A Systematic Mapping Study of Cloud-native Application Design and Engineering

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Abstract.
Cloud computing is a desirable paradigm that is providing services to users in a convenient manner and ensuring that Cloud service providers have value for their infrastructure. Applications designed to run explicitly on the Cloud are usually referred to as Cloud-native applications. Determining a research focus in a particular field of study is sometimes challenging. A systematic mapping study gives an insight into the research level that is being conducted in any field of interest. The results generated from such study are presented using a map. The method used in this study was analyzing three facets categories namely, topics, research and contribution. Topics were retrieved from primary studies, while type of research such as evaluation and contribution such as tool, were used in the analysis. The objective of this study is to conduct a systematic mapping study of Cloud-native applications designs and engineering. This will provide an insight into the frequency of work that has been done in cloud-native applications area. The results showed that from publications relating to security in the field of metric (1.94%), more articles in the topic of application in terms of tool (13.59%), more work done on architecture in terms of model (15.53%), more papers published on Cloud migration in the area of method (10.68%). Furthermore, 11.82% publications were identified on applications in terms of evaluation research, more publication on implementation in the area of validation research (1.82%), more publications on implementation in solution research (6.36%), more publications on security and application with respect to philosophical research (1.82%) and more work done on applications in terms of experience research (6.36%). From the study, several gaps were identified which would be beneficial to researchers, practitioners and providers.

Keywords: Computing, Systematic mapping, Cloud native Applications, Cloud native designs, Cloud native engineering, Cloud migration.

1. Introduction
Cloud is a collection of interconnected and virtualized computers systems that are parallel and distributed. These systems are presented and provisioned dynamically as one or more unified computing resources based on service level agreement established through negotiation between the services provider and users [1]. Applications are utilized on both divides of the cloud. The Cloud Service Provider (CSP) provides the user with applications and the user has the leverage to design and
deploy applications. Native Cloud applications are built from scratch to completion for use on the Cloud framework. However, there are security concerns because of the process of cloud virtualization and multitenancy [2][3]. There are services at all layers of the Cloud referred to as Everything-as-a-Service, there are also three basic cloud service types namely, the Platform-as-a-Service (PaaS), Infrastructure-as-a-Service (IaaS) and Software-as-a-Service (SaaS). The CSP provides applications that are custom built to users in SaaS; hence the user does not need to be concerned about license and installation issues. The CSP provides the infrastructure and the needed application-programming interface that enables a user design and deploy an application in PaaS. The CSPs have massive infrastructure and huge datacenters operated across several geographical borders providing computing and storage services to user in IaaS. Cloud computing is turning out to be very efficient and services are constantly improving and increasing due to the sound underlying architecture and cloud-based applications [4][5]. Furthermore, the Cloud has four models: private, public, community and hybrid Cloud. An organization can host a private Cloud on-premises or use a third party CSP, but in-house staff are utilized, making it more secure. An organization can also leverage on the state-of-the-art infrastructure available to CSP to host a public Cloud. Utilizing the Cloud in this manner implies that the customer does not expend resources on infrastructure. Communities of different kind with shared common interest can host a community Cloud. Hybrid Cloud provide flexibility in the outsourcing of data and utilization of the Cloud. Critical resources can be sustained on a private Cloud, while auxiliary data and services are outsourced to the public Cloud. Although the CSPs are striving to provide very effective and dependable services on the cloud, trust has been considered an issue [6][7].

To benefit from the Cloud, most applications need to be designed with a view to run on the cloud. Applications designed to run on the Cloud are commonly called cloud-native or cloud-ready applications, or occasionally called Cloud-aware [8]. Blueshift is a service for automated application transformation to a Cloud native architecture. Specifically, BlueMix, the IBM’s Cloud PaaS based on Cloud foundry open technology [9]. Blueshift automates an end-to-end transformation process including application discovery, analysis, artifact transformation and enablement of Cloud value-added service [9]. OpenWhisk is also a project from IBM that allows developers to benefit from server-less programming languages, enables composition of services using action sequence and availability of the entire OpenWhisk stack as open sources [10]. In [11], a redesign and deployment of a monolithic Security-as-a-Service (SecaaS) application using cloud native design pattern was carried out while considering appropriate layered security countermeasures at the application and Cloud networking layers. Cloud native applications frequently operate globally. While it is possible to access ordinary websites wherever the internet is unblocked, it is not a true global application. It involves replicating services and application data in local data centers in order to minimize interaction latencies [12].

Technical area of interest must be considered by a researcher when embarking on research or writing an article. Many studies are involved to get a grasp of the topic. This normally involves searching for various journals, books and conference proceedings. In addition, determining an area of interest may also require a lot of search on digital libraries, attending seminars, conferences and workshops [13]. Through the research process and the long hours spent reviewing the research of other people, researchers can often stumble on new and often unforeseen research ideas. In addition, many researchers are particularly interested in a particular observed phenomenon that serves as an impetus for a large amount of research across all fields of study. In summary, the fundamental curiosity of a researcher about an observed phenomenon typically provides enough motivation towards selecting a research topic.

It is obvious from the above that determining a topic for research is usually cumbersome at times. There are large numbers of research that has been undertaken in the area of Cloud native applications design and engineering as discussed in [12], hence it becomes imperative to summarize and provide an overview of some of the work that have been done in this field. A systematic mapping study offers a structured scheme for categorizing the research that has been carried out [14]. The method involves process of classification for relevant article to be sorted into schemes. There is process of extraction of
data for the determination of the different categories is done normally by utilizing a spreadsheet. Thereafter, the recurrence of distributions is utilized to make a systematic guide. The bubbles plots have sizes relating to the quantity of papers in such classifications in the different crossing points. The outcome of such work is presented visually using a map that provides a pictorial insight. The systematic mapping is done in facets depending on the review considerations. In this instance, three facets were utilized namely, the topic, research and contribution. The topic facet retrieves key issues relating to Cloud native applications, the research facet focuses on the research types. The contributions facet examines the nature of the research in terms of methods or models.

The aim of this paper is to conduct a systematic mapping study of cloud-native application designs and engineering. The rest of the paper is arranged as follows: section 2 discusses related work, description of the materials and methods used was covered in section 3. Section 4 presents the results and discussion while section 5 concludes the paper and suggests future work.

2. Literature review

In [15], while reviewing the systematic mapping study, emphasis was laid on the planning phase. The work identifies the patterns of software as evident throughout projects requirement-engineering stages, searching to understand the roles played by patterns based on fundamental factors needed during process of development. A protocol was established for the study with elementary phases to replicate such a work in the research community to validate of the research. Digital libraries utilized in the study includes ACM DL, IEEExplore, Web of Science, and Scopus. The laid down guidelines in [14] were adhered to for this work.

The work of [16] portrays the convention for a systematic mapping study, identifying domain-specific languages (DSL). The work is diverted in the direction of an upgraded perception of the DSL area of exploration with an attention on trends in research and the future heading. The study considered the time frame from July 2013 to October 2014, and it leverages on three rules for achieving efficient survey, this includes conducting the review, reporting, and planning.

The Study in [17] is grounded on investigating the use of computer Science idea maps for systematic mapping study. The resultant map is fixated on the gathering and appraisal of researches on idea maps in the field of Computer Science. Two seeking forms were utilized additionally, to be specific; in reverse snowballing and the manual methodologies. It showed broad concentration and nitty gritty examination of idea maps, utilizing learning and educating helps. Search strings of the study were used on SCOPUS, ScienceDirect, Compedex, IEEExplore, and ACM Digital Library.

In the paper of [18], a systematic mapping examination showed how games related procedures was utilized in education and strategies of software engineering that support explicit software engineering learning spaces, with future heading and gaps in research recognized. The essential investigations of the work secured on the utilization and assessment of games in software engineering education. Total sum of 156 essential investigations were recognized in this examination based on publication from 1974 to 2016. The process of mapping in the work was carried out in tandem with [14].

The work in [19] focused on the system model by giving an examination of the power framework and applications utilizing the mapping procedure. It is utilized by European associations for breaking down modeling highlights and distinguishing modeling holes. More than 228 overviews were passed on to control pros to evoke data, leaving just 82 questionnaires to be accomplished and utilized in the mapping.

In [20], the systematic study of DSL was finished with fundamental enthusiasm in type of research, the focus area, and type of contribution. The work includes inquiry from respectable sources between 2006 and 2012, while the systematic mapping study carried out depends on the procedure characterizing questions for in research, ordering, conducting search, the data extraction and screening. The research materials for the work includes: papers, solution proposal, opinion papers, validation research materials and philosophical or conceptual papers.
In [21] a systematic mapping of the literature on legal core ontologies, based their work on the concepts of [22]. The work based its search more on “lawful theory” and “lawful concepts”. Also, studies selected were categorized based on contribution as reflected in tool, model, method, and language. Other processes comprised of recognizing existing lawful theories in legal core ontologies and process building, using two ontologies with clear references and lastly, the analysis of any research selected for cogent legal and ontological research deductions.

In [14], a systematic mapping study in software engineering was conducted, the work is a foundation to many systematic mapping studies. It provides guidelines for the conduct of systematic mapping studies and a comparison of systematic maps and reviews based on the analysis of existing systematic reviews. The work reveals that systematic maps and reviews are not the same, based on goals, breadth, validity measures, and implications and employ different analysis methods.

The work in [23] is a systematic mapping study that gives a representation of experimental research in software cloud-based testing during the time spent putting up a grouping plan. Practical and non-Practical testing techniques were researched; additionally, the uses of the strategies and their traits. The work used 69 essential investigations as found in 75 publications. Rigorous statistical analysis alongside quantitative results was brought about by a fraction of the study. Most of the studies used a unique experiment to evaluate their proposed result. From analyzed literature, no work centred explicitly around systematic mapping study of cloud-native application designs and engineering were found.

3. Materials and Methods

A systematic map presents an observable representation of the nature or extract of publications in a specific area of study. This study is in the area of Cloud-native application design and engineering. The study was done using formal rules for systematic mapping studies in [14][22]. It is an iterative process for retrieving and interpreting existing materials that are related to the objective of the research [24]. There are some essential or primary steps, which are used in a typical systematic mapping study as shown in [14]. First is the description and explanation of research question where the scope of the review is stated. Thereafter, papers are searched and screened to determine the ones relevant to the study. There is a process of key wording used on abstracts of the searched papers with a view to designing a classification scheme. Finally, is the process of data extraction, which is expected to result in the conception of the systematic map. These various steps for developing a systematic map were useful in the formation of a map on cloud native application design and engineering.

3.1. Definition of Research Questions

The essence of this survey is to have an overview of the quantity and type of research that has been done on mobile and energy efficient use of Cloud. It may also be essential to recognize places were the research has carried out and published. The relevant research questions are determined by these issues to the used for the study. This paper is guided by the following are the research questions:

**RQ1:** What areas of Cloud-native application design and engineering are discussed and how many articles do the various areas cover?

**RQ2:** What are the types of published papers in this field and what assessment and novelty do they constitute?

3.2. Conduct of Search for Primary Studies

The conduct of search for primary studies is usually done by exploring electronic databases. This can also be accomplished through manual search on conference and journals. Papers for this study were gotten by
searching for papers on different online databases available. All papers chosen for the primary studies are in cloud computing field, thus all the facets dealt with matters that relates to cloud computing. The principal concept of a systematic mapping study is keywording, which is usually done on the abstract of a peer-reviewed articles. Subsequently, articles from papers, interpersonal organizations and different sources are not reasonable for directing efficient examinations, consequently the need to use fitting advanced libraries. Four (4) noteworthy online libraries were the focus of the search because of the high impact factor of conferences and journals publications in the databases. The online libraries and their Unified Resource Locator (URL) given in Table 1 were utilized to carry out the search for primary studies in this paper.

Table 1 Digital libraries utilized for the systematic mapping study

| Online Database | Uniform Resource Locator (URL) |
|-----------------|-------------------------------|
| ACM             | www.dl.acm.org                |
| Science Direct  | www.sciencedirect.com         |
| Springer        | www.springer.com              |
| IEEE            | www.ieeexplore.iee.org        |

The search string utilized for this study was designed in terms of outcome, comparisons, population and intervention. The keywords used for the search was taken from every aspects of the structure of the title of this study. For this study on Cloud-native application design and engineering the search string utilized on the digital libraries in Table 1 is given below:

\[((\text{TITLE-ABS-KEY ("cloud-native")}) \text{ AND TITLE-ABS-KEY (applications)}) \text{ AND (ALL (design) OR ALL (engineering)))}\]

The above customized search string was used to perform searches on the metadata of the given document to guarantee that appropriate papers were not missed out. The results for this study on cloud native application from appropriate databases involving computer science and cloud computing were considered. In view of the paper choice criteria characterized based on the requirement of the goal of the examination and research questions, 110 papers were observed to be incorporated in this examination from a first output consisting of 1,009 publications papers from 2010 to 2018. These 110 selected studies are listed at the Appendix 3.2.

3.2. Screening of Papers for Inclusion and Exclusion

The selection criteria are used for the purpose of finding and including relevant papers pertaining to the review. In this study the inclusion and exclusion criteria were used to eliminate studies that were not relevant to Cloud native application design and engineering. It was also utilized to get rid of articles that that are not relevant to the research questions. Some abstract actually mention the primary focus without sufficient facts and such papers were also not considered. Papers on editorials, panel discussions, slides, presentation, summaries, tutorials and prefaces were excluded because they do not have abstracts.
The articles considered had the main focus and sufficient secondary details in terms of relevance. The primary focus of this study is on Cloud native application design and engineering have the inclusion and exclusion procedure was carried out using Table 2.

Table 2 Inclusion and Exclusion Criteria

| Inclusion Criterion | Exclusion Criterion |
|---------------------|---------------------|
| The given abstract clearly references business implication and legal implications as it pertains to cloud computing. Furthermore, such legal and business implications directly influence the Cloud. | Non cloud-computing domain papers especially as it relates to cloud business and legal implications. The paper does not contribute in any way to legal and business aspects of the Cloud. |

3.3. **Keywording of Abstracts**

Keywording is an essential activity in the systematic mapping study. A systematic process involving the growth of a classification scheme and keywording is essential to this systematic process. Keywording is necessary to reduce the timing needed to develop the classification scheme for the cloud native application design and engineering. In addition, keywording guarantees that all articles in line with the study were considered in the scheme. The systematic process involves studying the abstracts on each included paper to extract keywords and concepts that relates to this study. Keywords from the abstracts of the different articles are combined to provide needed comprehension of the kind and contributions of the research in the area of cloud native application. The outcome of this was used to produce the topics categories of this study. Nevertheless, it was pertinent to examine the introduction and conclusion of few papers to ensure suitable keywording of the included papers. A cluster of keywords was used applied to the categories used for the systematic map of this study. In this study on Cloud-native application design and engineering, three facets were used. The first facet focused on topics in terms of Cloud native applications. The second facets focused on contributions to the study in terms of metrics, tools, methods, processes and models as discussed in [22].

3.4. **Research Type Facet with Category and Description**

The research type facet deals with the kind of research conducted in the included papers. This third facet is autonomous to the focus of this study because the approaches in research classification [25] was utilized. The approach includes these categories and their corresponding descriptions.

a. Validation Research: This process utilized are unique but not applied in terms of applications or lab experiments hence no proof of concepts.

b. Evaluation Research: The process used in the research have been applied and reviewed. The outcomes of the implementation exist in terms of advantages and disadvantages.

c. Solution Proposal: This procedure offers an exclusive remedy to an issue. The advantages and applications of such solution are verifiable.

d. Philosophical Papers: The procedure proposes new methods to examine a challenge in terms of frameworks and concepts.
e. Opinion Papers: This kind of research is independent of related work to any research methodology. It expresses the opinion of the researcher and describes how things could be done.

f. Experience Papers: Such research relates the experience of an author by also stating how things were completed.

These categories were considered sufficient and adequate for this study. All articles used for the study were all scrutinized on the basis of these categories in the classification scheme.

3.5. Data Extraction and Mapping of Study
Data extraction was a key feature of the classification process. The appropriate articles were arranged into the scheme through the process of classification, which enabled the extraction of data from the various papers included. During the extraction process, new categories were joined some categories were combined while others not considered relevant were removed. The process of data extraction was done using Microsoft Excel table. The Excel table contained data on the three facets used in this study, which represented the categories of classification scheme. The research and contribution categories were on separate tables. In terms of frequencies of publications, the overall frequencies of publications were combined on an Excel table containing either ‘topic/research’ or ‘topic/contribution’ types. The analysis was based on the results generated on the excel spreadsheet. The reason was to recognize the aspects of cloud-native application design and engineering were emphasized further in the study. This enables the identification of gaps, hence providing an avenue for recommending further studies.

To model the study a bubble plot was created and used to present the occurrence of the published articles on the basis of the results of the excel table. The systematic map was created utilizing a scatter plot of two x-y with bubble size which correspond to with the number of articles in that category. Two quadrants exist in this study in line with the number of facets used. A visual map is provided in each section based on the intersection of the categories of topics with either the research or contribution category. Hence, studying all the facets simultaneously was easy. Summary statistics were also added to the bubbles to improve understanding. Clearly, the map gives a quick overview of study in the area of Cloud native applications making it easy to identify gaps that can be utilized in further research as illustrated in Figure 1. The chosen primary studies that can be identified in the topics, the contribution facet and the research facet were demonstrated in table 3 and table 4 below. Furthermore, table 3 and table 4 treats the literature that fits within each class with a view to substantiating the percentages presented.

4. Results and Discussion
The primary focus of result analysis is to display the frequencies of publications in every category. This makes it likely to recognize which category has more emphasis in past work and thus indicating possibilities and gaps for further future research [26]. The main purpose of this systematic mapping study on Cloud native application design and engineering is on thematic analysis, classification and possible to identify publication. From the analysis, the map helped in identification of gaps, that showed the areas with shortage of publications. Furthermore, the map also indicated areas in terms of articles published that are covered. In this systematic study, advanced categories were utilized in assessing papers involved in summarizing the frequencies and creating the systematic map. The systematic map on Cloud native application, design and engineering is shown in Figure 1.

4.1. Contribution Category
The left quadrant of the x-axis in Figure 1 displays the result of the contribution facet. The facet indicates what kind of contribution to a study in terms of metrics, tools, models, methods and processes. The results portray that publications which covered models in relation to Cloud native application were 36.89% out
of the 103 topics included in this category. Also, metric contributed 3.88%, tool had 27.18%, method had 23.3% and process contributed 8.74%.

4.2. Research Types Category
The right quadrant of the x-axis is the result of the type of research conducted in the area of Cloud native applications. The result indicated that publications that discussed evaluation research in relation to Cloud native applications were 43.64% out of 110 papers reviewed. Also, validation research had 6.36%, solution research had 25.45%, philosophical research had 6.36% and experience research had 18.18%. There were no publications in the area of opinion research.

| Contribution Facet Topic | Metric | Tool | Model | Method | Process |
|--------------------------|--------|------|-------|--------|---------|
| Architecture             | PS99   | PS15, PS103 | PS18, PS24, PS32, PS47, PS52, PS53, PS61, PS73, PS75, PS85, PS89, PS90, PS94, PS102, PS109, PS110 | PS33, PS34, PS38 | PS11 |
| Cloud Migrations         | PS5, PS66, PS69, PS106, PS108 | PS104 | PS6, PS8, PS22, PS23, PS39, PS64, PS70, PS92, PS97, PS106, PS107 | PS40, PS58, PS60, PS63 |
| Development              | PS28, PS29, PS71 | PS2, PS27, PS50, PS65, PS80, PS83, PS86, PS96, PS100 | PS3, PS25, PS81, PS82 | PS26, PS30 |
| Implementation           | PS44, PS45 | PS16, PS51, PS59, PS95, PS105 | PS9, PS55, PS56, PS79, PS91, PS101 | PS62, PS84 |
| Security                 | PS54, PS98 | PS76, PS93 | PS77, PS78 |       |
| Applications             | PS49   | PS1, PS4, PS7, PS10, PS12, PS13, PS14, PS17, PS19, PS41, PS72, PS74, PS87, PS88 | PS20, PS21, PS31, PS48, PS57 |       |

Table 3 Topics and Contribution facet Primary Studies

| Topic                  | Metric | Tool | Model | Method | Process |
|------------------------|--------|------|-------|--------|---------|
| Architecture           | PS99   | PS15, PS103 | PS18, PS24, PS32, PS47, PS52, PS53, PS61, PS73, PS75, PS85, PS89, PS90, PS94, PS102, PS109, PS110 | PS33, PS34, PS38 | PS11 |
| Cloud Migrations       | PS5, PS66, PS69, PS106, PS108 | PS104 | PS6, PS8, PS22, PS23, PS39, PS64, PS70, PS92, PS97, PS106, PS107 | PS40, PS58, PS60, PS63 |
| Development            | PS28, PS29, PS71 | PS2, PS27, PS50, PS65, PS80, PS83, PS86, PS96, PS100 | PS3, PS25, PS81, PS82 | PS26, PS30 |
| Implementation         | PS44, PS45 | PS16, PS51, PS59, PS95, PS105 | PS9, PS55, PS56, PS79, PS91, PS101 | PS62, PS84 |
| Security               | PS54, PS98 | PS76, PS93 | PS77, PS78 |       |
| Applications           | PS49   | PS1, PS4, PS7, PS10, PS12, PS13, PS14, PS17, PS19, PS41, PS72, PS74, PS87, PS88 | PS20, PS21, PS31, PS48, PS57 |       |

Table 4 Topic and Research facet Primary Studies
| Research Facet | Topic | Evaluation | Validation | Solution | Philosophical | Experience | Opinion |
|---------------|-------|------------|------------|----------|--------------|-----------|---------|
| Architecture  |       | PS18, PS24, PS32, PS47, PS61, PS73, PS85, PS89, PS90, PS102 | PS11, PS99 | PS52, PS53, PS75, PS95, PS94, PS109, PS110 | PS15, PS33, PS34, PS38, PS103 |          |         |
| Cloud Migrations | PS18, PS24, PS32, PS47, PS61, PS73, PS85, PS89, PS90, PS102 | PS11, PS99 | PS52, PS53, PS75, PS95, PS94, PS109, PS110 | PS15, PS33, PS34, PS38, PS103 |          |         |
| Development    | PS2, PS27, PS50, PS65, PS80, PS83, PS86, PS96, PS100 | PS26 | PS30 | PS28, PS29, PS71 |  |         |
| Implementation | PS9, PS101 | PS55, PS56 | PS16, PS44, PS45, PS51, PS59, PS95, PS105, PS79 | PS62, PS84, PS91 |  |         |
| Security       | PS54, PS76, PS98, | PS77 | PS78, PS93 | PS62, PS84, PS91 |  |         |
| Applications   | PS1, PS4, PS7, PS10, PS12, PS13, PS14, PS17, PS19, PS41, PS74, PS87, PS88 | PS20, PS21, PS31, PS35, PS36, PS37 | PS49, PS72 | PS42, PS43, PS46, PS48, PS57, PS67, PS68 |  |         |
| Percentage     | 43.64% | 6.36% | 25.45% | 6.36% | 18.18% | 0% |         |

4.3. Topics and Contribution Facet

The key wording processes were used to extract high level topics during the classification process. The topics that were created in the classification scheme are:

- Architecture.
- Cloud migration.
- Development.
- Implementation.
- Security.
- Application.

In Figure 1, the left quadrant shows the existing links that joins the topics and contribution category. It has been observed that model contributed 36.89% of the given papers reviewed, with a breakdown indicating that 4.85% was related to applications 1.94% on security, 4.85% in terms of development, 0.97% related to Cloud migration and 15.53% in terms of discussion on architecture in the area of native
Cloud applications. Other dimensions of the category relating to the contribution in terms of topics are shown on the left quadrant of Figure 1.

4.4. Topics and Research Facet
The quadrant on the right of Figure 1 illustrates connections among facet of the topic and the research category. From the analysis 43.64% of the papers reviewed on Cloud native application dealt with evaluation research. The breakdown showed that 9.09% was on the topic of architecture, 10% on Cloud migration, 8.18% on development, 1.82% on implementation, 2.73% on security, and 11.82% on applications. Other aspects of the review relating to topics and research types are in Figure 1.

4.5. Findings
The first quadrant of Figure 1 is bubble plot with two x-y axis indicating at the inter-section of contribution category and the topic category. While the second quadrant is a two x-y scatter plot with bubbles at the intersection of the topic and research category. As discussed earlier, the map created makes it easy to identify which category has more publication emphasis. From Figure 1, it can be observed that there were more publications in terms of security in the area of metric (1.94%), more articles on the topic of application in terms of tool (13.59%), more work done on architecture in terms of model (15.53%), more papers published on Cloud migration in the area of method (10.68%) and more articles in the area of Cloud migration with respect to process.

Similarly, in terms of topics and research category, 11.82% publications were identified on application in terms of evaluation research, more publication on implementation in the area of validation research (1.82%), more publications on implementation in solution research (6.36%), more publications on security and application with respect to philosophical research (1.82%) and more work done on application in terms of experience research (6.36%).

On the other hand, as far as our knowledge serves, there were no publications on implementation, development, and Cloud migration relating to metric. There was no work identified on security and applications as it relates to method and process. Furthermore, no articles were seen on security and application on Cloud native issues as it relates to validation research. Also, there were no papers identified on architecture with respect to philosophical research and no work on security as it relates to experience research. There were no articles at all on solution research. Generally, it can be seen that there were articles on all aspects of the topics extracted for this study in of terms tool, model, evaluation research and solution research. It is obvious that a lot of information can be gleaned from the systematic map depending on the interest of a researcher or practitioner.
The visual appeal of the systematic map has been used to summarize the categories of publication making results available to researchers. The essence is to generate interest in the gaps, based on shortages in publications identified and then encourage further research. The value of a systematic map even without a successive systematic evaluation cannot be over emphasized. Research gaps can be identified with ease, based on shortage of publications as shown in frequencies of articles published. In relation to cloud-native application designs and engineering, this paper has created a systematic mapping studies which have pointed out such gaps as it relates to the topic. The importance of is all researchers at every dimension as well as businesses specialists can utilize this as a beginning stage to direct additional future research. Six classes of topics were provided in this study namely: privacy issues and challenges, frameworks, cloud trust, techniques, design, data security in relation to security, trust, and privacy in cloud computing. Furthermore, discussion on these six classes of study can be either in terms of model, process, method, tool and metric or in terms of validation, evaluation, philosophical, solution and opinion research. These areas among others are subsequently prescribed for forthcoming and further research. Records of included essential studies would likewise help proposing researchers. From this study, the essential knowledge acquired is that all research work and study is a continuum and it is vast.

4. Discussion and conclusion
Cloud computing has continued to grow in scope, finding application in virtually all aspects of human endeavor. This has continued to stimulate research with a wide range of work that is done in the diverse areas of Cloud computing. A systematic mapping study is a veritable tool in helping to summarize and visually depict the frequencies of publications in an area of study. The mapping process was applied to Cloud native applications with the attendant results shown on the systematic map. The gaps identified in terms of model, metric, tool, method and process in relation to cloud-native application designs and engineering forms the result of this study. Also, gaps have been identified in the area of evaluation, validation, solution, philosophical and opinion research on cloud-native application designs and engineering. Furthermore, the topics of architecture, cloud migration,
development, implementation, security, application were extracted on cloud-native application designs and engineering. As far as authors' knowledge serves, there were no publications on implementation, development, and Cloud migration relating to metric. The-re were no work identified on security and applications as it relates to method and process. Furthermore, no articles were seen on security and application on Cloud native issues as it relates to validation research. Also, there were no papers identified on architecture with respect to philosophical research and no work on security as it relates to experience research. There were no articles at all on solution research. This systematic mapping study has discovered areas where there is less emphasis in terms cloud-native application designs and engineering based on the categories utilized in the analysis. The paper therefore contributes to know-ledge by indicating various areas of the study where there are gaps on cloud-native application designs and engineering. The gaps that have been identified are recommended for further studies. It is likely that it will indeed serve as a wide guide into topics that can be researched on in the area of cloud-native application designs and engineering. Further research could also be done to corroborate this study or resolve inconsistent issues.

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**Appendix: List of Primary Studies**

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