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Networking for Cloud and Data Centre - A Systematic Mapping Study

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Abstract

Cloud computing is an important network model, which enables communication between the various components of the cloud using different service types and models. Although the issue of identifying a specific area of research that is networking-related for Cloud and data center is usually a concern to a researcher, a review or survey paper assists in easily identifying likely topics of research. Therefore, the aim of this work is to carry out of a systematic mapping study of networking for Cloud and data center. These allows for categorization in a subject area using a scheme based on certain classification process. The scheme used in this paper was categorized into three facets namely: topic, research and contribution facets. The results showed that there were more publications in terms of design on networking for Cloud and data center in the area of metric, model and method with 2.52%, 16.81% and 7.56% respectively. There were more papers on security in networking for Cloud and data center in terms of tool with 5.04%, and more articles on management and scaling in the aspect of process. Also, more articles got published on design in the area of evaluation research, validation research and solution research with 9.92%, 9.16% and 7.63 % respectively. There were more work on philosophical papers in terms of management and scaling with 2.29% and more articles on security in relation to experience papers. This study reveals gaps in networking for Cloud and data center, and it should arouse research interest in the academia and the industry.

Keywords: Cloud Computing, Systematic Mapping, Cloud Networking, Data Centers Networking.

1. INTRODUCTION

Cloud computing refers to distributed and parallel systems which are interconnected and are dynamically provisioned based on services level agreement between users and Cloud services providers (CSPs) [1]. The interconnected and virtualized systems operate on a reliable network to provide adequate services. Data centers are not located in one area hence the need for a good networking infrastructure. The three primary services types available on the Cloud are Software-as-a-Services (SaaS), Platform-as-a-Services (PaaS) and Infrastructure-as-a-Services (IaaS) [1]. SaaS is used to deliver applications to users over the Internet. The user does not have to be concerned about upgrades and licenses fees. PaaS utilizes CSPs in providing the framework on which a user can build and host an application. The underlying infrastructure is controlled by the CSPs, while the user has control of his application and data. IaaS is used to provide virtual machine, storage and bandwidth to the user on a pay per use basis by the CSPs. This eliminates the critical needs to invest in expressive Cloud infrastructure. The effectiveness of Cloud computing has brought about improved conveyance and constant expansion of services, which is based on the fundamental architecture and applications running on the cloud [2 & 3].

Whatever service type is utilized on the Cloud, the networking infrastructure is essential. Amongst the four Cloud models in existence today, Private Cloud is hosted on premise by an organization, sometimes as an extension of its data center. It could also be hosted by a third party for the organization, but run by in-house staff. Public Cloud is offered by major CSPs to provide virtual machines (VMs), storage and compute resources, using the massive data centers at their disposal. Community Cloud is hosted by institutions or corporations with common interests. While Hybrid Cloud takes advantage of the public and private Cloud by hosting critical data and applications on private Cloud, and less important data and services on public clouds. Nevertheless, security remains a significant point of concern because of the procedure of virtualization and multi-tenancy on the cloud [4 & 5].

Research works that have been carried out on network related issues for Cloud and data centers. A few of such research work are discussed subsequently. Data center networks (DCN) is an important infrastructure, which allows for the effective connections of multiple data center services, and supports numerous virtualization methods, networks and functions, thus enabling Cloud computing to serve its purpose [6]. The deployed data management and processing mechanism in the DCN such as Goggle file system, (GFS), the Hadoop distributed file system (D+DFS), Bigtable, MapReduce takes responsibility for the management and processing of large volumes of data [7]. Given that the networking infrastructure is vigorously depended on for the Cloud's performance, its failure at any point could result in less support of data-intensive and high-performance Cloud applications [8]. There is a need for net-work changes based on usage scenarios such as dynamic load, data mobility, heterogeneous resources and energy – efficiency considerations [8]. Numerous applications keep running inside a solitary data center, where every application is individually hosted on a set of server machines [9]. A solitary data centre network supports the flow of traffic

between external end systems and internal servers, and between internal servers [9]. The design consideration for modern Cloud data centers include scalability, incremental stability, cabling complexity, bisection bandwidth, aggregated throughout, oversubscription, fault tolerance, energy consumption, cost and latency [10]. The state-of-the-art data center networks are categorized into three classes based on diverse network interconnection rules, which are: switch–based networks, direct networks, and hybrid networks [10]. Although the CSPs attempts efficiency and reliability of Cloud services, we also need to be concerned with the issues of trust [11, 12].

Cloud based services all require data in order to function properly and it is important to realize that how effective and efficient a data center is, obviously it is critical for constructing and operating solid cloud services. Hence, the extensive study and research of data center networking and cloud networking cannot be overemphasized as these topics have drawn much attention especially in today's cloud computing driven world. Cloud networking as a concept explains usage of networking resources from a provider, leveraging on the internet. In cloud, the network as well as the computing resources can be shared thereby ensuring accessibility of resources. Whereas, data center networking enables and ensures communication and transfer of data between data center equipment on an external network or internet. If these researches are encouraged it will solve challenges such as data intrusion, data corruption, resource unavailability and service instability thereby enhancing performance and how agile, scalable, and available cloud computing services are.

From the foregoing, the study of networking for cloud and data centers is interesting and there are several issues related to Cloud data center network, which has resulted in a large volume of research. However, in research, there is a need to identify the focused context, this requires a deep knowledge of all details, thereby leading to a required rigorous process of getting a research focus [13]. Researchers will benefit immensely if such publications based on different aspects of data center networks, can be classified using a scheme to provide an overview. This can be accomplished using a systematic mapping study (SMS) [14]. An SMS categorizes the frequencies of publications based on a structure that leads to a visual summary using a map [14]. Three facets were used in the systematic study in this paper, which includes the research, contribution and topic facets. The topic facet yielded core aspects in the discussion on Cloud networks. The research facet discussed the study type, while the contribution facet relates to other areas, for instance; the method. The remaining part of this paper is as follows. Section 2 is a review of related work. Section 3 discusses materials and methods and Section 4 features the results and discussion. Section 5 concludes the paper with suggestions for further studies.

2. RELATED WORK

In [15], the planning stage of an SMS was explored. The work identifies the software patterns; this is evident in the requirement engineering phase of projects, with an intention to understand the prerogatives of these patterns based on development process standards. For this study, protocol development was undertaken with basic steps to replicate such a work in the research community to confirm how valid the research work is. The guidelines laid down in [14] guided this research.

In [16], the protocol for an SMS as it concerns domain-specific languages (DSL), with a strategic interest in future works and trends based on a sound understanding of DSL were discussed. July 2013 to October 2014 was covered for this work, based on planning, conducting the review, and reporting such, which is the standard for this type of a research.

[17] analyzed concept maps within Computer Science. The result of this work focuses on collection and evaluation of existing research on concept maps in that context. The databases consulted are Scopus, ScienceDirect, Compedex, ACM Digital Library, and IEEExplore; using the search strings on these repositories based on backward snowballing and manual approaches. The work concentrates on concept maps based on learning and teaching supports in that context.

The authors in [18] employed a mapping study in the investigation of how game related techniques have been used in software engineering education and how they support specific software engineering knowledge domains, with an identification of research gaps, and future direction. The work concentrated on the use, assessment of games, and their factor on software engineering education. Based on publications from 1974 to June 2016, there was an identification of 156 primary studies. The mapping process of the work was in accordance with [15].

The work in [19] provided a mapping of power system model in Europe; it analyzed modeling features and identified gaps. There were 228 surveys administered to experts for information elicitation, while 82 questionnaires were completed, and the knowledge mapping was done accordingly.

In [20], a systematic mapping study (SMS) of domain-specific languages was done with basic interest in research type, focus, and contribution. The work features a search of standard academic repositories from 2006 to 2012 with the SMS done based on specifying research questions, conducting the screening, search, data extraction and classifying.

In [21], an SMS of the literature on legal core ontologies was done. The search was based on "legal theory" and "legal concepts". The tool, method, and model were reviewed; legal theories in legal core ontologies building process; and finally researching into revelations about legal and ontological research.

The work in [22] is an SMS that gives a survey of an empirical research in software cloud-based testing in the process of building a categorization scheme and both non-functional and functional testing approaches were investigated alongside the applications of their peculiarities and methods. The work was based on 69 primary analysis from 75 publications. Many of the analysis used a particular experiment to evaluate the proposed solution.

The work in [23] presented a detailed overview of the knowledge management in organizations, with special emphasis on the role of Information Technology. It went ahead

to discuss several important issues centering on knowledge management processes and the procedures IT plays in driving and aiding these steps. Attention was also raised to aid the creation, storage, and transfer process of knowledge.

[24] in their paper examined the helpfulness and confinements of systematic literature review (SLR) in data framework and sociologies. They opined that systematic literature review does not give a comprehensive method to literature review, and that discreetness ought to be practiced while picking a systematic literature review.

[25] Explained the information gotten from applying SLR processes within software engineering domain. The researchers explained the SLR process and also described lots of reviews undertaken by them and other researchers, and finally extracted and discussed some lessons about application of the practice to software engineering domain.

[26] gave helpful bits of knowledge to researchers on conducting a literature review. They proposed orchestrating patterns and examples that can be followed while planning to conduct literature review, which incorporates identifying the reason for conducting the research, reassembling the noted key points, and creating the topical outline in line with the difference of opinion in the literature review. Thus, resulting in the principles for creating an intensive and reasonable literature review.

[27] stated the impact of SLR where it recommended evidence-based software engineering processes for combining evidence. Amongst twenty (20) relevant studies researched on, eight (8) examined research trends instead of the evaluating technique, seven (7) SLRs examine cost estimation, and the quality of SLRs was fair with only three scoring less than 2 out of 4.

[28] was of the opinion that evaluating how the process of systematic mapping is conducted is of paramount significance. In the affirmative, the authors discovered that in the substantial number of the research carried out, several guidelines were utilized and integrated, thus resulting in numerous approaches to conducting systematic mapping research.

[29] emphasized on the significance of scientifically conducting literature review and the need to avoid relying on sparse works for improving the content of related works. The authors further discussed problems encountered in research work. They also proffer solutions to the problems addressed.

In [30] is the systematic mapping of cloud computing management; The classification scheme, as regards cloud management, discussed service level agreement (SLA) monitoring, security, autonomous management, self-adaptive SLA, architectures and simulations were explored. The selected studies were utilized on the contribution facet with relation to tool, method, and model, and were utilized on the research facet with relation to evaluation, validation and solution researches.

3. MATERIALS AND METHODS

This systematic mapping study (SMS) portrays the results in pictures, this depends on a diligent and resourceful publication review in a context. The standard steps for systematic studies in [14 & 31] were adhered to, these are replicable for information elicitation and interpretation based on the research objective [32]. A typical SMS has important steps as detailed in [14]. The first step is to define research questions and the review scope.

A search must be conducted on all accessible articles in the proposed area of study and the accessible articles are then screened for relevance. There is a keywording process that uses the abstracts of the included papers to design a classification scheme.

Finally, the data extraction process yields a systematic map. At every step there is an outcome in terms of the review of the scope, searching the papers and determining relevant ones, the classification scheme and the eventual map [14]. These stages were employed to create a systematic map of networking for Cloud and data centers. In view of the article choice criteria employed and characterized by the requirements of the examination's goals and research questions, there was a selection of 131 articles included as relevant to the research focus from the 1114 initially returned by the earlier search; the year of coverage being 2012 – 2018.

3.1. Defining Research Questions (RQs)

The aim of an SMS is basically to impress a summary of the type of existing research and their quality as related to the particular field of study. However, understanding the extent of research done in this area coupled with publishers is significant. Based on these, the RQs for this study are as follows:

RQ 1: What are the different areas in networking for Cloud and data centre that existing studies have ad-dressed and the overall quantity of articles in this area?

RQ 2: How can we define the types of articles published based on evaluation and novelty in the chosen study area?

3.2 Primary Studies Search

In order to get papers for this systematic mapping study, search for papers was performed on the digital libraries shown on Table 1. The search focus was not placed on information from books and printed resources. The utilized search string was designed in terms of intervention, population, outcome and comparison. In addition, the utilized keywords in the search string were extracted from every aspect of the structure of the title for this study. For this study on networking for Cloud and data centre, the search string used on the selected databases is as follows: TITLE ((“Networking”) AND (““For Clouds”) OR TITLE (“Data Centre”))

The search string above was used on the four digital libraries in Table 1 due to the high impact factor of publications in these databases. Utilizing the custom-made search string on the document metadata gave the desired assurance that crucial and relevant papers were not expunged. Every result on Cloud and computer science got considered for the study.

Table 1. The utilized digital libraries

Electronic Databases	URL
IEEE	http://ieeexplore.ieee.org/xplore
Springer	http://www.Springerlink.com/
ScienceDirect	http://ww. sciencedirect.com/
ACM	http://dl.acm.org/

3.3 Screening Process

The importance of the selection criteria in this study is the ability to ensure only relevant papers were reviewed. The inclusion and exclusion criteria in Table 2 were employed for this study for articles selection in the area of networking for Cloud and data centers. Papers on panel discussion, presentation slides, prefaces, editorials, tutorials, and summaries were excluded. In addition, abstracts that contradict the subject matter got excluded. Papers that align with the main focus and those having sufficient discussion in secondary aspects were considered.

Table 2. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
The abstract explicitly mentions networking and data centre as it relates to clouds. Furthermore, such networking relates to Cloud and data centre	The abstract is not within the domain of cloud computing. In addition, there are no discussions related to networking, and data centre

3.4 Keywording of Abstracts

The Keywording of abstracts is a major part of the SMS based on its influence when to build classification scheme. Figure 1 shows the entities involved in the process.

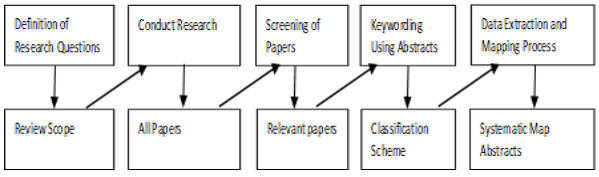

Figure 1. The Mapping Process [28].

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

The process of keywording is vital in minimizing the total time taken to conduct a systematic study. In addition, this procedure aids an assurance that only relevant articles were selected for consideration. This practice entailed the study of abstract to choose correct keywords, which demanded a sound knowledge of the study area. Keywords from diverse papers concentrating on networking for Cloud and data centre were combined to provide appropriate understanding into the types and contributions of the articles. Finally, a collection of keywords was used to condition the various categories for this study.

This study is based on networking for Cloud and data centre, which is divided into three facets. These facets were focused on topic is terms of networking for Cloud and data centre. The second facets was on the basis of research contributions in relation to metric, model, process, method and tool as outlined in [14] which is in line with the focus of this study. The third facet dwelt on research types applied in the papers that were included. All the categories and their major components are usually derived from research keywords, which are based on abstracts.

3.5 Research Types Fact with Categories and Description

The classification of research approaches in [33] was utilized in the research category of this study; and are listed below:

1. Validation Research: Unique procedures proposed but yet to be implemented in terms of experiments and possible applications.
2. Evaluation Research: The procedures got an implementation and evaluation. The outputs based on pros and cons have also being discussed.
3. Solution proposals: These papers present unique solution(s) to specified problem(s). The benefits and applications of such solutions are available.
4. Philosophical papers: These offer new ways to examine a problem based on concepts and framework.
5. Opinion paper: They do not depend on known methodology or conducted experiments. They simply relate the opinion of the author(s).
6. Experience paper: These papers detail the personal experiences of the author(s). It indicates how something was done

The classification of research approaches were considered adequate and appropriate for use in this study, the description above guided the selection process.

3.6 Data Extraction

As part of the systematic process, relevant publications were classified into various schemes. This process was introduced to effectively extract relevant papers from the various publications in the mentioned databases. The effectiveness of this process enhances the overall outcome of any systematic process study. This process allows the addition of new categories, merging of categories and removal of irrelevant

articles. A spreadsheet was used for this purpose and it allowed the entry of each category with its associated publication, including topic, contribution, and research aspects. The analysis was done for the purpose of presenting paper frequency based on results deduced from the excel sheet; this is to identify gaps in networking for Cloud and data center research, therefore recommending further research.

Based on the created spreadsheet, bubble plots represent paper frequency which results in a systematic map. This systematic process involved a two x-y scatter plot using bubbles to indicate where categories do intersect. The coordinates have bubble sizes, this is in a correlation to the volume of the selected research papers in each category within diverse intersections. Each quadrant gives visual maps centered on the topics category, research or contribution category. Furthermore, a simultaneous examination of diverse facets is enhanced. There is an inclusion of the statistical summary as it concerns the bubbles to have it well situated in the area of networking for Cloud and data centre.

4. RESULTS AND DISCUSSION

This paper is aimed at presenting the overall sectional identification of classification analysis. From the analysis conducted, limitations were identified through the graph highlighting the various research types and topics areas with limited publications. In addition, this study identified the areas with large publication coverage using high level categories for accessing articles thus depicting publications frequency.

4.1 Contribution Category

In this category, only 119 articles of the 131 articles gave a concise contribution, which in this context was broken down into five major areas which are metrics, tools, models, methods, and processes. The analysis table for this study is represented in Table 3, while the systematic map on network for Cloud and data centre as depicted in Figure 2. The result indicated that out of the 119 articles with contributions, the highest contribution as highlighted by existing study showed that contributions based on process and model with the highest percentage of 38.66% and 26.05%. However, contributions based on methods, tools and metrics were 19.33%, 10.08%, and 5.88% respectively.

Table 3. Contribution category table

Contribution Facet		
	X	Y
Metrics	7	5.88%
Tool	12	10.08%
Model	31	26.05%
Method	23	19.33%
Process	46	38.66%
Total No. of Articles	119	

4.2 Research Type Category

For this category, six research type areas were analyzed based on evaluation, validation, solution, philosophical, experience, and opinion. Table 4 depicts the number of articles that fell into the different research types with the associated percentiles. The result showed that 38.17% of the articles reviewed were based on evaluation, while the percentage of reviewed papers based on validation, solution, philosophical, experience and opinion were 25.19%, 19.85%, 7.63%, 8.40%, and 0.76% respectively.

Table 4. Research category table

Research Type Facet		
	X	Y
Evaluation	50	38.17%
Validation	33	25.19%
Solution	26	19.85%
Philosophical	10	7.63%
Experience	11	8.40%
Opinion	1	0.76%
Total No. of Articles	131	

4.3 Topic and Contribution Category

The major topics selected from the primary studies were:

- Security.
- Management and Scaling.
- Algorithms.
- Virtualization.
- Networking.

The list of primary studies used for checking the topics against the types of contributions is at Table 5. The left quadrant of Figure 1 shows the relationship between the topic and contribution facts. Process contributed to 38.66% of the paper reviewed with a breakdown of 10.08% on security, 5.88% focused on design, 11.76% was on management and scaling, 5.88% on algorithms, 4.2% on virtualization and 0.84% on networking. Other contribution in the category as shown in Figure 2.

4.4 Topic and Contribution Category

The list of primary studies as consulted to examine the topics in relation to the research types is represented in Table 6. The right quadrant of Figure 2 depicts the relationship between the topic and research category. Discussions on evaluation research constituted 38.17% of the articles reviewed on networking for Cloud and data centers. The breakdown shows that 6.87% is on security, 9.92% on design, 9.16% on

management and scaling, 6.11% on algorithms, 3.82% on virtualization and 2.29% on networking. Other research type articles are as shown in Figure 2.

Table 5. Primary studies for topic and contribution facet

Contribution Facet / Topic	Metric	Tool	Model	Method	Process
Security	7	11, 28, 31, 41, 49, 75,	32, 42, 33	8, 9, 24, 25, 27, 29, 118,122	31, 42, 96, 97, 76, 77, 105, 106, 107, 117, 123, 131
Design	34, 45, 116,	71, 84, 92,	5,10,14,19, 20,22, 26, 21, 34, 45, 87, 88,109, 110,111, 113,114, 115, 128, 129	3, 6, 12, 23, 44, 47, 61, 67, 79,	70, 81, 82, 100, 104, 125,126,
Management and Scaling		46, 127	43, 89, 91, 101, 108,	1, 62, 63, 83,	2, 4, 13, 30, 37, 38, 48, 69, 78,85, 86, 124, 119, 120
Algorithms	15, 16, 55, 59, 98, 103, 112, 121,	56, 58, 60, 130,	18,	35, 40	,
Virtualization	36, 54, 72, 73, 74,	53,		90, 93,	
Networking	51, 52, 68	39, 65, 66, 95, 99,	102		17, 64
Percentage	**6.67%**	**32.50%**	**30.00%**	**15.83%**	**15.00%**

Table 6 Primary studies for topic and contribution facet

Research Facet / Topic	Evaluation	Validation	Solution	Philosophical	Experience	Opinion
Security	7, 8, 9, 24, 25, 27, 29, 96, 97,	11, 28, 31, 41, 42	32, 33, 49, 75, 76, 77, 117,	105, 107	106, 118,122, 123, 131	
Design	3, 6, 12, 23, 44, 47, 67, 79, 81, 82, 100, 116, 128	10, 19, 22, 26,71, 84, 92, 111, 113, 114, 115, 129	5, 14, 20, 21, 34, 45, 87, 88, 109, 110	61	70, 104, 125,126,	80,
Management and Scaling	2, 13, 30, 37, 38, 48, 69, 78, 85, 86, 124, 119,	43, 46, 50, 57, 94, 127	62, 63, 83, 89, 91, 101, 108,	1, 4, 120		
Algorithms	15, 16, 55, 59, 98, 103, 112, 121,	56, 58, 60, 130,	18,	35, 40	,	
Virtualization	36, 54, 72, 73, 74,	53,		90, 93,		
Networking	51, 52, 68	39, 65, 66, 95, 99,	102		17, 64	
Percentage	**38.17%**	**25.19%**	**19.85%**	**7.63%**	**8.40%**	**0.76%**

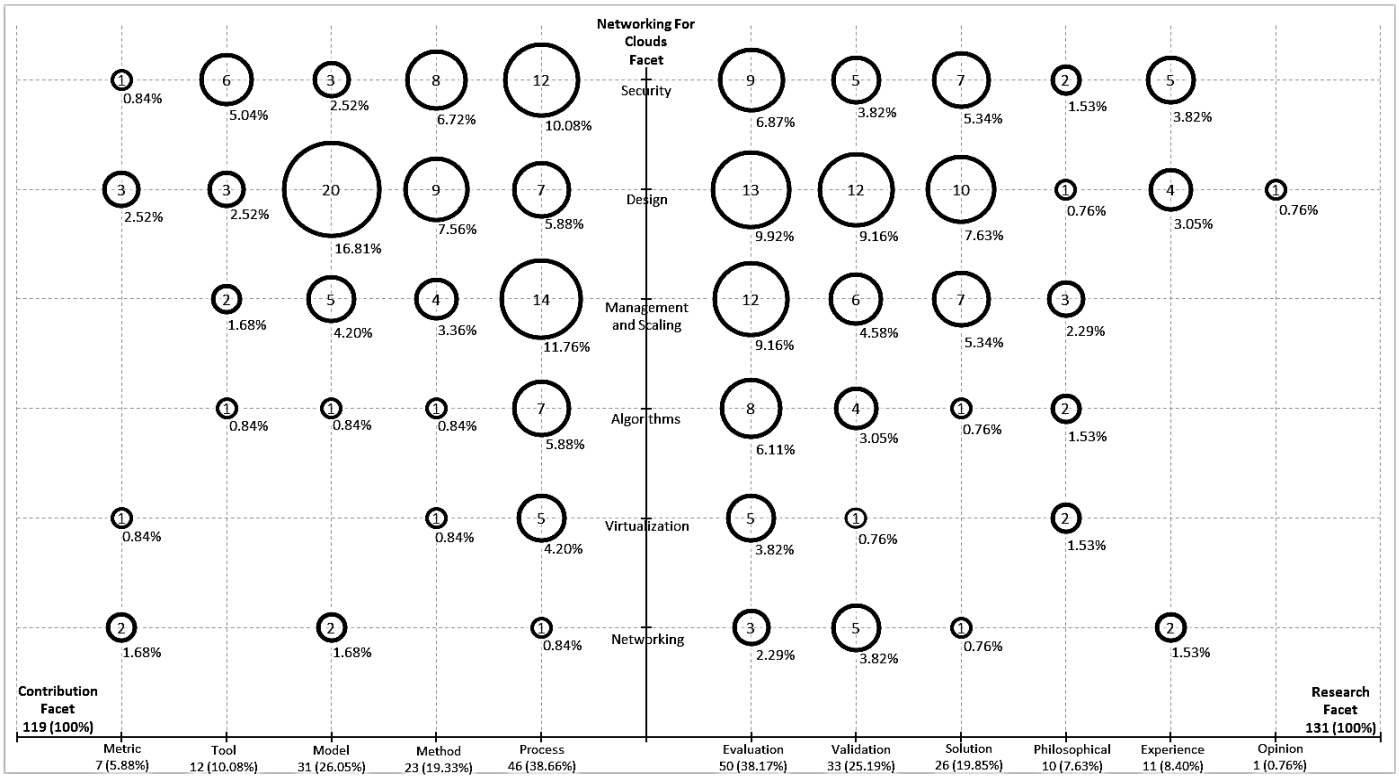

Figure 2. Systematic Map on Network for Cloud and Data Center

4.5 Major Findings

Considering Figure 2, the first quadrant presents the topic and contribution facet intersection, while the second quadrant presents the topic and research facet intersection. This analysis however, makes it easier to visualize which category had the highest focus. The following are the major findings from the result:

a. It can be deduced from the first quadrant that design, model, and method have high rate of publications with 2.52%, 16.81% and 7.56% respectively. There were more publications on security in terms of tool with 5.04%, more articles on management and scaling in the aspect of process with 11.76%.

b. Likewise on the right quadrant, more papers were published on design in the area of evaluation research, validation and solution with 9.92%, 9.16% and 7.63 % respectively. There were more works on philosophical paper in terms of management and scaling with 2.29% and more articles on security in relation to experience papers.

c. There were no publications identified on management and scaling, and algorithms in terms of metrics to the best of the authors' knowledge. There were no papers identified on virtualization and networking as regards tools, no papers on networking as regards methods, no papers on virtualization as regards solution research, and no papers on networking as regards philosophical papers.

d. There were no published articles on management and scaling, algorithms and virtualization in terms of experience. Only one aspect of opinion was covered which was design with 0.76% as depicted in Figure 2. In general, all aspects of process, evaluation and validation had published papers. In addition, looking at both sides simultaneously, there were more articles published on design in relation to networking for Cloud and data centers. The least set of articles are in the topics of algorithms, virtualization and networking.

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5. CONCLUSION

Cloud computing has continued to expand the frontiers of research. This is because the Cloud is becoming more and more relevant every day. There is constant technological development on the Cloud and increase in the usage of Cloud researchers. Networking application for Cloud usage and data centers is important in a study of Cloud computing. A number of studies are ongoing in this topic area, hence there are more publications being done. In spite of the huge publications, not all aspects of this topic have sufficient papers while some do not have published papers. This systematic mapping study used a two x-y scatter chart with a bubble to show the different aspects of the study. This would certainly enhance further

studies on networking for Cloud and Data Centre. Furthermore, based on the groupings used in the scheme, this study has revealed areas that lack required attention in terms of Network for Cloud and Data Centre, thereby revealing research gaps. The identified gaps are recommended for further studies, as they are relied upon to fill in as an extensive guide into research areas on networking for Cloud and Data Centre. Further research could likewise be done for the justification of this study or to resolve opposing observations. Conclusively, the creation of a systematic map of Network for Cloud and Data Centre would be useful to the cloud community by assisting researchers to uncover the crucial gaps that were previously unexplored.

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Appendix: List of Primary Studies

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