area of study constitute?

Maintaining the integrity of the specifications: In order to obtain materials for this study, a search was carried out on major scientific digital libraries available and accessible online. The search did not include articles in books, newspapers and other printed materials. This was because key wording which is a core concept of a systematic mapping studies would not be easy on such materials. Similarly, articles on social media and related platforms were not considered as they mostly lacked abstracts. All the papers selected for this study were in the domain of cloud computing, hence all the facets dealt with issues relating to cloud computing. The search for primary studies was conducted on four major digital libraries because of their high repute and impact factors of conferences and journal in their databases. The digital libraries searched and their URL is shown in Table 1.

The search string used for this study was constructed based on population, intervention, comparison and outcome. The basic keywords explored in the search string were taken from the structure of the title of this study. The search string used on the digital libraries used for this study on cloud research management and scalability is shown in Fig. 1.

The searches were performed using the customized search string above on the document metadata to ensure that relevant studies are not omitted. For this study, all outcomes from the four selected digital libraries applicable to the cloud and computer science were examined.

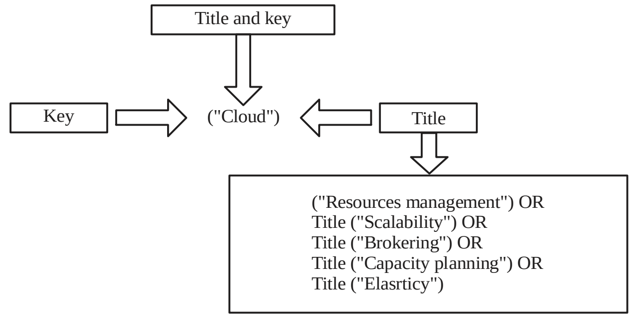

Fig. 1: Search string for systematic mapping

Table 1: Digital libraries sources

Electronic database	URL
ACM	http://dl.acm.org/
IEEE	http://ieeexplore.ieee.org/Xplore/
Science direct	http://www.sciencedirect.com/
Springer	http://www.springerlink.com/

Screening process for inclusion and exclusion: The essence of a selection criteria is to find and include all articles that are required and appropriate for the review. The inclusion and exclusion criteria were used to remove all paper that were irrelevant to this study. In addition, the selection criteria were also used to remove all articles that were not contributing to answering the research questions. Some abstracts which focused on the main study without sufficient further details were also excluded. Furthermore, presentation slides, prefaces, tutorials, editorials, panel discussion and summaries

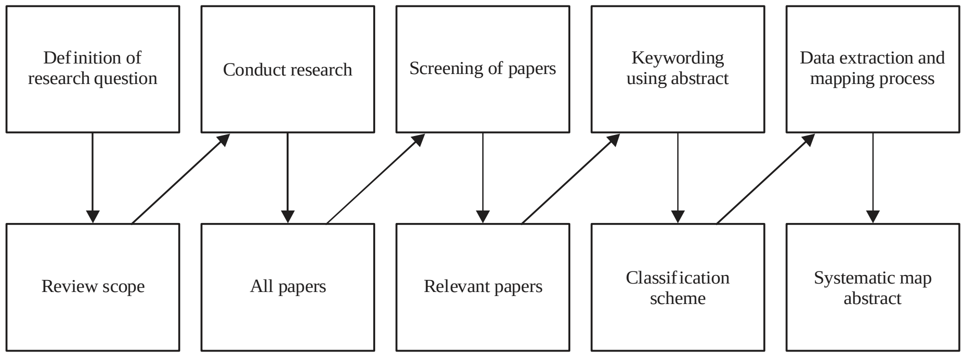

Fig. 2: Systematic mapping process[14]

Table 2: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
The abstract explicitly mentioned resource management and scalability. Furthermore, the abstract discussed brokering, scheduling, capacity planning and elasticity in relation to cloud computing	The paper was outside the domain of cloud computing. In addition, the paper did not discuss resource management and scalability. It also did not mention brokering and other aspect of resource management

were all excluded from this study. Papers that discussed the main focus of this study which is cloud resources management and scalability were all included, hence, the inclusion and exclusion criteria are in Table 2.

Keywording of abstracts: The keywording of abstracts is the core aspect of the systematic mapping research. Keywording of abstracts enhances the development of the classification scheme. The classification scheme is usually designed during the systematic mapping process as shown in Fig. 2. The systematic mapping process involves the following entities[14].

- Abstract
- Keyword
- Classification scheme
    - Articles
    - Sorting articles into the scheme
    - Updating scheme
- Systematic map

Keywording was paramount for reducing the time required to produce a classification scheme. In addition, the procedure of keywording ensured that all relevant studies are considered. This procedure involved studying the abstract of the included papers to extract important concepts and keywords that are useful to the study. This also involved an understanding of the context of the study. Keywords from different abstract relating to the study were collated to provide adequate insight into the type and contributions of the paper. This process was used to build a classification scheme and the topic category for this study on cloud resources management and scalability. However, it was imperative to further study the introduction and conclusion of some included papers to articulate appropriate keywording.

This study focused on resource management and scalability on the cloud and it employed three facets. The first facet was about the topics extracted from the abstracts based on this field of study. The second facet discussed types of contribution to the study in terms of tool, model, method, process and metric as outlined in Petersen *et al.*[14]. The third facet focused on the classification of the research approaches applied in the surveyed publications.

Research types facets with categories and descriptions: The third category was the research facet which is very important, but independent of the study focus. This study employed the classification of research approaches in Wieringa *et al.*[25]. This approach has the following categories and descriptions as explained below:

- **Validation research:** The procedures used are distinctive, but yet to be implemented
- **Evaluation research:** The procedures used have been implemented and evaluated. There are proof of concept with pros and cons discussed
- **Solution proposal:** The procedures show that a unique solution has been provided to a problem discovered and the benefits of such solutions application are available
- **Philosophical papers:** The procedures offer some improved ways to explore a problem in terms of concepts and frameworks
- **Opinion papers:** Any known methodology for research is not applied by this procedure rather it simply expresses the opinion of the authors
- **Experience papers:** The papers relate personal experiences of the author and explain how things were done

The classifications of research approaches discussed above were considered appropriate and adequate and thus used in this study. All the articles included in this study were closely examined and grouped into categories. The various categories make up the research facet for this study.

Data extraction and mapping of study: Sequel to sorting of relevant articles into groups during the classification process, data extraction was performed on the articles. This step was necessary as it enabled effective extraction of data from the various publications. The extraction of data further helped to fine tune groupings. During the process newly identified categories were added, closely related categories were merged while some were discarded being irrelevant to the study. A Microsoft Excel sheet was used for the entry of the data extraction. The Excel sheet contained entries for each category in the classification scheme. Thereafter, the frequencies of publications in each table are integrated to form new tables containing either the topic/contribution or the topic/research issues. The obtained results focused on presenting the frequencies of articles using the values obtained from the Table 3. The use of frequencies (article count), helped to easily achieve the sole purpose of this study, which was to identify which aspects of cloud resources management and scalability were given more emphasis and which area were ignored thus having shortage of publications. With this, knowledge gaps are easily identified for further research work. Bubble plots were used to present the frequencies of publications on the tables on the Excel sheet, thus creating a systematic map.

The systematic map comprised two x-y scatter plots, on which bubbles were used to represent intersections between categories. The bubbles sizes correspond to the number of papers identified in each matching category. Two quadrants were used to represent the three facets used for this study. Each quadrant provided a visual map based on the focus of this study at the node of the topics category with either the contribution or research category. It therefore becomes easy to consider different facets simultaneously. In addition, summary statistics were added further to enhance clarity. The overall systematic map thus provides insights into what had been done in the area of resource management and scalability on the cloud.

RESULTS AND DISCUSSION

The main crux of this systematic mapping study is to provide thematic analysis and classification. The results of the analysis showed gaps in research works on cloud resources management and scalability. Conversely, the results also identified areas that are fairly well covered in terms of publications. In this study, high-level categories were used to assess the papers included in producing the frequencies of publications and the systematic map that was subsequently created. A total of 131 papers were selected and all the papers were used to create Table 3 which dealt with the contribution category. In addition, only 125 papers dealt with the items under the research category and they were used to create Table 4. However, a paper could simultaneously discuss aspects of contribution and research category, hence, such papers appeared on Table 3 and 4. All references listed before Table 3 and 4 in the text were listed in ascending sequence from 1-25. However, this cannot be the case with the references listed on Table 3 and 4. This is because the references were extracted from the selected primary studies based on the content of the article. For example, only papers in the primary studies which was related to "Resource management and tool" were listed in column 3, row 2 of Table 3. In view of this, references 26-156 appeared randomly on Table 3 and 4 based on their content.

Main findings: Table 3 shows a summary of the distribution of studies in the contribution facet. The results indicated that publications which discussed process in terms of resource management and scalability on the cloud were 32% out of 125 papers in this category.

Table 4 shows a summary of the distribution of studies by research type. The result showed that papers which discussed evaluation research were 31.3% out of 131 papers in this category.

The topics that were extracted during classification scheme in the area of resources management and scalability are as follows:

- Resource management
- Scalability-brokering
- Scheduling
- Capacity planning
- Elasticity
- Resource sharing

Process discussion contributed 32% of the papers reviewed. Evaluation research constituted 31% of the type of research on resource management and scalability.

Table 3: Distribution of publications by contributions

	Contribution facet				
Topic	Metric	Tool	Model	Method	Process
Resource management		Abadi and Arani[26], Aldwyan and Sinnott[27], Arkian *et al.*[28] and Ma *et al.*[29] Maenhau *et al.*[30,31]	Chaabouni *et al.*[32], Chen *et al.*[33] and Haseeb *et al.*[34]	Abbasi and Qureshi[35], Abdelaal *et al.*[36], Manvi and Hegde[37], Pandya and Virparia[38] and Park *et al.*[39,40]	Aazam and Huh[41], Abrol and Gupta[42], Alelaiwi[43], Arianyan *et al.*[44], Arkian *et al.*[45], Buyya and Ranjan[46], Chen *et al.*[33], Cheng *et al.*[47], Clohessy *et al.*[48] and Odun-Ayo *et al.*[49]
Scalability brokering		Bermejo *et al.*[50], Bjorkqvist *et al.*[51], Chowdhury and Tripathi[52], Iqbal *et al.*[53] and Jhawar and Piuri[54]	Zhang and Cao[55]	Abrol *et al.*[56], Adinarayan[57], Ahmed *et al.*[58], Aruna and Prasad[59], Aslam *et al.*[60], Olaniyan and Maheswaran[61], Oppong *et al.*[62] and Pal and Hui[63]	Carvalho *et al.*[64], Huang *et al.*[65] and Jin *et al.*[66]
Scheduling		Bouchareb *et al.*[67], Bouterse *et al.*[68], Chen *et al.*[69], Jiang *et al.*[70], Mustafa *et al.*[71] and Nimkar and Ghosh[72]	An *et al.*[73], Boukerche and Meneguette[74], Kaewpuang *et al.*[75], Kang *et al.*[76] and Keshavarzi *et al.*[77]	Chen[78], Cheng and Chen[79], Hu *et al.*[80], Jakaria and Rahman[81], Jennings and Stadler[82], Jhawar and Piuri[83], Jlassi and Martineau[84], Marinescu *et al.*[85] and Mastorakis *et al.*[86]	Almutairi and Ghafoor[87], Al-Rawahi *et al.*[88], Alsarhan *et al.*[89], Arianyan *et al.*[90,91], Caglar *et al.*[92], Chen *et al.*[93] and Park *et al.*[94]
Capacity planning	Brummett and Galloway[95], Mateo *et al.*[96] and Mo *et al.*[97]	Ahokangas *et al.*[98], Cai *et al.*[99], Carvalho *et al.*[100] and Park *et al.*[101]	Abadi and Arani[102], Haratian *et al.*[103], Higginson *et al.*[104], Ikram *et al.*[105], Jia *et al.*[106], Patel *et al.*[107] and Yaqub *et al.*[108]		Abdelaal *et al.*[36], Giessmann *et al.*[109], Cardellini *et al.*[110], Carrasquilla[111], Kaseb *et al.*[112], Mashayekhy *et al.*[113] and Yu *et al.*[114]
Elasticity	Patel *et al.*[107]		Chung *et al.*[115], Heilig *et al.*[116], Karneyenka *et al.*[117] and O'Sullivan and Grigoras[118]	Kamila[119] and Khatibi *et al.*[120]	Abbasi *et al.*[121], Chen *et al.*[122], Chen and Deng[123], Heilig *et al.*[124], Hossain and Song[125], Kaseb *et al.*[126], Khan *et al.*[127], Mann[128], Moghaddam *et al.*[129] and Ning *et al.*[130]
Resource sharing		Johannes *et al.*[131], Manvi and Shyam[132] and Xu and Li[133]	Chang *et al.*[134], Kang *et al.*[135], Kapsalis *et al.*[136], Marchetto *et al.*[137] and Park *et al.*[101]	Arianyan *et al.*[138], Arianyan *et al.*[139], Bittencourt *et al.*[140] and Karatza[141,142]	He *et al.*[143] and Yunhui *et al.*[144]
Percentage	3.20%	20.00%	20.00%	24.80%	32.00%

Table 4: Distribution of publications by research type

	Research facet				
Topic	Evaluation	Validation	Solution	Philosophical	Experience
Resource management	Aazam and Huh[41], Abrol and Gupta[42], Alelaiwi[43], Arianyan *et al.*[138], Chen *et al.*[33] and Clohessy *et al.*[48]	Arkian *et al.*[28], Buyya and Ranjan[46], Marinescu *et al.*[85] and Odun-Ayo *et al.*[49]	Griffo *et al.*[21], Abadi and Arani[26], Aldwyan and Sinnott[27], Caglar *et al.*[92], Chaabouni *et al.*[32], Ma *et al.*[29], Maenhau *et al.*[30] and Park *et al.*[101]	Abbasi and Qureshi[35] and Abdelaal *et al.*[36]	Brummett and Galloway[95], Jhawar and Piuri[54], Manvi and Hegde[37] and Park *et al.*[39,40]
Scalability brokering	Abrol *et al.*[56], Adinarayan[57], Ahmed *et al.*[58], Aruna and Prasad[59], Aslam *et al.*[60], Olaniyan and Maheswaran[61], Oppong *et al.*[62], Ostberg *et al.*[145] and Pandya and Virparia[38]	Bjorkqvist *et al.*[51] and Ikram *et al.*[105]	Bittencourt *et al.*[140] and Keshavarzi *et al.*[77]	Huang *et al.*[65]	Iqbal *et al.*[53]
Scheduling	Bouchareb *et al.*[67], Bouterse *et al.*[68], Chen *et al.*[69], Jiang *et al.*[70], Nimkar and Ghosh[72], Yu *et al.*[114] and Yanagawa[146]	Carrasquilla[111], Cheng *et al.*[47], Cheng and Chen[79], Hu *et al.*[80], Jakaria and Rahman[81], Jennings and Stadler[82], Jhawar and Piuri[83], Jlassi and Martineau[84], Mastorakis *et al.*[86] and Ngenzi *et al.*[147]	Chen *et al.*[33] and Chen and Deng[123]	Kaewpuang *et al.*[75], Kang *et al.*[76] and Khatibi *et al.*[120]	Almutairi and Ghafoor[87], Al-Rawahi *et al.*[88], Alsarhan *et al.*[89], Arianyan *et al.*[90,91], O'Sullivan and Grigoras[118], and Park *et al.*[94]
Capacity planning	Boukerche and Meneguette[74], Higginson *et al.*[104], Kamila[119], Pal and Hui[63] and Patel *et al.*[107]	Abadi and Arani[102]	Jia *et al.*[106], Mateo *et al.*[96], Mustafa *et al.*[71] and Yaqub *et al.*[108]	Giessmann *et al.*[109], Cardellini *et al.*[110], Chen *et al.*[93], Chen[78], Kaseb *et al.*[112] and Mashayekhy *et al.*[113]	Ahokangas *et al.*[98], Cai *et al.*[99], Carvalho *et al.*[100] and Carvalho *et al.*[64]
Elasticity	Karneyenka *et al.*[117] and Park *et al.*[148]	Abbasi *et al.*[121], Chen *et al.*[122], Kaseb *et al.*[126], Mann[128], Mo *et al.*[97], Moghaddam *et al.*[129] and Ning *et al.*[130]	Jiang and Xiao[149]	Heilig *et al.*[116], Hossain and Song[125], and Khan *et al.*[127],	An *et al.*[73], Heilig *et al.*[124], Johannes *et al.*[131] and Zhang and Cao[55]
Resource sharing	Arkian *et al.*[45], Bermejo *et al.*[50], Arianyan *et al.*[139], Chaabouni and Khemakhem[150], Chang *et al.*[134], Jin *et al.*[66], Kang *et al.*[135], Kapsalis *et al.*[136], Karatza[141, 142] and Marchetto *et al.*[137]	Chung *et al.*[115], Manvi and Shyam[132], and Xu and Li[133]	Choi and Lim[151], Haratian *et al.*[103], Haseeb *et al.*[34], Hassan *et al.*[152], He *et al.*[143], Yunhui *et al.*[144], and Okafor *et al.*[153]	Arianyan *et al.*[91]	
	31.30%	19.85%	19.85%	12.98%	16.03%

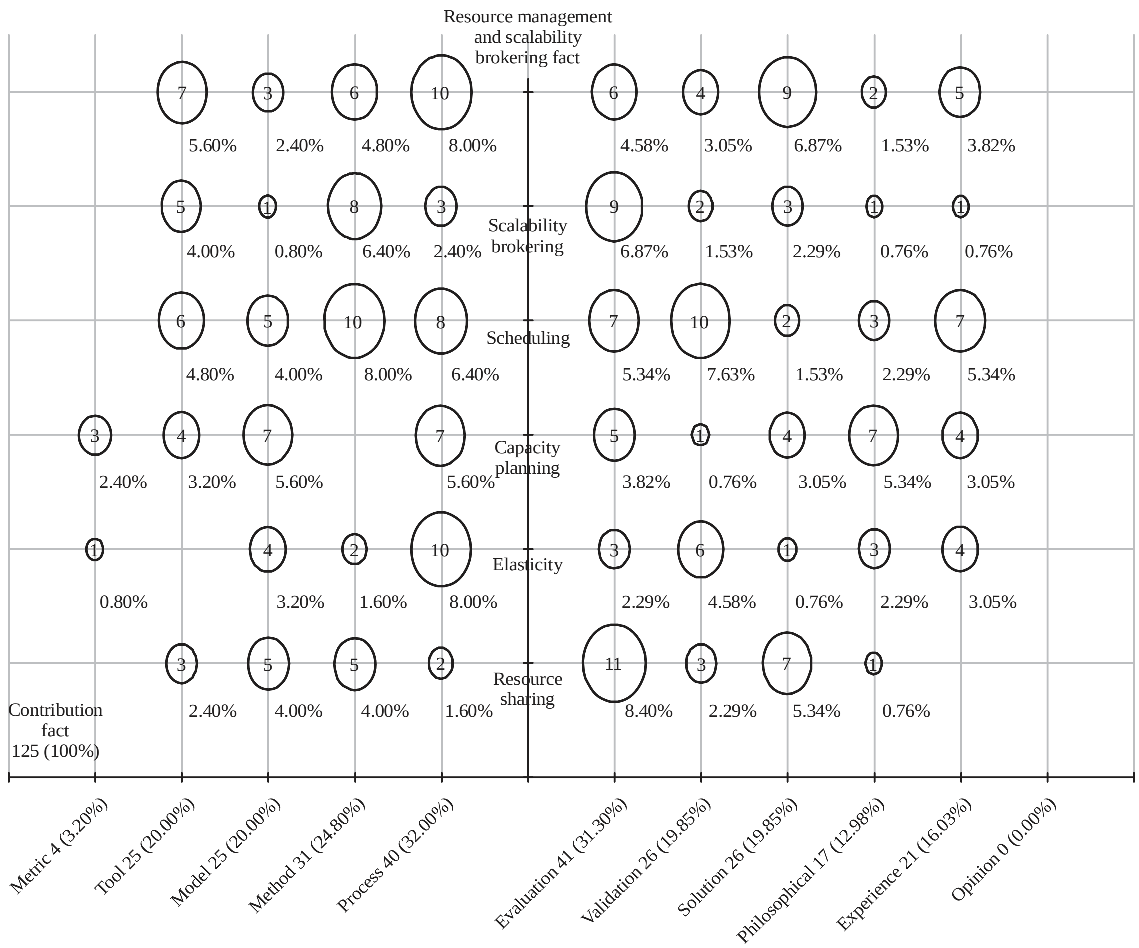

Fig. 3: Systematic map of cloud resources management and scalability

Systematic map of cloud resource management and scalability: The circles in Fig. 3 were referred to as bubbles in a systematic map. The bubble sizes and the numbers inside indicated the quantity of primary studies found under a particular category. The first quadrant of Fig. 3 identified that there were more publications on metric in the area of capacity planning with 2.4%, more publications on tools in relation to resource management with 5.6%, more publications on models in terms of capacity planning with 5.6% and more papers published on methods in terms of scheduling with 8%. There were more articles on process in relation to resource management and elasticity with 8%.

Similarly, on the second quadrant there were more articles on evaluation research in terms of resource sharing (8.4%), more papers published on validation in terms of elasticity (4.58%), more publications on solution in the area of resources management (6.87%), more articles on philosophical papers in relation to capacity planning (5.34%) and more papers on experience research in terms of scheduling.

On the other hand, there were no publications identified on tool in terms of resource management, capacity planning, scheduling and resource sharing. There were no articles on tool in terms of elasticity and no articles on method in relation to capacity planning. Furthermore, there were no articles identified on experience research in terms of elasticity and no opinion research on all aspects of the focus of study.

The study further revealed that the lowest publications in the area of evaluation research were on elasticity (2.29%) and the lowest papers identified in validation were on capacity planning (0.76%). The lowest article published on philosophical research were in the area of scalability brokering and resources sharing.

The systematic map has a visual appeal which helps to summarize and present results to interested persons. The results of a systematic map would also generate interest because combining categories makes the result more useful. Suffice to state that conducting a systematic mapping study without a follow up systematic literature review is quite valuable on its own. This is because the visual appeal of the systematic map makes gap identification quite easy, hence pointing to areas for further studies. The relevance of this is that researchers at all levels and industries practitioners can use this as a starting point to conduct further studies. This study provided six classes of focus in the areas of resource management, scalability-brokering, scheduling, capacity planning, elasticity and resource sharing in relation to the focus of study. In addition, the six classes of study can be discussed either in terms of tool, model, method, metric and process or in terms of evaluation, validation, solution, philosophical and opinion research. The gaps identified in these areas amongst others are therefore recommended for future research. The list of primary studies will also assist intending researchers. The important lessons learnt in this study is that research work is a continuum and it is inexhaustible.

CONCLUSION

The recent proliferation of cloud computing and its wide spread acceptability, has resulted in numerous researchers proposing ways of improving various aspects of the cloud. The sheer number of cloud related articles published in recent times is enormous yet many more are being reviewed and considered for publication. With the large number of articles it is easy to get lost in the large maze of cloud relating articles and makes it difficult for new researchers in the field to identify prospective focus areas. This study sought to address this challenge. A systematic mapping of cloud resource management and scalability was presented in this study. The paper considered various research types and contributory facets relating to the title. The paper was able to identify gaps in the areas of capacity planning and elasticity as well as of metrics for resource scaling in the cloud. Furthermore, there were no articles identified on experience research in terms of elasticity and no opinion research on all aspects of the focus of study. This study has therefore contributed to knowledge by indicating gaps in areas of studies. It is expected that it will serve as a broad guide into topics that can be researched on in the area of cloud resources management and scalability.

SIGNIFICANCE STATEMENT

This study created a systematic map of cloud resources management and scalability in terms of brokering, scheduling, capacity planning and elasticity that can be beneficial for cloud community. This study will help the researchers to uncover the critical gaps of cloud resources management that many researchers were not able to explore. Thus, expanding the frontiers of knowledge in cloud computing.

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