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A SYSTEMATIC MAPPING STUDY OF MOBILE AND ENERGY-EFFICIENT USE OF CLOUD

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Abstract. *Cloud computing allows for the exchange of data between the various aspects of the cloud using different service types and models. The issue of deciding a specific area of research in relation to mobile and energy-efficient use of cloud may sometimes be challenging for a researcher. However, a review or survey paper assists in easily identifying likely topics of research. The objective of this work is to conduct a systematic mapping study of mobile and energy-efficient use of cloud. The results indicated that there were more publications on efficient transmission in the area of metric and tool with 3.33% and 9.17% respectively. There were more papers on architecture in terms of model and method with 11.67% and 5.83% respectively. Also, there were more articles on fault tolerance and data storage in relation to process with 5%. In addition, there were more publications on efficient transmission in terms of evaluation and solution research with 12.95% and 10.07% respectively. Also, there were more articles on fault tolerance and data storage in relation to validation and experience research with 6.47% and 3.6% respectively. The study clearly identified gaps in mobile and energy-efficient use of cloud as it relates to architectures, computation offloading, efficient transmission, allocations, collaborative mobile cloud, fault tolerance and data storage, which ought to invigorate enthusiasm for further research by scientists, providers and experts.*
Keywords: Cloud computing, Systematic mapping, Energy usage, Energy transmission, Efficiency in cloud

1. **Introduction.** The cloud is a framework comprising of interconnected and virtualized PCs, progressively provisioned and exhibited as a unified computing resource, which is dependent on service-level understanding between the users and the cloud service providers [1]. The interconnected and virtualized computers run in large data centers belonging to the Cloud Service Provider (CSP). These data centers consume massive amounts of energy, which has become a factor in locating them. Data must move from the data center to the client system, which also leads to further energy consumption. The energy consumption takes place in connecting with the cloud services and models. 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]. Three (3) paramount services are associated with cloud computing, which

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are Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). Although the CSPs are striving to provide these services efficiently and reliably on the cloud, trust continues to be a significant point of concern [4]. There are also concerns on security because of the procedure of virtualization and multitenancy on the cloud [5,6].

Several papers have been written in the area of mobile and energy-efficient use of clouds. Some of the papers are examined subsequently. The limitations of mobile users in the Mobile Cloud Computing (MCC) environment is down to insufficient energy and resources of mobile devices [7]. MCC is utilized in executing rich mobile applications such that a user can write codes and thereafter, all the processing is done on the cloud [7]. The backlight used to illuminate the display subsystem on mobile devices consumes most of the energy, thus requiring attention with a view to improving energy consumption in mobile applications [8]. Limiting the energy utilization brought about by the backlight for multimedia streaming application on mobile devices, without antagonistically affecting the users viewing experience is the focus of [8]. Mobile cloud offloading relieves mobile devices from concentrated processes, thus increasing the mobile application performance, saving more energy, and improving the user's reliability on the device [9]. Several mobility management approaches have been proposed to handle the processes initiated by mobile devices through cloud computing, but because traditional methods are used to obtain cloud services from the CSPs, excess energy consumption still occurs [10]. Consequently, there is an extreme interest for secure and energy-efficient handover process in the MCC environment [10]. Application off loading is a solution for extending the capabilities of mobile devices for computation intensive applications through the offloading of computations to cloud server [11]. By offloading computation to the cloud, a lot of energy consumption is saved on the mobile device [1]. Nonetheless, research efforts are still ongoing to allow for further optimization.

Carrying out a systematic mapping study plays a significant role in pointing out areas not sufficiently covered, and providing a summary of research that has been conducted in a specific research area, which includes categorizing them using a structure and a scheme [12]. The method involves a classification process for sorting relevant articles into scheme and a data extraction process for determining the various categories usually done on a spreadsheet. Thereafter, the frequency of publications is used to create a systematic map. The bubbles plots have sizes corresponding to the number of papers in such categories in the various intersections. This method of research aids researchers in having an overview of previous work done in a field of study, the areas well covered and those not adequately covered.

The primary motivation of this systematic mapping study on mobiles and energy-efficient use of cloud is thematic analysis and classification, which requires utilizing graphs to identify publications and gaps. This analysis will show which topic areas and research types have shortages of publication, and the areas having adequate research. The rest of the paper is organized as follows. Section 2 examines related work. Section 3 discusses the materials and methods. Section 4 presents the results and discussion. Section 5 concludes the paper and suggests further studies.

2. **Related Work.** The planning stage of a systematic mapping study was examined in [13]. The authors identified the software patterns present in software development projects (with respect to requirement engineering) in order to understand the roles played by these patterns, based on basic parameters required in the development process. This resulted in the development of a protocol for the study, which includes simple steps for replicating such work in the research community, with the aim of confirming the legitimacy of the research. IEEExplore, SCOPUS, ACM DL and Web of Science were scientific databases used in the research. The guidelines from [12] were adhered to for this work.

[14] carried out a systematic mapping study of Domain-Specific Languages (DSL), to have a firm grasp of the DSL field, seek out research trends, and identify research gaps. The study covering from 2013 to 2014 utilized three review guidelines: planning, conducting and reporting the review.

The authors in [15] utilized a mapping study to explore the adoption game-related methods in software engineering, while identifying research gaps. An aggregate of 156 essential investigations between 1974 to June 2016 were distinguished in this examination. The mapping procedure of the work was done coupled with [12].

[16] is a mapping study of the literature on legal core ontologies, which is dependent on the ideas of [17]. The authors identified publications on "legal theory" and "legal concepts", which were categorized in accordance to languages, tools, methods and models.

The work in [12] is a foundation to many systematic mapping studies as regards software engineering. 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.

3. **Materials and Methods.** This survey provides a visual portrayal of results, which are dependent on a thorough review of publications in a related research area. A systematic study is a repeatable process for eliciting and interpreting accessible materials identified with a research objective [18]. The formal guidelines for systematic studies in [12,17] were utilized.

3.1. **Definition of research questions.** Defining the research questions for this study results in a summary of the amount and kind of research done on the research topic, and the identification of the places the research has been published. In this paper, the following are the research questions:

RQ1: What are the addressed areas in mobile and energy-efficient use of clouds, and what number of articles are covered in the distinctive areas?

RQ2: What are the kinds of published articles in the distinctive areas, and specifically what are the established innovativness?

3.2. **Conduct of search for primary studies.** Four (4) major digital libraries were considered in conducting the search, which are the ACM DL, IEEExplore, ScienceDirect, and SpringerLink. The search string for this study was formulated in relation to outcome, population, comparison and intervention. The utilized keywords was extracted from each part of the structure of the title for this study. The search string used on the major digital libraries is: (TITLE (Mobile AND Energy-Efficient AND use AND of AND CLOUDS) OR KEY ("mobile and energy-efficient" use AND of AND clouds)).

3.3. **Screening of papers for inclusion and exclusion.** The inclusion and exclusion criteria, as shown in Table 1, were utilized in adding or removing publications not relevant to this study and the research questions.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	**Exclusion Criteria**
The abstract explicitly mentions mobile use of clouds and energy-efficient use of clouds. Furthermore, the paper focuses on mobility and energy in the use of clouds.	The paper lies outside the domain of cloud computing especially in terms of cloud usage as it relates to mobile and energy-efficient uses.

3.4. **Keywording of abstracts.** The key wording process involved examining the abstracts to highlight keywords essential to the study, thereby understanding the context of the study. The keywords from the primary studies were collected for further insight into the type and contribution to the study, which resulted in the development of the classification scheme, and subsequently the categories used for this study.

Three (3) facets were utilized in this study: the first facet focused on topics in terms of mobile and energy-efficient use of clouds, the second facet concentrated on the types of contribution in terms of metric, tool, model, method and process [12], and the third facet deals with the research types.

3.5. **Research type facet with categories and description.** The research facets, which were classified using the approaches applied in [19], are listed below.

1) **Validation Research:** These include techniques that are unique but have not been implemented as proof of concept.
2) **Evaluation Research:** These include implemented techniques, whose results have been discussed in relation to points of interest and hindrances.
3) **Solution Proposal:** These include papers that present unique solutions to specified problems, while highlighting the advantages and applications of such solutions.
4) **Philosophical papers:** These include papers that offer alternate perspective to examining problems with respect to concepts and frameworks.
5) **Opinion Paper:** These include papers that rely on the researcher's opinion rather than any known research methodology.
6) **Experience Paper:** These include papers that rely on the experience of the researcher and emphasize on the 'what' rather than the 'why'.

3.6. **Data extraction and mapping study.** The primary studies were organized into the classification scheme. This phase was used for the data extraction from the relevant articles being used for the study. The data extraction process was done on a Microsoft Excel sheet, while the Excel table was used for each category of the classification scheme. Subsequently, the frequencies of papers contained in each table were combined into the tables comprising of either the topic/contribution or the topic/research category. The eventual analysis presented the frequencies of the publication using the results on the Excel sheet.

The bubble plot was utilized in presenting the frequencies of publications for the creation of the systematic map. The systematic map was a two x-y scatter plot with bubbles at the intersection of the categories. The coordinates had bubble sizes that match the number of articles in the category. The utilization of three (3) facets in the categories resulted in the design of two (2) quadrants, with each quadrant offering a visible map on the focal point of this study at the node of topics category, hence, making it easier to examine the different facets simultaneously.

4. **Results and Discussion.** The systematic map on mobile and energy-efficient use of cloud is shown at Figure 1, while Table 2 and Table 3 show the selected primary studies as it relates to the topics, the contribution facet and the research facet.

4.1. **Topics and contribution facet.** Listed in Table 2 are the primary studies utilized in checking the topics against the types of contributions, while the left quadrant of Figure 1 shows the relationship between the topic and contribution facet. In Table 2, the result indicates that publication that discussed tool in terms of mobile and energy-efficient use of cloud was 32.5% out of 120 papers in this category. Similarly, metric had 6.67%, model had 30%, method had 15.83% and process had 15%. Other contribution in this category is as shown in Figure 1.

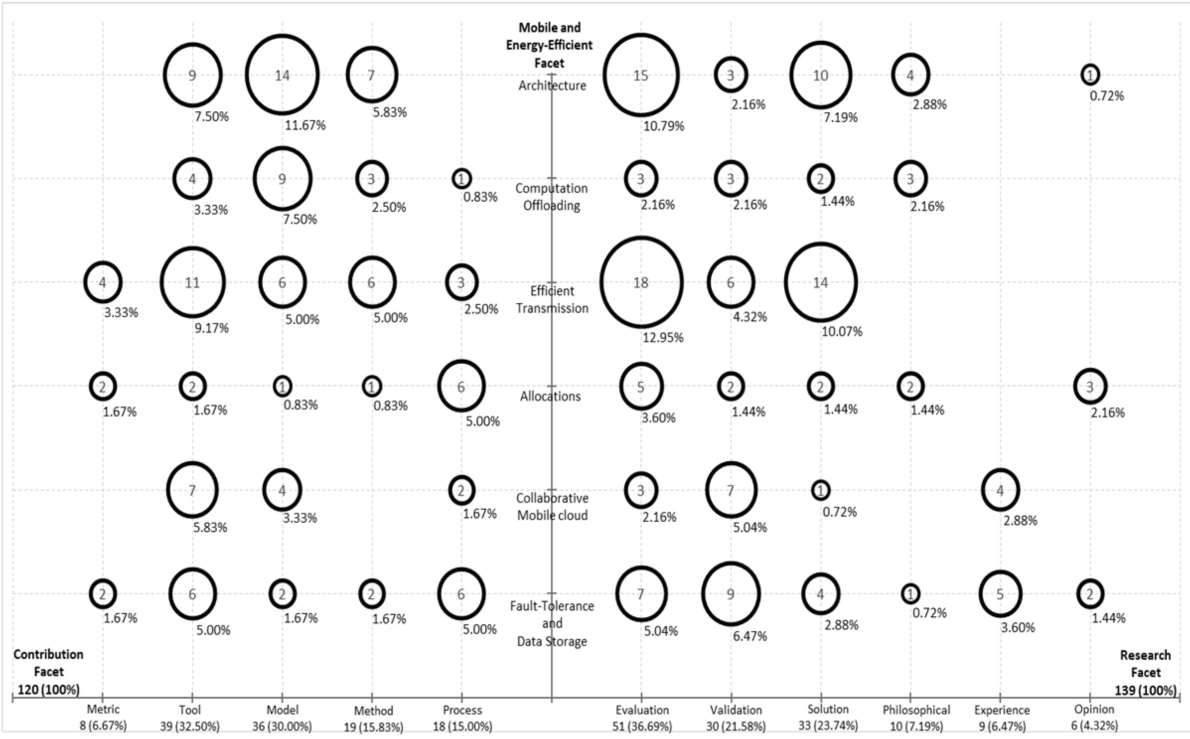

FIGURE 1. Systematic map on mobile and energy-efficient use of cloud

TABLE 2. Topics and contributions primary studies

Contribution Facet / Topic	Metric	Tool	Model	Method	Process
Architecture		5, 6, 7, 29, 30, 31, 70, 104, 112	45, 85, 86, 87, 51, 52, 53, 54, 72, 73, 74, 68, 80, 110	35, 36, 40, 89, 115, 116, 117	
Computation Offload		1, 64, 106	91, 119, 127, 136, 98, 108, 4, 24, 25, 55	46, 50, 57	103
Efficient Transmissions	122, 123, 124, 125	8, 9, 10, 90, 93, 94, 95, 96, 97, 99, 120	43, 67, 69, 71, 75, 76	77, 78, 79, 81, 82, 83	84, 92, 100
Allocations	33, 34	130, 134	105	133	32, 107, 132, 109, 131, 135
Collaborative Mobile Cloud		2, 19, 20, 22, 26, 27, 28	14, 21, 121, 129		15, 17
Fault Tolerance and Data Storage	1, 24	12, 13, 23, 37, 113, 114	60, 61	62, 63	3, 44, 47, 64, 102, 106
Percentage	**6.67%**	**32.50%**	**30.00%**	**15.83%**	**15.00%**

4.2. **Topics and research facet.** Listed in Table 3 are the primary studies utilized in checking the topics against the types of research, while the right quadrant of Figure 1 indicates the relationship between the topics and research facet. In Table 3, the results indicate that evaluation research type had 36.69%, validation had 21.58% and opinion had the least percentage of 4.32% out of 139 articles identified in this category. Similarly,

Table 3. Topics and research primary studies

Research Facet / Topic	Evaluation	Validation	Solution	Philosophical	Experience	Opinion
Architecture	5, 6, 7, 29, 30, 45, 85, 86, 87, 88, 89, 115, 116, 117, 118	31, 70, 104	51, 52, 53, 54, 72, 73, 74, 68, 80, 110	35, 36, 40, 48		112
Computation Offload	98, 108, 4	119, 127, 136	91, 103	46, 50, 57		
Efficient Transmissions	8, 9, 10, 90, 93, 94, 95, 96, 97, 99, 120, 122, 123, 124, 125, 126, 128, 139	11, 41, 42, 100, 101, 138	43, 67, 69, 71, 75, 76, 77, 78, 79, 81, 82, 83, 84, 92			
Allocations	32, 33, 34, 49, 111	130, 133	105, 134	107, 132		109, 131, 135
Collaborative Mobile Cloud	14, 121, 129	2, 19, 20, 22, 26, 27, 28	21		15, 16, 17, 18	
Fault Tolerance and Data Storage	1, 24, 25, 55, 56, 58, 59	12, 13, 23, 37, 38, 39, 113, 114, 137	60, 61, 62, 63,	102	3, 44, 47, 64, 106	65, 66
Percentage	**36.69%**	**21.58%**	**23.74%**	**7.19%**	**6.47%**	**4.32%**

solution had 23.74%, experience had 6.47% and philosophical had 7.19%. Other research types in this category are as shown in Figure 1.

4.3. **Findings on mobiles and energy-efficient use of cloud.** From the left quadrant of Figure 1, it can be identified that there were more publication on efficient transmission in the area of metric and tool with 3.33% and 9.17% respectively. There were more papers on architecture in terms of model and method with 11.67% and 5.83% respectively. Finally, there were more articles on fault tolerance and data storage in relation to process with 5%.

Similarly, the right quadrant indicated that there were more publications on efficient transmission in terms of evaluation and solution research with 12.95% and 10.07% respectively. In addition, there were more articles on fault tolerance and data storage in relation to validation and experience research with 6.47% and 3.6% respectively.

However, there were no publications on collaborative mobile cloud, computation offloading and architecture, which focused on metrics. There were no publications on collaborative mobile cloud in terms of method, and none on architecture in term of process. Similarly, there were no articles on collaborative mobile cloud and efficient transmission in the area of philosophical research. There were no experience papers on allocations, efficient transmission, computation offloading and architecture. Furthermore, the lowest publications were in the area of allocations topic on both sides of the quadrant. There were publications on all aspects of the extracted topic in terms of tool, model, evaluation research, validation and solution paper. Generally, there were more publications on the topic of efficient transmission.

5. **Conclusion.** Cloud computing is virtually assisting users in all aspects of life through the provision of relevant services and massive infrastructure, both of which are energy-intensive.

In spite of the extensive amount of available articles on mobile and energy-efficient use of the cloud, this research work has identified some areas with less emphasis, in view of the categories used in the analysis. To the best of the authors' knowledge, there were no publications on collaborative mobile cloud, which focused on metric, method and philosophical research. There were no publications on architecture in terms of process and experience papers. Similarly, there were no articles on efficient transmission in the area of philosophical research and experience papers. Also, there were no experience papers on allocations. In addition, there were no experience papers and metrics discussion on computation offloading.

This paper has hence added to learning by showing distinctive parts of the study where there are gaps on mobile and energy-efficient use of cloud. The identified gaps are recommended for further studies, as they are relied upon to fill in as an extensive guide into research areas on mobile and energy-efficient use of cloud. Further research could likewise be done to justify this study or resolve opposing observations.

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