Virtualization, Containerization, Composition, and Orchestration of Cloud Computing Services

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Abstract. Cloud Computing is a dynamic concept which applies virtualization cum allied techniques to facilitate the provision of services to users. To support provision of resources to users by the service and deployment models, core technologies such as virtualization, containerization and orchestration are used on the cloud. However, the task of having to determine a research focus is challenging and rigorous. A systematic map enables a synthesis of a scheme for categorizing data in a domain that interests researchers. This work conducts a systematic mapping study of virtualization, containerization and orchestration of cloud computing services. The results indicated that articles on virtualization in the area of valuation research and experience papers were 8.56% and 3.28% respectively. In addition, many articles discussed deployment based on validation and solution research with 4.92% and 13.93% respectively. There were more papers published that discussed orchestration in terms of philosophical papers with 2.45%. The lowest publications on models were on the topic of orchestration which was 1.9%. Also, the lowest number of papers on evaluation research was on deployment which was 3.28%. Furthermore, the lowest numbers of articles on validation research were on composition enabler which was 0.82%, while that of solution proposal were on orchestration with 0.82%. The result of this research reveals the gaps that will be beneficial to the trio of researchers, industries, and providers.

Keywords: Cloud computing · Virtualization · Containerization · Composition · Orchestration · Systematic mapping

1 Introduction

Cloud is a parallel and distributed computing system consisting of a collection of interconnected and virtualized computer with a dynamic provisioning and it makes its resources available with reference to standard agreements between all the cloud stakeholders [1]. Virtualization is the core technology being adopted on the cloud. It allows the provision of virtual resources to clients in form of operating system, servers, file, and storage. The importance of virtualization is underscored as it is often considered

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the key to the success of cloud computing [2]. However, based on virtualization and multi-tenancy on the cloud, security challenges do exist [3, 4]. Containerization takes virtualization to the next level in terms of architecture and efficiency. The concept of host and guest operating system (OS) is eliminated, including the virtual machines (VM) concept, and making the use of a container to achieve the same task but now on a single host OS.

The cloud automation tools that enhance the activities on the cloud orchestration involves workloads, servers and VM, through a complicated process. The core architecture and applications of the cloud environment have made Cloud computing very effective and regularly enhancing the services [5, 6]. The main cloud consulting services are Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). Cloud SaaS is a solution provided to users that enables them access applications and database on the internet using web browser based on CSP provision. Cloud PaaS provides freedom from the need for underlying infrastructure and allows a user to focus on application design and deployment using the CSP infrastructure. IaaS in the cloud makes storage, network, and compute recourses available to the user based on payment subscription. The cloud user has limited control of the CSPs infrastructure but there is no need spending at all in infrastructure.

The cloud deployment models are private, public, community, and hybrid clouds. Private clouds are hosted and utilized by one organization only and it is adjudged to be of a better security. Public clouds offerings are available through the CSP that do possess large data centers with sophisticated infrastructure spanning different geographical locations. Services are on demand, elastic, and scalable and the resources appear to be infinite. Community cloud are hosted by organizations and institutions involved in similar activities like universities and hospitals. Hybrid cloud combines private and public clouds. The basis is to outsource processes that are not critical to the public cloud while retaining critical processes on private clouds. Although the CSPs are striving to provide very efficient and reliable services despite the trust concerns [7].

A container is a collection of many applications running on one host [8]. Containers are lightweight-virtualization solution with benefits related to size and flexibility, and relevant to PaaS cloud in terms of application packaging and orchestration [9]. The prominent concepts that ensure containerization are: (i) A lightweight portable runtime environment; (ii) The ability for development, testing, and deployment of applications to many servers; (iii) The ability to do an interconnection of containers [10]. An example of the container technology is Docker, which implemented the concept of micro-service model for application development and publishing.

Virtualization is a “sandbox” environment where the computer hardware is abstracted to an operating system called virtual machines; the operating system, the application, and the configurations of a physical server make up the virtual machines [11]. Virtualization aims to enhance how flexible the deployed cloud is and how well it is integrated to new network services in the networks of the operators [12]. While virtualization helps cloud stakeholders to achieve an optimization of their application performance in a pocket friendly way, it can also carry some security risks [13]. Presently, several tools can manage and instantiate containers in the cloud and they include Docker Swarm, Kubernetes, Magnum, Google Container Engine, and Open Stack Neutron [14]. There are two basic approaches to virtualization which are the

para-virtualization which requires having the guest operating system (OS) modified, and the full virtualization which is a guarantee for unchanged guest OS [15]. Despite many works published on cloud virtualization, containerization and orchestration, significant shortfalls in understanding of cloud orchestration techniques remain [16].

Generally, embarking on a qualitative research requires identifying specialized areas of interest, which involves searching several conference proceedings, journals, books, digital libraries, and also involves making observations in research environments, attending workshops, seminars and conferences, with the goal of identifying a research topic [17]. During the process of literature review, researchers do discover new research concepts. This allows for collaboration and cross-fertilization of ideas that do motivate the choice of research topic; which is a rigorous task.

This work conducts a systematic mapping study (SMS) of virtualization, containerization, and orchestration in the cloud. SMS provides an avenue for revealing research areas and topics that are not sufficiently covered. An SMS is utilized to categorize such reports based on a unique scheme and structure, and the summaries are presented visually as a map [18]. There is a classification process for sorting relevant articles into a scheme. There is a data extraction process for determining the various categories to be applied and it is usually presented on a spreadsheet. Subsequently, the frequency of publications is used to create a systematic map. The bubbles plots have sizes corresponding to the number of papers in such categories. The analysis of publications in this study was carried out based on three concepts: the topic, contribution, and research concepts. The topic concept is used to extract key aspects of the discussion on virtualization, containerization, and orchestrations. The research facet establishes the type of research conducted in the publications. The contribution facet considers issues like the method or tools applied in the study. Based on reviewed literature, no previous research has explored SMS of cloud virtualization, containerization and orchestration. This paper has created a systematic map pointing to areas lacking in studies in terms of systematic mapping study of virtualization, containerization, and orchestration in the cloud. Therefore, it is obvious that subsequent researches in the industry and the academia can leverage on this work to advance research work in diverse domains.

In this paper, Sect. 2 focuses related work. Section 3 discusses the systematic mapping process, Sect. 4 presents the results and discussion; while Sect. 5 concludes the paper, and suggests future direction of research.

2 Related Work

The work of [19] elaborated on the planning stage of an SMS. Furthermore, it identifies the software patterns as evident during the requirement engineering level of projects, it provides a thorough understanding of the relevance of those patterns in relation to the basic parameters of the development process. The work provided a protocol with required steps to replicate the work by interested researchers, thereby confirming its validity. The academic digital repositories explored in this research are ACM DL, IEEExplore, SCOPUS, and Web of Science. The standards in [18] were employed for this work.

The work of [20] described the protocol for a systematic mapping study (SMS) in relation to domain-specific languages (DSL) which is a point of concentration of the work; this is based on current trends and the direction for future research. The work spans through July 2013 to October 2014, with basic guidelines to perform systematic review, which are: planning, the conduct of the review, and reporting such.

The SMS in [21] analyzed the use of concept maps in Computer Science. It delivers an SMS result that centers on the collection and evaluation of existing research on concept maps in the computing field. Five digital libraries were utilized with backward snowballing and manual approaches employed for the search. The work displayed extensive focus and a thorough investigation of concept maps, based on supports that have to do with how to learn and teach. SCOPUS, ScienceDirect, Compedex, ACM DL, and IEEExplore digital libraries were the resources employed in this work based on the search strings.

In [22], an SMS was employed in the examination of how games related techniques were used in software engineering education, with research trends, shortcomings, and identification of the future direction. The laid down rules in [18] were adhered to for its mapping process based on primary studies that spans 1974 through 2016 that yielded 156 primary studies for the work.

The work in [23] did a mapping of power system model by providing an overview of power system models, which entails the analysis of their modelling features and identification of modelling gaps. A total of 228 surveys were administered to power experts to elicitate information, but only 82 were filled and returned which was utilized for the mapping.

In [24], an SMS of domain-specific languages was carried out with emphasis on the contribution, the type of research, and the context. The search based on reputable search engines spans 2006 to 2012. The SMS concentrated on the process defining research questions, the search conduct, how papers were screened, classified, and then how data was extracted. Opinion papers, experience papers, philosophical or conceptual papers, solution proposal, and validation research materials were consulted.

[25] did an SMS of the literature on ontologies in the legal context. The work based its search on “legal theory” and “legal concepts”. Also, the selected studies were categorized based on contributions in terms of language, tool, method, and model; with ontological research was involved.

[26] were of the opinion that the evaluation and the SMS conduct should be noted for updates. The authors conducted an SMS of systematic maps, and discovered that in the large number of the studies conducted, a collection of guidelines were consulted and integrated which lead to different ways in conducting SMS.

The work of [27] is an SMS that gives an overview of empirical research in software cloud-based testing in the process of building a classification scheme. There was an investigation of testing methods; its applications, and peculiarities. The work was primarily based on 69 studies coined out of 75 publications. This yielded a resourceful statistical analysis and eventual quantitative results. From literature examined, no work has focused on SMS of Cloud business and legal implications.

The protocol for systematic mapping study (SMS) of human computer interaction evaluation for ubiquitous applications was explored in [21], with interest in relevant quality characteristics, and methodologies or models to be employed in the evaluation under study. The systematic mapping process was adapted from [26]. The resource databases are Scopus, IEEExplore, ACM Library, Springer, ScienceDirect, and Compedex. From literature, no work has focused on systematic mapping study of cloud virtualization, containerization and orchestration.

3 The Systematic Mapping Process

3.1 Review Stage

An SMS covers a visual presentation of results based on literature review in a related field. This study was based on the guidelines established in [18, 28]. An SMS is a process that can be replicated, it is employed to extract and interprete ready materials relation to a research objective [29]. Firstly, the research questions are defined, where the research scope is enunciated; then a primary studies search to obtain all available papers in the field is done. Having obtained all papers, the next step is to screen all the paper to determine those relevant for inclusion in the study. Thereafter, the keyword process is applied to the abstracts in an attempt to developing a classification scheme. Finally, the process to extract data from the included papers which leads to a systematic map. The design of a systematic map for visualization, containerization, composition and orchestration entails all the steps discussed so far. In context of our selected paper criteria depicted by the prerequisites of the examination's destination and research questions, we have considered 122 papers to be relevant for inclusion out of an initial list of 1,678 papers from 2010 to 2018.

3.2 Definition of Research Questions

The purpose of an SMS is to find out the research type and the volume of research carried out in a research domain. It is necessary to know the publication outlet of the papers. These are the concepts that influence the choice of research questions for the study. The research questions for this study are:

RQ1: What areas of virtualization, containerization, composition and orchestration in relation to the cloud are addressed and how many articles concern the different areas?
RQ2: What types of papers are published in the area and in particular what evaluation and novelty do they constitute?

3.3 Conduct of Research for Primary Studies

This is fundamentally the starting point for any review. It is carried out by an exploration of major digital libraries. However, it is possible to do it manually for journals and conference papers. To get papers for this research, the necessary search was

conducted on major academic digital repositories that are accessible online. It was not done on information from books and other printed materials.

This process was actually carried out on a couple of major electronic databases because of the high impact factor of the publications in these digital libraries. The selected repositories used for the search is shown in Table 1.

Table 1. Electronic databases used for systematic mapping study

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/

The search string used for this study was designed in terms of population, intervention, outcome and comparison. The search keywords used represent all aspects of the title for this study. The employed search string on the academic digital repositories selected is as follows:

(TITLE (Virtualization) OR TITLE (Containerization) OR TITLE (composition) OR TITLE (Orchestration) OR TITLE (enablers)) AND (TITLE (Cloud) OR KEY (cloud)) AND (LIMIT- TO (SUBJ AREA, "COMP")).

The searches were carried out based on the process and strings above on the digital academic repository to be sure that prominent studies were not excluded. In this work, search for primary studies in terms of cloud and computer science were considered in the established repositories adopted.

3.4 Screening of Papers for Inclusion and Exclusion

The reason to have some criteria to select is to find and include all papers that are relevant to the study. The standard criteria were employed to eliminate publications that are not significant to the study. The criteria were also used to discard papers that do not relate to the research questions. There are abstracts that had the focus of study, but without sufficient details, hence they were excluded. In addition, the study excluded papers on panel discussions, presentation slides, prefaces, editorials, tutorials and summaries because they do not contain abstracts. However, papers were included if it discussed the main focus with adequate details of secondary issues. The main focus of this study is cloud enablers in terms of visualization, containerization, composition and orchestration. Therefore, Table 2 shows the process that ensured the papers were effectively screened base on relevance.

3.5 Key Wording of Abstracts

Key wording of abstract is a core aspect of the systematic mapping process (SMP). It influences the design of the classification scheme. It is usually produced as part of the SMP as shown in Fig. 1 based on the established standard in [18].

Table 2. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• The paper fully discusses enablers in cloud computing • The paper discusses the enablers in terms of containerization, virtualization, composition and orchestration	• The paper is off context of cloud computing • The abstract does not discuss cloud computing enablers

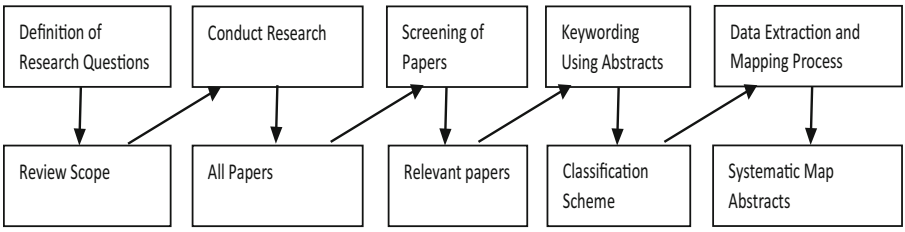

Fig. 1. The systematic mapping process [18]

- Abstract
- Key wording
- Classification scheme
  - Articles
  - Sorting articles into scheme
  - Updating scheme
- Systematic map

Key wording is necessary in reduce the period that is required to produce a classification scheme. Furthermore, keywords does a confirmation of the coverage of classification scheme of prominent publications. This usually involves knowing the context of the study. For this study, keywords from the included publications on virtualization, containerization, composition and orchestration were collected to provide sufficient understanding in terms of the types and contributions of all the articles. Subsequently, the process was applied to the set of categories for the scheme. However, it was sometimes necessary to study what introduced and concluded an article to ensure reliable key wording for the study. Finally, a group of keywords was used to establish the categories used to the map of this study.

In this study on virtualization, containerization, composition and orchestration, three facets were used in producing the results. The first facet is the topic facet which is based on topics from different aspects of the focus of study. The second facet is the contribution facet in terms of metric, method, model, tool and process as discussed in [18]. Although, this is independent of the focus of this study, it was considered very appropriate for the study. The third facet deals with the types of research conducted in tandem with the focus of the study.

3.6 Research Type Facets with Categories and Descriptions

This study adopted the classification approaches in [30], based on the explanations below:

- **Validation research:** The procedure used is unique but not yet implemented, as it is still at the experimental stage.
- **Evaluation research:** The procedure has been implemented and the resultant outcomes are outlined based on pros and con.
- **Solution Proposal:** These include papers that present unique solutions to specified problems, while highlighting the advantages and applications of such solutions.
- **Philosophical papers:** These include papers that offer alternate perspective to examining problems with respect to concepts and frameworks.
- **Opinion Paper:** These include papers that rely on the researcher's opinion rather than any known research methodology.
- **Experience Paper:** These include papers that rely on the experience of the researcher and emphasizes on the 'what' rather than the 'why'.

This classification of research approaches were considered adequate and appropriate for use in the classification scheme of this study. All the included papers were assessed based on the categories and description in the classification of research approaches. The outcome of this process is the research category results used in this study.

3.7 Data Extraction and Mapping Studies

During the classification phase, the relevant articles were sorted in a scheme. The next phase was used to extract data from the included papers. The data extraction process follows after the classifications scheme; which entails categories addition, merging, and removal of irrelevant ones. After the classification process, the procedure to extract data for this study was carried out by calculating the frequencies of each category of publications. The essence is to see which aspect of the selected topics on virtualization, containerization, composition and orchestration were emphasized more in the study. This provides insight into the gaps and enables recommendation for the cloud computing researchers.

Based on the results, a bubble plot was used to present the frequencies of publications thereby creating a systematic map. The systematic map involves a two dimensional x-y scatter plot with bubbles at the meeting point of the categories. The coordinates have bubble sizes that represents the number of articles in such categories at the various meeting points. There are two quadrants in the maps because of the three categories being used in this study. Each quadrant provides visual maps based on the facets of study at the nodes of the topics category with either the contribution or research category. Hence, a simultaneous consideration of diverse facets gets easier. Furthermore, summary statistics got included to the bubble to fine-tune understanding. Overall, the systematic map offers a quick insight into research on virtualization, containerization, composition and orchestration of web services in cloud computing.

4 Results and Discussion

The primary focus of this study on virtualization, containerization, composition, and orchestration is thematic analysis and classification. Although, it may sometimes be necessary to identify the location (venue) of publication. As a result of the analysis, gaps were identified by graphing using the bubble plot, thus showing which research types and topic areas are well covered in terms of publication. It also shows topic areas where there is shortage in research. In this work, high level categories were utilized in the assessment of the references utilized in creating the frequencies of articles and the subsequent systematic map produced. The systematic map on virtualization, containerization, composition and orchestration on the cloud is at Fig. 2.

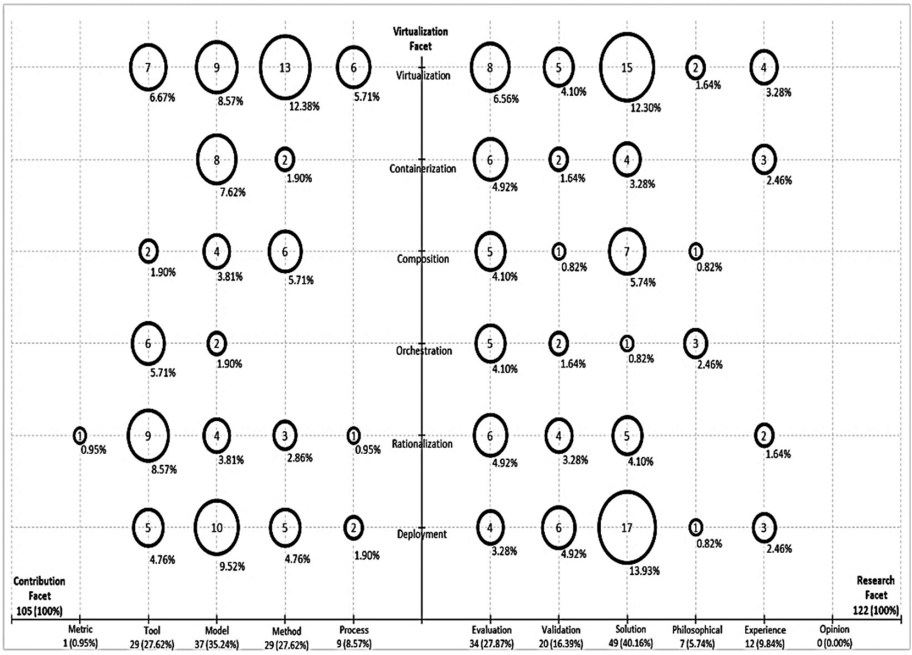

Fig. 2. Bubble map of selected studies

4.1 Topic and Contribution Facet

The topic category is central to this study. The topics that were extracted on virtualization, centralization, composition and orchestration during classification in the area of cloud computing services are:

- Virtualization
- Centralization
- Composition
- Orchestration

- Rationalization
- Deployment.

The left quadrant of Fig. 2 shows the relationship between the topic and contribution facet. The total number of articles included during the data extraction process for the contribution category is 105. The results show that publications that discussed model in respect of virtualization, containerization, composition, orchestration, rationalization and deployment is 35.24% out of 105 papers in this category. Similarly, metric contributed 1%, tool and method had 28% each, and process had 9%. The results are summarized in Table 3.

Table 3. Topics and contribution facet primary studies

Topic	Contribution facet				
	Metric	Tool	Model	Method	Process
Virtualization		PS24, PS43, PS44, PS63, PS67, PS91, PS95	PS5, PS8, PS14, PS17, PS48, PS115, PS117, PS118, PS122	PS4, PS20, PS55, PS56, PS64, PS65, PS75, PS85, PS100, PSPS105, PS107, PS108, PS114	PS53, PS74, PS86, PS97, PS116, PS117
Containerization			PS2, PS12, PS49, PS77, PS78, PS90, PS98, PS106	PS3, PS112	
Composition		PS1, PS40			
	PS6, PS9, PS15, PS35	PS10, PS11, PS35, PS40, PS16, PS76			
Orchestration		PS7, PS26, PS27, PS30, PS62, PS79	PS28, PS83		
Rationalization	PS18	PS18, PS36, PS39, PS42, PS47, PS82, PS87, PS109, PS119	PS93, PS99, PS101, PS110	PS33, PS42, PS58, PS59	PS70
Deployment		PS21, PS23, PS25, PS104, PS120	PS29, PS31, PS38, PS51, PS54, PS88, PS96, PS102, PS103, PS111	PS41, PS60, PS68, PS84, PS121	
Percentage	**0.95%**	**27.62%**	**35.24%**	**27.62%**	**8.57%**

4.2 Topic and Research Facet

The right quadrant of Fig. 2 indicates the relationship between the topic facet and the research type. The total number of papers included during the data extraction process for the research category is 122. The results indicate that solution proposal discussions in relation to the topics of the study was 40% out of the 122 papers in this category. Approximately, evaluation research had 28%, validation had 16%, philosophical had 6%, and experience had 10%. The results are summarized in Table 4.

4.3 Systematic Map of Virtualization, Centralization, Composition and Orchestration

The result of the analysis carried out and presented on Fig. 2, makes it easy to identify which areas had more emphasis based on the frequencies of publications. The results presented the category of the study that has been emphasized more or otherwise. Also, the number in each bubble plot in Fig. 2 indicates the number of publications in the study on virtualization, centralization, composition, orchestration, rationalization and deployment that discussed the contribution and research facets.

Starting with the left quadrant, it is obvious that there are more publications in terms of rationalization in the area of tool with 8.57%. There are more paper published in the area of virtualization, in terms of model, method and process with 8.57%, 12.38%, and 5.71% respectively. There is only one publication in terms of metric on the topic of rationalization which is 0.95%.

Similarly, the right quadrant indicates that there are more publications that discussed virtualization in the area of evaluation research and experience papers with 8.56% and 3.28% respectively. In addition, there are more articles that discussed deployment in the area of validation and solution research with 4.92% and 13.93% respectively. There are more papers published that discussed orchestration in terms of philosophical papers with 2.45%.

On the other hand, the lowest publication on the model discussion is on the topic of orchestration which is 1.9%. Similarly, the lowest number of papers on evaluation research is on deployment which is 3.28%. The lowest numbers of articles on the validation research discussion is on the composition enabler which is 0.82%. The lowest paper published in terms of solution proposal is on orchestration with 0.82%.

There are no publications in the study on virtualization, centralization, composition that discussed metric. There are no articles that discussed tool in the area of containerization. There are no papers published that discussed method as it relates to orchestration. Finally, there are no publications on containerization, composition and orchestration that focused on process.

From the map, the discussion on virtualization and development has the highest number of publications generally. This is of relevance because researchers of all sorts can leverage on this for the advancement of their work. Six categories of studies were provided namely: Virtualization, centralization, composition, orchestration, rationalization, deployment in relation to the focus of study; they can be discussed in terms of tools, models, methods, metrics and processes, evaluation, validation, solution, philosophical and opinion research.

Table 4. Topics and research facet primary studies

Topic	Research facet					
	Evaluation	Validation	Solution	Philosophical	Experience	Opinion
Virtualization	PS5, PS8, PS48, PS53, PS56, PS63, PS64, PS65	PS14, PS17, PS20, PS75, PS85	PS24, PS43, PS44, PS67, PS91, PS95, PS97, PS100, PS107, PS108, PS114, PS115, PS117, PS118, PS122	PS74, PS116	PS4, PS55, PS86, PS105	
Containerization	PS3, PS19, PS22, PS57, PS61, PS73	PS49, PS90	PS2, PS98, PS106, PS112		PS12, PS77, PS78	
Composition	PS10, PS11, PS46, PS69, PS81	PS66	PS1, PS6, PS9, PS15, PS16, PS35, PS40	PS76		
Orchestration	PS27, PS30, PS79, PS83, PS113	PS7, PS26	PS13	PS28, PS45, PS62		
Rationalization	PS39, PS47, PS82, PS87, PS109, PS119	PS18, PS36, PS93, PS110	PS58, PS59, PS70, PS99, PS101		PS33, PS42	
Deployment	PS29, PS31, PS38, PS41,	PS32, PS37, PS52, PS71, PS89, PS92	PS21, PS23, PS25, PS34, PS51, PS54, PS60, PS68, PS84, PS88, PS94, PS96, PS102, PS103, PS111, PS104, PS120	PS72	PS50, PS80, PS121	
Percentage	**27.87%**	**16.39%**	**40.16%**	**5.74%**	**9.84%**	**0%**

5 Conclusion

Recently cloud computing has continued to evolve both in terms of usage and technology. More individuals and organizations are embracing the use of the cloud. The future success of cloud computing must be the perfect combination of cloud technology and end computing enabled by virtualization, containerization, orchestration, and composition.

This paper has created a systematic map of virtualization, containerization, orchestration, and composition on the cloud. the topics of virtualization, centralization, composition, orchestration, rationalization, and deployment were extracted from the included papers based on the focus of this study. The visual appeal of the systematic map makes it quite useful. It is easy to view the categories simultaneously. The map easily generates interest because different aspects can be seen at the same time. In addition, the systematic map helps to summarize results and transfer to those who need it. It is important to state that conducting a systematic mapping study without a follow-up systematic literature review is very unique; also, gaps are easily identified in the topic area and make available areas for further studies.

The results from this study is based on the gaps identified in terms of tools, models, methods, metrics, and processes, in relation to virtualization, containerization, orchestration, and composition on the cloud. In addition, the paper identified gaps in the area evaluation, validation, solution, philosophical and opinion research on virtualization, containerization, orchestration, and composition on the cloud. To the best of our knowledge, studies are lacking in the area of virtualization, centralization, composition on the cloud as it relates to metrics. Also there are no articles that either discussed tool as it relates to containerization or method as it relates to orchestration. Finally, there are no publications on containerization, composition and orchestration that focused on process.

This systematic mapping study has been able to identify some areas where there is minimal focus in terms of virtualization, containerization, orchestration, and composition by virtue of the categories employed for the analysis. The gaps that have been identified are recommended for further studies, as it is expected that it will serve as a broad guide into topics that can be researched on in the area of virtualization, containerization, orchestration, and composition on the cloud. The list of references will be of assistance to interested researchers. Further research could also be carried out to validate this study or resolve contradictory issues.

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