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A SYSTEMATIC MAPPING STUDY OF CLOUD COMPUTING MIDDLEWARE, STACKS, TOOLS, DELIVERY NETWORKS

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ABSTRACT

Cloud computing is presently playing a significant role in the provisioning of vital services in information technology. A unique aspect of cloud computing is the cloud middleware and other related entities which supports applications and networks. Determining a particular research area especially in terms of cloud middleware and services at all levels could be a cumbersome process for a researcher, hence the need for reviews and paper surveys that identify research gaps. The purpose of this paper was to conduct a systematic mapping study of cloud computing middleware, stacks, tools and services at all layers. The focus was on three facets of studies, the research facet, topic facet and contribution facet. The results showed that there were more publications on tool in the contribution facet with tool, model, method and process having 18.10%, 13.79%, 6.03% and 8.62% respectively. In addition, evaluation and solution research had the largest number of articles in terms of tool with 14.17% and 26.77% respectively. A most striking aspect of the systematic map is that solution research has the highest frequencies of publication in relation to all aspects of the topics extracted for the study. This study clearly identified gaps in the field of cloud computing middleware, which should stimulate interest for further studies by both researchers and industry practitioners.

Key words: Cloud computing; cloud stack; cloud middleware; cloud delivery network; XaaS; Systematic mapping

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1. INTRODUCTION

Cloud is a parallel and distributed computing system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service level agreements established through negotiations between the service providers and the users [1]. Cloud computing provides on demand elastic services to users on a pay-per-use basis. Although there is Everything–as–a-Service (XaaS) providing comprehensive services to the users, there are

three primary cloud service types namely, Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). In SaaS, the cloud service provider (CSP) delivers applications to the user, hence no installation or license fee is required. Such providers include salesforce.com and Google Cloud. Cloud computing is becoming very effective, while services are improving and expanding on a regular basis because of the sound underlying architecture and applications running on the cloud [2][3]. PaaS enables the user to develop and deploy an application to the cloud. Such providers include Google Cloud and Microsoft Azure. IaaS delivers storage, computing and network resources using the processes of virtualization and multi-tenancy to the user. However, the process of virtualization and multitenancy on the cloud, raises concerns about security [4][5]. Such providers include Amazon Web Services and Microsoft Azure. Apart from the cloud service types, there are also four cloud architectural models: the private, public, community and hybrid clouds. Private clouds are usually hosted on-premises by organizations or through third party CSPs. Private clouds are considered more secure. Public clouds are hosted by the major CSPs who have state-of-the-art infrastructure spread across several geographical boundaries. Community cloud is operated by institutions such as universities with shared common interest for learning or research purposes. A hybrid cloud is a combination of any of the cloud types. It enables organizations to maintain core activities on-premises while migrating auxiliary data and services to the public cloud. Although the CSPs are striving to provide very efficient and reliable services on the cloud, there are still issues of trust [6].

The cloud middleware, stacks, tools and all layers of services basically enhances operations on the cloud by connecting computers and devices to other applications. The CloudSim discussed in [7] allows the modeling and simulation of large scale cloud computing infrastructure, including data centres on a single cloud node. The cloud toolkit is also a self-contained platform for modeling data centers. The IBM Altocumulus middleware provides cloud users convenient deployment of web applications to a variety of clouds [8]. In addition, there are provisions for backing up and restoring database contents as well as cloud image creation and migration [8]. In [9], the cloud bus toolkit has seven components. Aneka is a software for developing and deploying cloud computing applications [9]. Broker is a middleware for scheduling distributed applications across Windows and UNIX–variant distributed resources [9]. Five cloud computing tools were also examined in [10], which are the virtual voyager, architect, network, native and mobile mover. The virtual voyager comprises the SaaS, PaaS and IaaS with business process as a service and iMmobility as additions. Virtual voyager improves flexibility, capitalizes on improved time to market, and reduces cost [10]. An application delivery network (ADN) is an integrated infrastructure comprising both message-level devices and packet-level devices that host-applications layer services, as well as network layer services [11]. However, the trend now is software defined network (SDN). This is a new approach for managing and operating computer networks. Clearly, the area of cloud middleware constitute a fertile area for conducting research. However, before embarking on research in general, a researcher must consider a technical area of interest. This involves a lot of studies in an attempt to understand the topic. It usually entails searching several conference proceedings, journals and even books. Additionally, there might be need to search through digital libraries, attend workshops, seminars and conferences to in order to identify a research focus. Also, observed phenomenon in an environment can serve as impetus for many researchers to pick interest in certain areas. From the foregoing, it is obvious that the process of determining a research topic can be cumbersome. A systematic mapping study provides a pictorial representation of results in a particular field of interest [12]. A systematic map indicates the frequency of publications based on categories applied in the study. This makes it possible to have an overview of the level of publications in different aspects of the research. In this instance, a systematic mapping study was conducted by

examining issues relating to cloud middleware, stacks, tools, delivery networks and services at all layers. This was used to identify the frequency of publications or research done in this area. This study was carried out by establishing three facets for the scheme, they are the contribution, topic and research facets. The contribution facet considered method and model amongst others, while the research facet dealt with the type of research conducted. The topic facet was executed by extracting key areas of cloud middleware, stacks, tools and services on the cloud. The aim of this paper is to conduct a systematic mapping study of cloud middleware, stacks, tools, delivery networks and services at all layers. The first objective is to extract and determine relevant primary studies. The second objective is to conduct an analysis of the primary studies. The third objective is to create a systematic map indicating gaps in this field of study. The remaining part of the paper is organized as follows: Section 2 examines related work. Section 3 provides the materials and methods applied in the study. Section 4 presents the results and discussion on the outcome of the mapping process. Section 5 is conclusion and recommendation for further studies.

2. RELATED WORK

S/N	Reference	Work
1.	[12]	This paper laid down the guidelines for systematic mapping studies.
2.	[13]	This work was a systematic map that identified the software patterns as evident during the requirement engineering phase of projects, providing a comprehension of the roles played by these patterns based on basic parameters required in the development process.
3.	[14]	This work dwelt on the description of the protocol for a systematic mapping study as it relates to domain-specific languages (DSL).
4.	[15]	This work delivers the result of a systematic mapping study that centers on collection and evaluation of existing research on concept maps in Computer Science.
5.	[16],	In this paper, a systematic mapping study was used to examine how games related techniques have been employed in software engineering education and how these techniques support specific software engineering knowledge domains, with research gaps, and future direction identified.
6.	[17]	The authors did a systematic mapping of power system model by providing an overview of power system models and their applications used by European organizations in terms of analysis of their modelling features and identification of modelling gaps.
7.	[18]	In this paper, a systematic mapping study of domain-specific languages was done with basic interest in type of contribution, type of research, and the focus area.
8.	[19]	A systematic mapping of the literature on legal core ontologies was carried out in this work. The work based its search on “legal theory” and “legal concepts”. In addition, the selected studies were categorized based on contributions in terms of language, tool, method, and model.
9.	[20]	The work is a systematic mapping study that gives an overview of empirical research in software cloud-based testing in the process of building a classification scheme.
10.	[21]	A systematic map was used to present a comprehensive

		review of knowledge management in organizations with a focus on the potential role of information technology in the process.
11.	[22]	The authors in their paper discussed the usefulness and limitations of systematic literature review in information system and social sciences. They were of the opinion that the general stand that systematic literature review provide a holistic and superior approach to literature review is not only questionable, but also unacceptable.
12.	[23]	The paper discussed the lessons learnt from applying systematic literature review process within software engineering domain.
13.	[24]	This paper opined that research reviews must pay close attention to rigorous methodology that is required of a primary researcher.
14.	[25]	The paper provided useful insights to researches used for carrying out literature review. They suggested synthesizing trends and patterns while preparing to write literature review.
15.	[26]	The paper assesses the impact of systematic literature review in terms of evidence-based software engineering methods for aggregating evidence.
16.	[27]	The authors were of the opinion that there is need to evaluate how researchers conduct the process of systematic mapping and identify how the guidelines should be updated based on lessons learnt from existing systematic maps and systematic literature review guidelines.
17.	[28]	The authors stressed the importance of literature review in scientific enquiry and the need to avoid standing on the shoulders of dwarf literature search as major issues for enhancing an effective literature review.
18.	[29]	The authors did a systematic mapping of designs and deployment models for Cloud computing.

3. MATERIALS AND METHODS

This study focused on developing a systematic map of cloud computing middleware, stacks, tools, delivery network and services at all layers. The study was conducted using the formal guidelines for systematic mapping studies in [12][30][31]. A systematic mapping study is a repeatable process for extracting and interpreting available materials related to a research objective [31]. There are some essential steps required for accomplishing a successful systematic mapping study [12]. Research questions have to be defined, which focuses on the scope of review to be conducted. A search is also conducted on all papers available in the particular field of study under review. After the search, the papers are screened to determine the ones suitable for the study. A classification scheme is designed through keywording by examining the abstracts in the relevant papers. The process of data extraction, which leads to the creation of a systematic map, concludes the steps. The various steps discussed above were applied in the creation of a systematic map for middleware, stacks, tools, delivery networks and services at all layers on the cloud. In the context of the selected paper criteria depicted by the prerequisites of the review focus and research questions, 127 papers were considered relevant for inclusion out of an initial list of 1,158 publications. This study covered the period 2001 – 2018. The list of primary studies applied for this work is at the Appendix.

3.1. Definition of Research Questions

A systematic map aims to provide an overview of the quantity and type of research that has been carried out in a particular field of study. This enables the presentation of trends over time by depicting the frequencies of publication. It may also be necessary sometimes to know the places in which research in the study has been published. These pertinent issues determine the appropriate research question to be used for the study. In this paper, the research questions are as follows:

--RQ 1: What areas in cloud computing middleware, stacks, tools, delivery networks and services at all layers are addressed and how many articles cover the different areas?

--RQ 2: What types of papers are published in the area and in particular what evaluation and novelty do they constitute?

3.2. Conduct of Research for Primary Studies

Conducting search for primary studies is usually done by exploring major digital libraries. This is accomplished by manually searching for conference papers and journals online. To obtain papers for this systematic mapping study, searches were carried out on different scientific digital libraries accessible online. The search did not focus on information from books and printed materials. The search utilized four major databases due to the high impact of conferences and journal publications available of these databases. The digital libraries searched and their corresponding URL is at Table 1.

Table 1: Electronic databases used for the systematic mapping study

Electronic Databases	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 was designed to produce results in terms of outcome, population, comparisons and intervention in the field of study. The keywords used in the search string was taken from all aspects of the focus of this study. For this study on cloud computing middleware, stacks, tools, delivery networks and services at all layers the search string used on the major digital libraries is:

(TITLE (‘’Cloud middleware’’) OR TITLE (‘’cloud computing middleware’’) or (ALL(‘’cloud’’)AND ALL(middleware)))AND (TITLE (Stacks) OR TITLE (tools) OR TITLE (‘’delivery networks’’) OR TITLE (XAAS) OR TITLE(‘’services at all layers’’)).

The above search string which was customized for this study was used for searches on the document metadata to ensure that all relevant papers were obtained. For this study on cloud computing middleware, stacks, tools, delivery network and services at all layers, all the results from the four digital libraries relating to cloud and computer science were considered.

3.3. Screening of Papers for Inclusion and Exclusion

The purpose of a selection process was to ensure that all relevant papers were found and included in the work. The inclusion and exclusion process was used to eliminate papers not relevant to the study, while papers on cloud middleware stacks, tools, delivery networks and services at all layers were included. This process also helps to exclude studies that do not directly contribute to answering the research questions. Some abstract mentioned the main focus without sufficient details and such papers were also excluded. In addition, the study also excluded papers on tutorials, summaries, panel discussions, prefaces, editorials and

presentation slides. It was pertinent to consider papers that examined the main focus of this study and also discussed the secondary aspects to a certain extent. The main focus of this paper is middleware, stack, tool, delivery network and services at all layers on the cloud. Therefore, the inclusion and exclusion criteria is as detailed in Table 2.

Table 2: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
The abstract explicitly discussed middleware, stacks, tools, delivery networks and services at all layers in relation to the cloud. Furthermore, the researcher is able to conclude that the focus of the abstract contributes to the topic of the study.	The paper lies outside the domain of cloud and computer science and does not contribute to issues of middleware, stacks, tools, delivery networks and services at all layers. The papers are not related to cloud computing.

3.4. Keywording of Abstracts

The classification scheme used for the study is accomplished through a systematic process. The process is as shown in Figure 1.

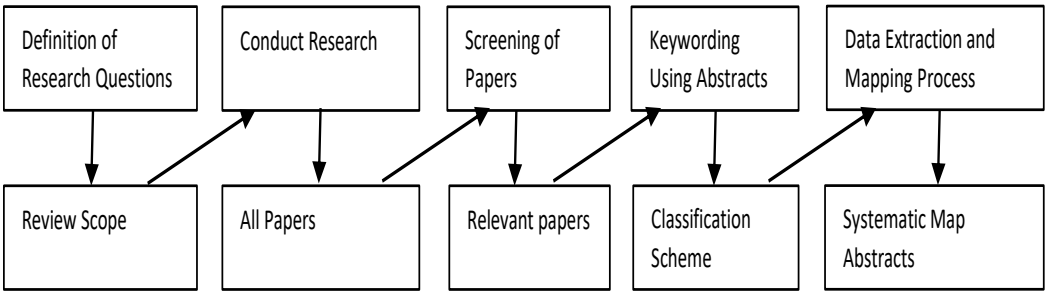

Figure 1: The Systematic Mapping Process [27].

a. Abstracts
b. Key wording
c. Classification scheme
    1) Articles
    2) Sorting articles into scheme
    3) Updating scheme
d. Systematic map

Keywording was necessary to reduce the time required for developing the classification scheme on middleware, stacks, tools, delivery network and services at all layers on the cloud. Furthermore, keywording enables the researcher to consider all relevant publications through the classification scheme. The process involved studying the abstracts to extract concepts and keywords relating to this study. This include knowing the context of the study and applying it in the scheme. After the extraction process keywords from different papers relating to middleware, stacks, tools, delivery network and services at all layers in the cloud were combined to provide sufficient insight into the type and contribution of the research. Thereafter, this was used to determine the set of categories for this study. However, it was sometimes necessary to review the abstract, introduction and conclusion of the publications to ensure reliable keywords are used for this study. A cluster of keywords was finally used to determine the categories which were eventually used to create the systematic map.

In this study on cloud computing middleware, stacks, tools delivery networks and services at all layers three facets were utilized. The first facets focused on topic, which was directly associated with the various aspects of the tittle of this study. The second facets discussed the types of contribution by these topics in terms of metric, model, tool, method and process used in the research paper. The third facets was on the research types that were conducted. All the categories utilized were related to the keywords.

3.5. Research type Facts with Category and Description

The third facet considered the type of research that had been carried out. An existing classification of research approaches discussed in [30] was utilized. The approach has the following categories and descriptions [30].

Validation of research: The techniques used in the papers reviewed are unique but not yet implemented, for example conducting an experiment in the laboratory.

Evaluation research: The techniques have been evaluated and implemented. Also the result of the findings discussed in the papers.

Solution proposal: The process point towards a unique solution that was found to a problem. The applications and benefits of such solution is also mentioned.

Philosophical papers: The techniques attract new ways of examining a problem in terms of concepts and framework.

Opinion papers: The study considered here does not rely on any known method of conducting research. It simply expresses the opinion of individuals.

Experience papers: These papers relate to the personal experience of the author and it discusses how things were done.

These categories were considered very apt for use in the classification scheme of this study. The papers included for this study were examined using this research types. The outcome of the three facets is discussed in the analysis.

3.6. Data Extraction and Mapping Studies

During the classification scheme the relevant articles were sorted into appropriate categories. This allowed for data extraction from the various papers that were included in the study. During the process new categories may be added, while some categories were merged and others were not considered sufficiently relevant. The process of data extraction was carried out using a Microsoft Excel table. The Excel tables contained each categories of the classification scheme. The frequency of publication was obtained by combining the tables of the topic/contribution and topic/research type. Therefore, the analysis was done on the basis of frequencies of publication from the result on the Excel tables. The importance of this was to identify which aspect of the field of study had more emphasis. This made it easy to identify the gaps in the area of cloud middleware, stacks, tools, delivery network and services at all the layers, thereby allowing for the recommendation of further work in areas of low publications. Based on the result contained on the Excel tables, bubble plot was used to depict the frequencies. The map containing the bubble plot involved a two x-y scatter chat with bubble at the intersection of the categories. There were two quadrants because of the three facets that were utilized in the study. Each quadrant provided a visual map based on the intersection of the topic category with either the contribution or research category. Therefore, it was easy to examine all the facets simultaneously. In addition, summary statistics were also added to the bubble for easy understanding. Overall, the map provided a quick overview of the study in the area of middleware, stacks, tools, deliver network and services at all layers on the cloud.

4. RESULTS AND DISCUSSION

The main focus of the systematic mapping study on cloud computing middleware, stacks, tools, delivery network and services at all layers was thematic analysis, classification and likely identification of the publication fora. From the thematic analysis, gaps were identified through the map, thus depicting which area of the field of study had shortage of publications. On the other hand, the study also indicated the areas that had more articles published. In this systematic mapping study, high-level categories were used to assess the primary studies used for producing the frequencies and in the creation of the map.

4.1. Topic and Contribution Facet

The topics used in the classification scheme reflected the different aspects of the title of the paper. Hence the topics considered were stacks, tools, delivery network, services at all layers, middleware and orthogonal. The list of primary studies in the Appendix was used for checking the topics against the types of contributions and the result is at Table 3. The systematic map on cloud computing middleware, stacks, tools, delivery network and services at all layers is at Figure 2. On the x-axis of the left quadrant of Figure 2 is the contribution facet. This category dealt with the type of contribution a paper offered the research in terms of metric, method, tool, process and model. In the study, metric had 10.34% out of the 116 papers in this facet. Tool had 28.45%, model had 27.59%, method had 18.10% and process had 15.52%.

Furthermore, the left quadrant indicated that 1.72% of the model contribution were each on orthogonal, middleware, delivery network and stacks. Model contributed 2.59% to services at all layers, while the contribution to tool had the largest which was 18.1%. Other aspects of the contribution category as it relates to topics is shown in Figure 2.

Table 3: Primary Studies for Topic and Contribution facet

Contribution Facet / Topic	Metric	Tool	Model	Method	Process
Stack	23, 24, 122	18, 25, 103, 111	7, 26	21, 27, 29, 59, 110, 120, 126	2, 45, 116
Tools	4, 13, 28, 102, 105, 125	31, 33, 65, 66, 67, 71, 77, 82, 85, 86, 89, 91, 99, 100, 113, 117,	34, 37, 38, 39, 40, 60, 61, 62, 63, 75, 76, 79, 80, 81, 82, 84, 104, 112, 115, 124	32, 47, 56, 57, 64, 74, 93,	6, 10, 16, 72, 73, 90, 113, 119, 123,
Delivery Networks	15,	22, 48,	14, 50,	42, 43	51, 83, 127
Services at all layers (XAAS)	1, 55	19, 20, 69,	70, 118, 108,	87, 109,	98, 106
Middleware		5, 12, 17, 78, 88, 92, 94, 107	9, 11, 49, 68	30, 96	
Percentage	10.34%	28.45%	27.59%	18.10%	15.52%

4.2. Type and Research Facet

The list of primary studies in the Appendix was also used for examining the topics against the types of research and the result is at Table 4. On the x-axis of the right quadrant of Figure 2 is the result of the type of research conducted in the area of cloud computing middleware, stacks, tools, delivery network and services at all layers. On the x-axis of the right quadrant of

Figure 2 is the research type category. Evaluation research had 28.35% out of 127 articles reviewed. Solution research had 54.33%, philosophical had 5.15% and experience had 11.88%. There were no articles on validation and opinion research in field of study under review.

Evaluation research had 28.35% out of the 127 publications included in this study. The breakdown of this 28.35% indicated that 0.79% dealt with orthogonal, 6.3% of the evaluation research was on tool and 3.94% was on stacks. Other aspects of the research facet as it related to topics is as depicted in Figure 2.

Table 4: Primary studies for topic and research facets

Research Facet / Topic	Evaluation	Validation	Solution	Philosophical	Experience	Opinion
Stack	23, 24, 103, 111, 122		7, 8, 18, 25 26, 27, 29 45, 59, 110, 120, 126	21	2, 116	
Tools	4,13, 28,31, 33,65, 66,67, 71,85, 86,89, 91,99, 100, 102, 105, 125		6, 10, 16, 34,37, 38, 39,40, 47, 56,57, 60, 61,62, 63, 64,72, 73, 74,75, 76, 77,79, 80, 81,82, 84, 104,112, 115,117, 119,123, 124	32, 93,	90, 113	
Delivery Networks	15, 48,		14,22,42, 43,50,		51, 83, 127	
Services at all layers (XAAS)	1, 55		19,20,69, 70,87,108,109, 118,		98, 106	
Middleware	3, 5, 12, 17,52, 53,97, 101, 121,		9, 11, 49, 54,68, 78, 88,92, 94, 107,	30,58, 114, 96	35, 36, 41, 44, 46, 95	
Percentage	28.35%	0.00%	54.33%	5.51%	18.81%	0.00%

4.3. Major Findings

The systematic map on middleware, stacks, tools, delivery network and services at all layers on the cloud can be visualized in Figure 2. The left quadrant provided the two x-y scatter chart with bubbles at the intersection of the topic and contribution facet. The right quadrant is the map depicting the intersection of the topic and research type facet also using a two x-y scatter plot with bubbles. The map made it easy to identify which category had more emphasis. From Figure 2,

- It can be identified that there were more publications in the area of metric as it relates to tool. In fact, it can be clearly identified that there were more publication on tool in terms of

contribution facet with tool, model, method and process having 18.10%, 13.79%, 6.03% and 8.62% respectively.

- Evaluation and solution research had the largest number of articles in terms of tool with 14.17% and 26.77% respectively. In terms of experience research, middleware had the highest number of papers with 4.72%. Also middleware had more articles in relation to philosophical research with 2.36%. There were no publications dealing with validation and opinion research to the best of our knowledge. In addition, there were no articles on delivery networks and services at all layers in terms of philosophical research. There were also no articles on process and metric on the topic of middleware.
- A most striking aspect of the map is that solution research has the highest frequencies of publication in relation to all aspects of the topics. This type of result shown on the systematic map can easily ignite the interest of researchers. The visual appeal of a systematic map has helped to summarize and make results available to researchers.

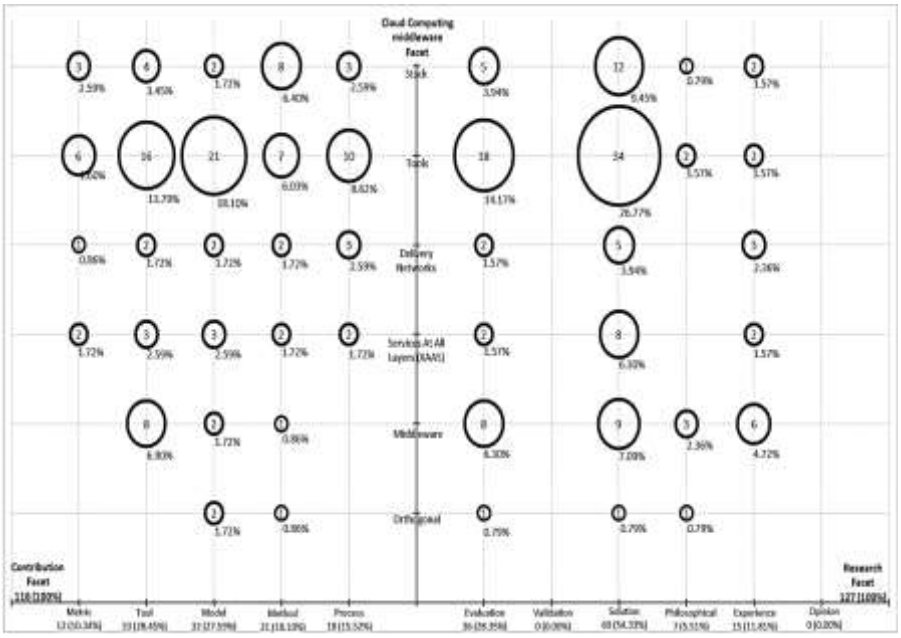

Figure 2: Systematic Map of Cloud Computing Middleware, Stacks, Tools, Delivery Networks and Services.

The relevance of this is that researchers at all levels and industries practitioners can use this as a starting point to conduct further studies. This study focused on six topics namely: stacks, tools, delivery network, services at all layers, middleware and orthogonal in relation to cloud computing middleware. In addition, the six classes of study were discussed either in terms of tool, model, method, metric and process or in terms of evaluation, validation, solution, philosophical and opinion research. These areas amongst others are therefore recommended for future research. The list of primary studies would also assist intending researchers. The important lessons learnt in this study is that research work is a continuum and it is inexhaustible.

5. CONCLUSION

Cloud computing operates extensively on middleware. There are also stacks, tools, delivery network and services at all layers on the cloud that enhance activities of cloud service providers. Despite the volume of research done in this field of study, the systematic map

created indicated that there were gaps. Suffice to mention that a systematic map without conducting a successive systematic review has a value in itself as it helps to identify research gaps in a topic area as has been shown in the outcome of this study. This systematic mapping study has enabled the identification of some areas where there were less emphasis in terms of cloud computing middleware, stacks, tools, delivery network and services at all layers based on the categories used in the scheme. This paper has therefore contributed to knowledge by indicating different aspects of the study where there were gaps. The gaps that have been identified on the systematic map are recommended for future. In particular, future work should focus on publications dealing with validation research and opinion research, delivery networks and services at all layers in terms of philosophical research, and process and metric on the topic of middleware. Further research could also be carried out to validate this study or resolve contradictory issues. The major limitation of this work is that although there were volumes of papers in this field, the primary studies were restricted to those relevant to this study. In summary, this study created a systematic map of cloud computing middleware, stacks, tools, delivery network and services at all layers that could be beneficial to the cloud community. This study would also help researchers to uncover the critical gaps of cloud computing middleware, stacks, tools, delivery network and services at all layers that many researchers were not able to explore. Thus, expanding the frontiers of knowledge in cloud computing.

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APPENDIX: LIST OF PRIMARY STUDIES

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