

## Cloud management and monitoring: a systematic mapping study

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### ABSTRACT

A key component of ensuring that services are available on the cloud at the right time in the right manner is adequate cloud management. This makes it possible to provide services that meets user demands. The purpose of this research is to carry out a systematic study of management and monitoring on the cloud. Three facets were applied in conducting the categorization. These are the contribution, research, and topic facets. The purpose was to determine the level of work so far carried out in the field of cloud management. This enabled the creation of a pictorial representation of the research coverage. The result of the study showed that there are no opinion research on cloud management. Generally, articles on experience research, philosophical research and metric are the lowest at 6.62%, 4.41% and 1.90% respectively, while articles on models, solution research and evaluation research are the highest with 52.38%, 46.32% and 31.62% respectively. The outcome of this study will stimulate further research in the area cloud management and systematic studies.

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## 1. INTRODUCTION

A unique aspect of the cloud is that the user can participate in the management of cloud activities albeit in a very limited manner. In view of the massive infrastructure on the cloud, cloud computing lends itself to various forms of management. Autonomic form allows activities to run with little or no human interaction. Adaptive nature of the cloud allows flexibility in user operation. Service level agreements (SLA) monitoring deals with ascertaining that tested metrics meet the required standards [1]. Autonomic communication services has the capacity to start and end a requested process based on the network services and operating environment [2].

Cloud computing fully lends itself to self-service on the part of the user and there are cloud-monitoring tools for this purpose. They ensure a mutually beneficial operation; there are SLA's that determine the nature of contract between the CSP and the consumer. For a SaaS provider to guarantee smooth operations, there are several critical quality of service (QoS) parameters that must be considered in a service requiring provisioning such as response time [3]. There are other metrics that must be considered such as availability and uptime, list of services and resources being offered by the CSP to the user [4].

On the cloud, monitoring has various levels which help to determine the status of the physical infrastructure [5]. The issues of management on the cloud and its attend realization of satisfactory SLA is of prime importance in cloud computing [6, 7]. Cloud monitoring and management is vital to offering data as it

relates to performance and availability of service on the cloud relevant to provisioning in real time in ensuring that service demands are met [8]. It also supports the provisioning of virtualized resources and ensuring the configuration process is automated. Autonomic computing is another aspect of cloud management that provides efficient service level agreement (SLA) centred on a systems ability to automatically handle resources and meeting requirements [9]. There are autonomic managers, analyzers, and reconfiguration managers that supports SLA, analyze monitoring data and generates reconfiguration actions [9]. In the traditional method, allocation of resources are not scalable because the management is centralised making them unsuitable the cloud environment [10]. It therefore becomes pertinent to develop systems that are not centralized and capable of meeting the demands of cloud systems and applications. There is the possibility of showing that resources are scalable in terms of the number cloud servers and the amount of applications to be placed on such cloud servers, making it possible to optimize the numbers of servers to be deployed on a particular domain [10]. From the foregoing, it is obvious that cloud management and monitoring is an area of cloud computing that is worth studying. The essence of conducting this research is that there is still a need for more papers in the area of cloud management and monitoring. Hence, the research is conducted to identify areas where papers are lacking and make them available to prospective researches. A lot of papers have already been written, however it is important to provide an overview and summary of such work. A systematic study helps in summarizing what has been done in a field of study and also putting it in a pictorial form. The aim of the research is therefore to carry out a study on monitoring and management on the cloud. This paper contributes to knowledge by producing percentages and a visual map indicating the extent of work that has been done using indices such as research and contribution in cloud management and monitoring. The rest of the paper is as follows: In Section 2, the related work is discussed. In Section 3, the materials and method is presented. The result and discussion is presented in Section 4, while the paper is concluded in Section 5.

## 2. RELATED WORK

The papers in [11, 12] focuses primarily on guidelines for conducting a systematic literature review. Several studies in the areas of systematic mapping studies were examined and lessons were drawn from such studies. Such lessons offered insight to guide studies in the practice of designing systematic maps.

The work in [13] focuses on the requirement engineering process. The work dealt with identifying software patterns during a software development activity. The paper examined parameters related to these patterns and how they can be subsequently replicated in further research in this area of study.

The paper in [14] conducted a Cloud based IoT-enabled solid waste monitoring system for smart and connected communities. In this paper, an intelligent solid waste monitoring system is developed using internet of things (IoT) and cloud computing technologies. Waste containers are strategically situated within the communities and the fill level of solid waste in each of the containers is detected using ultrasonic sensors. The sensor data is transmitted to an IoT cloud platform, ThingSpeak, via a wireless fidelity (Wi-Fi) communication link.

The work carried out in [15] focused on maps relating to concepts in Computer Science. The contribution was the examinations of papers dealing with Computer Science concept maps. A review on the subject was also depicted in terms of teaching and learning supports. To enhance the search backward snowballing was employed, and major digital databases were used on the search string.

The paper in [16] examined the concept of composition, virtualization, orchestration and virtualization using a systematic mapping study. Six features were considered in the classification process which are development, virtualization, composition, rationalization and centralization. The paper centered on producing the map using the contribution and research facets which examined method and tool, and validation and solution research respectively.

The primary focus of the paper in [17] has to do with designs on the cloud and development models. A review was done with unique features to examine extent of study in this field. The six features employed were service development, designs, implementation, privacy, configuration and security. The protocol was applied on the standard research and contribution categories. In the research category, experience, validation, opinion and solution research were discussed, while tool, method and model was examined in the contribution category.

The paper in [18] dealt with cloud-based testing. A review was done with the empirical aspect of this software process. The classification process focused on non-functional and functional testing methods. The methods were subjected to statistical analysis with results contributing to knowledge in this field. Sixty nine (69) primary studies was used in the examination process of the proposed solution, extracted from major digital databases.

In [19], a review of testing based on cloud mobile application was carried out. The systematic mapping study provides result relating to testing of mobile cloud-based applications. The classification scheme used

features such as compatibility testing, securing testing, GUI testing and functional testing. These features were used in the contribution categories to examine metric, framework, tool, model and method. In addition, Testing-as-a-Service was done on topics in the contribution facet. The research facet focused on validation, evaluation and solution research types.

The paper in [20] did a review in the software engineering domain. It dealt with the lessons that accrue from software engineering systematic literature review process. Several works were examined in this domain and the lessons that were learnt from the experience were systematically summarized in a map. Such lessons would have useful applications to the practice of software engineering.

The paper in [21] also carried out a systematic literature review in the area of software engineering. In this instance, the focus was on assessing the impact of such review using evidence-based process in contributing to knowledge. Relevant materials were drawn from both journal and conference papers.

The work in [22] is a study on the software measurement process in software engineering. A review was done based on measuring software quality model were discussed. The classification process considered intervention, population, outcome and comparison. The software quality model was examined in terms of ISO/IECSQuaRE and ISO/IEC 9126. The result indicated that the ISO SQuaRE was more suitable.

The work in [23] surveyed various monitoring tools. The paper conducted a comprehensive survey of on the objectives and capabilities of tools for monitoring on the cloud. A taxonomy on the importance of the monitoring tools was carried out including an analysis. It was concluded that cloud specific monitoring tools are platform dependent and proprietary.

The work in [24] is focused on quality of service (QoS) as it relates to SLA on the cloud. It examine how service compositions can be managed in terms of self-service resources. The work discussed the properties, designs, structure in terms of service components required for managing runtime with a bid to providing personalized services to meet SLA's. An architecture relating to service components was defined for constructing discovery of services, adapting to SLAs and creating QoS components to ensure that service components are available for different functionalities. Clearly, there were no papers in the area of cloud management based on systematic studies.

### 3. MATERIALS AND METHOD

#### 3.1. The systematic mapping process

The systematic mapping study on cloud management and monitoring as shown in Figure 1, utilized the steps provided in which served as guidelines [11, 12]. A systematic mapping study is repetitive in nature meant to examine the extracted publications based on the objectives of study [25]. All the steps for carrying out a systematic were utilized in creating a systematic map on cloud management and monitoring.

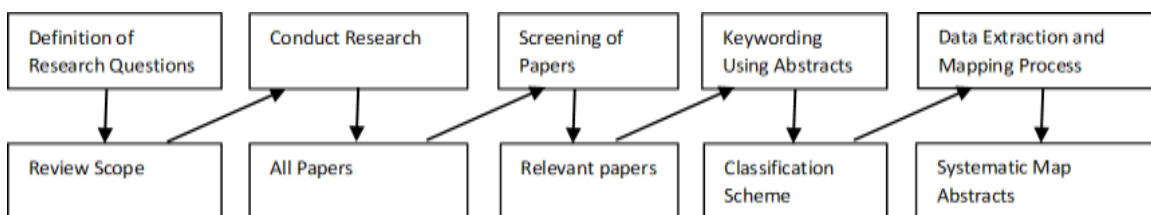


Figure 1. The process of systematic mapping [11]

#### 3.2. Definition of research questions

The research questions are as follows:

RQN1: What aspects of cloud management and monitoring are considered and the number of papers discussed in different areas ?

RQN2: Which form of articles constitute publications in this field and in particular what evaluation and novelty do they constitute?

RQN3: What methods of research were used in the studies and what was the level of contributions?

#### 3.3. Conduct of search for primary studies

Five (5) digital electronic libraries as shown in Table 1, were used because they have journals and conference papers with high impact factor. The major libraries are ACM, IEEEExplore, Science Direct, Springer and Scopus. The keyword used is based on the various aspects of cloud management associated with the title

of this work. The starting point of the studies is examining relevant digital databases for the appropriate papers. In addition, the backward snowballing process is adopted to refine the search [26]. In this particular study on cloud management and monitoring, the string adopted for search on the digital databases is as follows: (TITLE (“CLOUD management”) OR TITLE (service level agreement “) OR TITLE (“SLA’’) AND (TITLE (adaptive) or TITLE (monitoring) OR TITLE (autonomic) AND (KEY (CLOUD) OR KEY (SLA)

Table 1. Digital libraries

Electronic Databases	URL
IEEE	<a href="https://ieeexplore.ieee.org/Xplore/home.jsp">https://ieeexplore.ieee.org/Xplore/home.jsp</a>
Springer	<a href="https://link.springer.com/">https://link.springer.com/</a>
Science Direct	<a href="https://www.sciencedirect.com/">https://www.sciencedirect.com/</a>
ACM	<a href="https://dl.acm.org/">https://dl.acm.org/</a>
Scopus	<a href="https://scopus.com">https://scopus.com</a>

### 3.4. Screening of papers for inclusion and exclusion

The inclusion and exclusion criteria as shown in Table 2, was employed to exempt topics not relevant to cloud management, and papers that were not in conformity with the questions of the research. Abstracts that mention only the main focus of this research without providing in-depth details were removed. This study did not include presentation slides, summaries, tutorials, editorials, panel discussions and prefaces. Articles that had this study as its primary focus with some additional secondary aspects of this paper were also considered. The Appendix contains the list of primary studies.

Table 2. Exclusion and inclusion criteria

Inclusion Criteria	Exclusion Criteria
Abstract explicitly mentions management and monitoring, as it relates to clouds. Furthermore, such abstracts that relates to SLA and autonomic.	The abstract does not relate to cloud computing. Furthermore, there are no discussions related to management and monitoring on the cloud.

### 3.5. Keywording of abstracts

Keywords from the various articles relating to cloud management was combined to ensure proper understanding of types of research and contributions. The outcome of this was used to determine the set of categories adopted in this study. In this study, three facets were adopted. The first facet focused on the topic, which was derived from the keyword and the constituent parts of the title of this work, the types of contributions were discussed in the second facet as related to this research, and the third facet involves research issues.

### 3.6. Research and contributions descriptions

This research facet used the approaches for research classification as enunciated in [27].

- Validation Research: The techniques used in the research are unique but not yet implemented. No experiments are conducted.
- Evaluation Research: The techniques outlined had been implemented and evaluated. There are results discussing the benefits or otherwise.
- Solution Proposal: The technique proposes a unique guidance to an issue. The value of such solution are also discussed.
- Philosophical Papers: The research offers new ways to solve a problem by proffering concepts and framework.
- Opinion Papers: Opinions are expressed not based on any method of research, but still provides valuable insights.
- Experience papers: An author’s personal experience is provided. Such experience details how things can be done.

These categories were considered appropriate for use in this study. This was used as part of the classification scheme; hence articles used for this study were classified using the different research categories.

The aspect of contribution considered the topics listed [19]:

- Framework: A well-structured and detailed method, with wide scope and purpose, focusing on a number of research questions or areas.
- Model: Provides an abstraction view of a topic and problems rather than a tangible and specific approach for solving specific problem.
- Tool: Provides means of evaluating a concept using specific tool.

- Evaluation: A technique used for empirically measuring the proposed solution(s).
- Metric: Provides guidelines for measuring particular phenomena.
- Method: Focuses on a more specific goal with a narrow research question or purpose.

### 3.7. Data extraction and mapping of studies

Data extraction was done using a Microsoft Excel table for the classification scheme categories. The extent of publication in the contribution and research facets were extracted on different microsoft excel tables. The overall frequency of publication was obtained from a combined chart for the topic, research and contribution aspects. The analysis was centered around frequency depictions of publication for categories within the scheme. The essence of this was to determine which aspects of management and monitoring on cloud was emphasized more in the study. This enables the determination of gaps and it provided a means to recommend more studies.

Bubble plots were created to present the frequencies of articles which is the map. The intersection of the categories had a two x-y scatter plot with bubbles used to create the map. The bubble coordinates have bubble sizes that correspond to the frequency of publication in that category. There are two quadrants due to the fact that more than one facet was used. The different quadrants provided information relating to the topics, research and contributions areas of the study. Hence, it becomes easy to visualize the two quadrants at the same time. In addition, relevant statistics were added to the bubbles providing a quick overview of the study on cloud management.

## 4. RESULTS AND DISCUSSION

### 4.1. Contribution and topic category

The main focus of analysis are the topics extracted form the keywords. During the classification process, the extracted features for this study are:

- SLA monitoring
- Security
- Autonomous management
- Self-adaptive SLA
- Architectures

Table 3 depicts the primary studies selected in relation to the contribution and topics categories, while Figure 2 indicates the topics' percentage in the research category. The map of management and monitoring on the cloud is shown in Figure 4. On the left quadrant of the x-axis of Figure 4, is the the contribution facet's results. The contribution facet dealt with the types of contribution in the papers included in this study. On Table 3, the result indicated that articles that out of 105 papers examined, only 1.9% discussed metric in relation to cloud management. Also, tool had 17.14%, model had 52.38%, method had 13.33% and process had 15.24%. Simulations. The left quadrant of Figure 4 indicates the dynamics of publications between the contribution and topics facet. For example, model contributed 52.38% of the articles considered. The breakdown in relation to the topic facet shows that 1.9% of model contributions were on simulation, 11.43% were on architectures, 8.57% were on self-adaptive SLA, and 2.86% were on autonomous management, 14.29% on security and 13.33% on SLA monitoring. Other aspects of the contribution category as it relates to topic is as shown in Figure 4.

Table 3. Topic and contribution primary studies

Contribution Facet	Metric	Tool	Model	Method	Process
Topic					
SLA Monitoring			3, 11, 14, 15, 31, 34, 37, 39, 57, 61, 73, 81, 104, 124,	2, 7, 8,	6, 10, 123
Security	103	13, 19, 38, 56, 77, 80, 109, 119, 120, 121, 17, 20, 127	4, 5, 12, 26, 36, 45, 58, 59, 70, 78, 115, 117, 118, 134, 136	22, 35, 98, 99, 133	49
Autonomous Management			27, 30, 46,		89, 92
Self-Adaptive SLA		28, 42, 101, 107, 132	18, 43, 44, 87, 88, 95, 100, 108, 129	50, 54, 97	60, 62, 83
Architecture	63		1, 9, 55, 66, 74, 106, 112, 116, 131, 122, 130, 135	114	
Simulations			110, 128,	71, 65	64, 67, 68, 72, 75, 76, 91
Percentage	1.90%	17.14%	52.38%	13.33%	15.24%

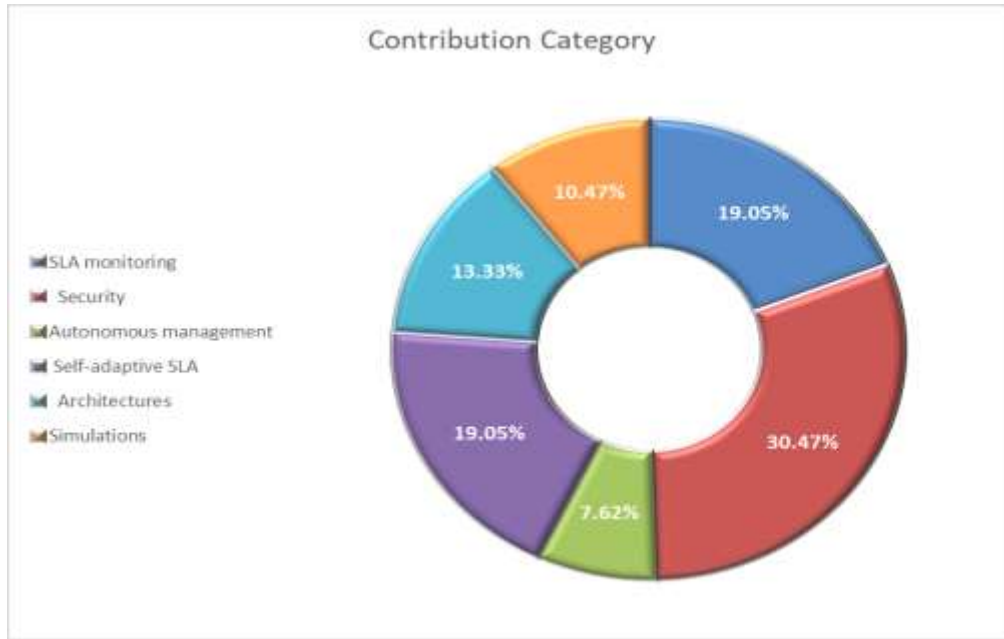


Figure 2. Percentage of topics on contribution category

**4.2. Topic and research type category**

Table 4 depicts the topics and research category in relation to primary studies selected for this paper, while Figure 3, indicates the research category’s percentage in terms of topics. On Table 4, the result shows that out of 136 papers reviewed in the research facet, evaluation research had 31.62%. In addition, solution research had 46.31%, validation research had 11.03%, experience had 6.62% and philosophical had 4.41%. There was no result for opinion research. On the x-axis of the right quadrant of Figure 4, is the result of the type of research carried out in the area of cloud management and monitoring issues. The right quadrant of Figure 4 indicated the relationship between the topics and research type facet. From Figure 4, out of the 136 papers reviewed on cloud management, 46.32% of the papers were on solution research. The breakdown shows that 5.15% of solution research was on simulation, 1.47% on architectures, 9.56% on self-adaptive SLAs, 2.21% on autonomous management, 14.71% on security, and 13.24% on SLA monitoring. Other aspects of the research type category are in Figure 4.

Table 4 Topic and Research Primary Studies

Research Facet	Evaluation	Validation	Solution	Philosophical	Experience	Opinion
Topic						
SLA Monitoring	2, 10, 11, 25, 31, 39, 81, 85, 96, 102, 104, 124	29, 125	3, 7, 8, 14, 15, 16, 21, 23, 24, 32, 33, 34, 37, 57, 61, 73, 111, 123	6	90	
Security	4, 36, 78, 80, 99, 117, 118, 119, 136	47, 48, 49, 51, 53, 56,	5, 12, 13, 19, 35, 38, 41, 45, 58, 59, 70, 77, 103, 109, 113, 115, 120, 121, 133, 134	94, 98	22, 26	
Autonomous Management	17, 89, 92, 127,	69	30, 46, 52,	20, 126	27	
Self-Adaptive SLA	18, 28, 42, 129, 132	43, 44, 101	50, 54, 60, 62, 79, 82, 83, 87, 88, 95, 100, 107, 108	97		
Architecture	1, 66, 106, 112, 116, 122, 135,	55, 74	9, 131			
Simulations	40, 75, 76, 91, 93, 105,	130	71, 72, 84, 86, 110, 114, 128,		63, 64, 65, 67, 68,	
Percentage	31.62%	11.03%	46.32%	4.41%	6.62%	0%

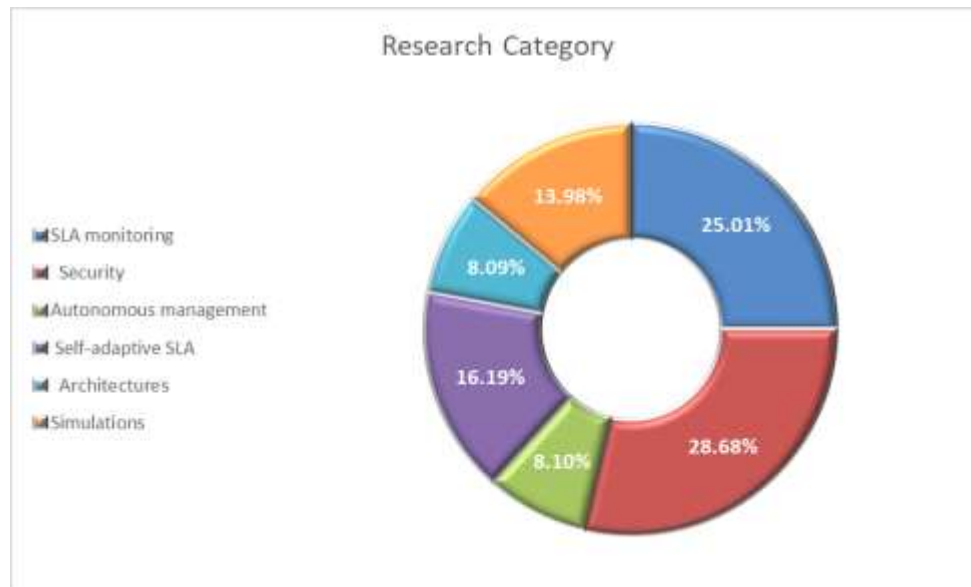


Figure 3. Percentage of Topics on Research Category

#### 4.3. Findings

The focus of the cloud management and monitoring systematic mapping study on is thematic analysis, classification, and also identifying the publication areas. From the analysis, gaps were identified through graphing; this indicated which topic areas has a shortage of articles. Conversely, the map showed the areas that were sufficiently examined in the primary studies. In producing the systematic map and showing the frequencies, the category of assessment was at the highest level.

The left and right quadrant of the systematic map in Figure 4, is a two x-y scatter plot with bubbles at the intersection of the topic and contribution facets, and the topics and research facet respectively. It can be seen from the map that there were more publications on tool as it relates to security (9.52%), more publications on model in terms of security (14.29%), more articles on method as it relates to security (4.76%) and more papers on process as it relates to simulation (6.67%). Similarly, on the right quadrant it can be seen that more papers discussed SLA monitoring as it relates to evaluation research, more articles discussed security in terms of solution and evaluation research with 6.62% and 14.71% respectively. Furthermore, more papers on simulation with respect to experience research (3.68%) were recorded. At a glance, it was depicted that there were generally more articles on cloud monitoring as it relates to security.

On the other hand, to the best of the authors' knowledge, there were no publications in the area of simulation, self-adaptive SLA, autonomous management and SLA monitoring on tool as a contribution. In addition, there were no publications that focused on process in terms of architectures and lack of papers on autonomous management in the area of method. On the right quadrant, there were no publications on philosophical research in terms of simulations and architectures on cloud management. There were no articles on experience research in the area of architectures and self-adaptive SLA. Interestingly, there were no opinions on cloud management. Generally, articles on validation, philosophical and evaluation research were the lowest.

#### 5. CONCLUSION

Cloud computing has continued to evolve in different topic areas. This evolution has led to volumes of publications and articles providing insight into various aspects of the cloud. Despite the quantity of publications, several areas still have shortage of articles. A classification scheme was used to extract data in the area of cloud management and monitoring. Based on the categories produced in the classification, a systematic map was created using a two x-y scatter plot with bubbles. This visual representation allows researchers to observe frequencies of publications with an indication of areas where there is shortage of publications. This outcome provides vast opportunities for further research. This research paper will certainly contribute to broadening the frontiers of knowledge in cloud computing. This is because it uncovered gaps in the area of monitoring and management on the cloud that had not been explored by many researchers.

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## APPENDIX - LIST OF PRIMARY STUDIES

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