Challenges of Infrastructure in Cloud Computing for Education Field: A Systemmatic Literature Review

Nurma Ayu Wigati, Ari Wibisono and Achmad Nizar Hidayanto
Faculty of Computer Science, Universitas Indonesia, Depok, Indonesia

Keywords: Cloud Computing, Eductional Sector, Infrastructure as a Service (IaaS), Resource, Security, Finance, Kitchenham, Challenges.

Abstract: The usage of cloud computing is needed for educational sector, especially in universities to ease all of administration and learning access to everyone. So that, the development infrastructure cloud computing need to concern the aim of the university. Infrastructure as a Service (IaaS) in cloud computing has problems, like resource, security, and finance. This study follows Kitchenham protocol to explore the challenges in the cloud computing as a infrastructure service for education field literature systematically, then reviewed their techniques which can use to all of university in Indonesia. This study recommends that the management of IaaS should be considered well to get result development of cloud computing optimally.

1 INTRODUCTION

Cloud computing is defined as a services that together provide ways to deliver cloud services. In higher education, cloud computing services are commonly used to provide the means for students to collaborate and interact in a distributed learning space (Al-Samarraie & Saeed, 2018). Cloud computing technology is one of the services provided by the use of IT in it to facilitate human work in various fields to be more efficient and effective, such as in education (Njenga, Garg, Bhardwaj, Prakash, & Bawa, 2019). Universities and colleges usually do not have sufficient fund to install and continuously maintain state-of-the-art ICT technologies for learning environment that can support students, staff, researchers and developer (Elamir, Jailani, & Bakar, 2013). Thus, cloud computing and its applications are vital to the future of distance education worldwide. The rate at which ICT technologies change, will continue to place pressure on institutions' budget. Increasing bandwidth availability has enable cloud computing to be a potential solution in reducing ICT cost and freeing them from the expense and hassle of hardware and software maintenance. Several universities in UK have adopted Google Apps due to cost and unreliable in-house email systems. Even universities and schools in poor countries in Africa are using cloud computing supported by Google and Microsoft.

Based on the conditions and problems that have been described, the output of study is expected to identify and map the right solutions to be carried out when implementing cloud computing infrastructure in educational sector. To answer the expected research objectives, our work is organized as follows: Section 1 shows why we choose to raise the issue of the challenges faced in cloud computing infrastructure as a service, Section 2's regarding the theoretical basis of cloud computing infrastructure as a service (IaaS) and its chalenges. Section 3 is about research methodology which tells the workmanship of the research on how the research was conducted. Section 4's regarding the results and analysis that shows the results of research that has been done and how the analysis of the outputs on these results. In Section 5, the authors provide conclusions from this literature study.

2 RELATED WORKS

Cloud computing (CC) also presents new security challenges (A. M. Ibrahim & Hemayed, 2019). In education field, we have some problems about cloud computing. Education institutions will continue to enhance infrastructure and curriculum to attract

Wigati, N., Wibisono, A. and Hidayanto, A.
Challenges of Infrastructure in Cloud Computing for Education Field: A Systemmatic Literature Review.
DOI: 10.5220/0010522603510358
In *Proceedings of the 23rd International Conference on Enterprise Information Systems (ICEIS 2021) - Volume 1*, pages 351-358
ISBN: 978-989-758-509-8

students (Sun, 2020). Scholars and researchers have done lots of studies concern the cloud computing adoption model and proposed a suitable way for different categories of cloud computing such as layout, implementing, challenges and so many. Students, staff and lecturers in the studied area suffer enough due to the problem of data storage for their academic purposes (Juma & Tjahyanto, 2019). Unfortunately, these methods require the suspension of the cloud computing applications due to the mandatory shutdown of the associated virtual machines (Lin, Wang, Liang, & Qi, 2011).

3 METHODOLOGY

The need for cloud computing infrastucture as a service is needed to support the profits to be obtained by university (Lis & Paula, 2015). This study needs to map the problems arising from cloud computing infrastructure as a service (IaaS) implementation over the past 5 years using Kitchenham's SLR and are expected to be grouped in a more structured way in Figure 1 (Suryono, Purwandari, & Budi, 2019).

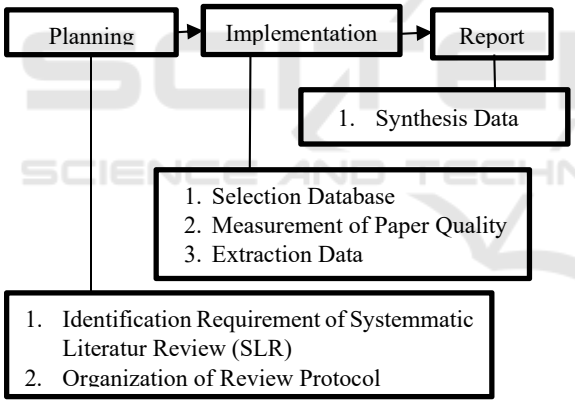

Figure 1: Methodology by Kitchenham.

3.1 Identification Requirement and Organization of Review Protocol

It is categotized as the planning stage to search for keywords of the problems, the research questions to be submitted in this study is "What are the challenges that have been proposed in the paper article that is reviewed in the implementation infrastructure using cloud computing in the education field?"

Meanwhile, the Review Protocol is used to map keywords such as what will be used and not used in the SLR that is done and this looks like in table 1.

Table 1: Research Question Structure.

Review Protocol	Scope
Population	cloud computing, education filed
Intervention	challenges, implication, infrastructure
Comparison	n/a
Outcome	challenges of infrastructure in cloud computing

3.2 Selection Database

The selection process can be shown in table 2. The inclusion criteria are should be relevant with the search keywords, written in English, published in 2015 – 2020, include all of education domain, contain the impact or challenge of cloud computing, and accesible. The exclusion criteria are articles that have no relevance with the search keyword, not include education domain, not contain the cloud computing topics, not accessible, duplicate articles, and review articles.

Table 2: Database Result.

Database	Initiation Stage	1st Stage	2nd Stage
ACM Digital Library	915	120	14
Emerald Insight	43	23	4
IEEE Xplore	36	7	2
Science Direct	83	55	10
Scopus	773	145	23

3.3 Measurement of Paper Quality

This paper quality test measurement is used to select the final paper used as an analysis, this can be seen in table 3.

Table 3: Article Quality Assessment Checklist.

Checklist	Checklist Question
C1	Does the article describe the objectives of the research clearly?
C2	Does the article provide literature review, background, and context of the research?
C3	Does the article show related works from previous studies in order to highlight the main contributions of the research?
C4	Does the article explain the architecture of the idea or method used?
C5	Does the article deliver results?
C6	Does the article produce relevant conclusion with the objective of the research?
C7	Does the article recommend future work or improvement?
C8	Indexes (Q1/Q2/Q3/Q4/conf)

3.4 Extraction Data & Synthesis Data

Result of extraction data with summary and analysis with implication or impact, challenges, and solution.

4 RESULTS & DISCUSSION

We reviewed the paper and determined the database that we used, then qualified it. Table 4 showed the resource and database we reviewed in the 2nd stage, but we could not use them. The quality of articles result with did not have 4.5 scores can be seen in table 5. For that purpose, an 8-item checklist on a five-point scale:" not at all" (0), "very little" (0.25), "a little" (0.5), "yes, but not adequate enough" (0.75), and "adequately" (1). Therefore, the possible range of scores is 0–8. We choose to include articles that scored more than 4.5 for further analysis in Figure 2.

Table 4: Database and Paper Resource.

Database	Resource Paper
Scopus	(Peniak, Franekova, & Zolotova, 2016)
Scopus	(X. He & Tian, 2017)
Scopus	(Yong, Zhang, Chen, & Zhou, 2017)

Table 5: Article Quality Assesment Result.

Source	1	2	3	4	5	6	7	8	Total
(Peniak et al., 2016)	1	1	0	0	0	0,25	0,5	1	3,75
(X. He & Tian, 2017)	1	1	0,5	0,5	0,25	0	0	1	4,25
(Yong et al., 2017)	1	1	0,25	0	0,25	0	0,25	1	3,75

We got total all of the documents with Kitchenham methodology were 1850 for initiation stage, 350 for 1st stage, and 53 for 2nd stage. This final stage, we used as an analysis. There are 3 literatures which do not fulfill the requirements. The techniques used in IaaS are convolutional neural networks, genetic algorithms, SDN approaches, LSTM-RNN networks, deep neural networks, cloud e-learning for technology (CLEM), GPU accelerated algorithm, CMBA, and SVM approach.

("challenges" or "issue") and ("education" or "university") and ("cloud computing") and ("solution") and ("infrastructure as a service") and ("storage" or "data center" or "network")

Figure 2: Requirement by Keyword.

After that, we collected the article which we done with synthesis that development of infrastructure in cloud computing as a service still has problems, such as security can not accomodate maximal yet (no backup), amount of the data used is greater, of course server development increase by complex, and the cost is expensive when using complex data because it requires a lot of space.

Cloud computing has delivered services efficiently (Ashouraie & Jafari Navimipour, 2015), (Rao, Ma, & He, 2018), (Singh & Chen, 2019), (Jayanetti & Buyya, 2019). Data centers application

play important role to support network diverse to array of requirements from latency-sensitive application such as web servers with a distributed data processing and virtual machine live-migration (Sharma, Javadi, Si, & Sun, 2017), (Chaufournier, Ali-Eldin, Sharma, Shenoy, & Towsley, 2019). One of algorithm such as PLBA and SVM algorithm can be implemented (Hamza, Abderaouf, Abdelhak, & Okba, 2017), (Gao & Yu, 2017). Another algorithm like GPU for allocating virtual infrastructure in cloud data centers can be handle large data center (Nesi, Pillon, de Assunção, & Koslovski, 2018). The technology of cloud computing virtualization provides efficient resources for end users (Metwally, Jarray, & Karmouch, 2015). The characteristics of cloud computing include manageability, scalability and availability (Jun, Jie, & DingHong, 2019), (Allison, Turner, & Allen, 2015). Cloud computing mainly provides three service delivery models and one of the type's IaaS (Shaik & Baskiyar, 2018).

There are several problems to be considered while managing resources, such as, type of resource required (physical/logical), allocation, brokering, provisioning, mapping, adaptation and estimation (Diouani & Medromi, 2019), (Alqahtany, Clarke, Furnell, & Reich, 2016), (J. He & Zhang, 2017), (Manvi & Krishna Shyam, 2014). Virtual machine introspection (VMI) is a technique whereby an observer can interact with a virtual machine client from the outside through the hypervisor (Dykstra & Sherman, 2012).

Capabilities complexity can be handled by the traffic scheduling detection to fix the problem (Yazidi, Abdi, & Feng, 2018). Many resources need to build the architecture the cloud computing data servers (Ataie et al., 2019). So, we can minimalized the financial by concerned with acquiring broadband connectivity to the cloud (Atiewi, Abuhussein, & Saleh, 2018). The efficiency allocation cloud computing also offers the usage of CPU core, memory, and disk storage based on cloud providers (Alshamrani, 2018). On the e-learning development, the role of cloud computing about availability, reliability, cost, flexibility, ease of use, and waiting time must be considered (Yuvaraj, 2016). Because it has the high influence and significant to teachers and students who use it (Rajabion, Wakil, Badfar, Nazif, & Ehsani, 2019).

Low cost computing can be integrated with web services to optimum the cost (Yuvaraj, 2015). Private cloud design still need (Makori, 2016), (E. A. Ahmed & Ahmed, 2019). Configuration and availability can be build by combination deep neural network (Chiba, Abghour, Moussaid, omri], & Rida, 2019). There are potential benefits of adopting cloud computing technology in higher education institutions (Tashkandi & Al-Jabri, 2015), (F. F. Ahmed, 2015), such as Google Docs (Amron, Ibrahim, & Chuprat, 2017), (Farzai, Shirvani, & Rabbani, 2020) and consultation services in addition to the cloud solutions offered to higher education institutions (Shorfuzzaman, Alelaiwi, Masud, Hassan, & Hossain, 2015). Collaboration solutions, infrastructure computing or virtual desktops solutions (Couto et al., 2018) offers a shift from computing as a product that is owned to as a service that is delivered from large-scale data centers or clouds (Kumar, Goomer, & Singh, 2018).

Cloud computing technology has revolutionized to make the cost become effective and resource efficient (Kertesz, Dombi, & Benyi, 2016), (Njenga et al., 2019). The deployment of a data-intensive application to a cloud poses a number of serious challenges, mainly concerning the provider and resources selection process, based on the Quality of Service expected, as well as the management of the Virtual Machines in the provider premises (Psychas et al., 2020) and Control system can use by mechatronics (Chao et al., 2015), (Cerroni et al., 2015). Component failures within the cloud infrastructure are common, but large cloud data centres should be designed to guarantee a certain level of availability to the business system (Cheng, Cao, Yu, & Ma, 2017).

Cloud systems have a high failure rate because they have many servers, which are geographically dispersed and have a large workload (Patel, Patel, & Patel, 2016). In order to ensure that cloud users can use the service, the cloud infrastructure should be designed so that their system downtime is minimal or irrelevant. The latest advances in machine learning and cloud storage provide an excellent opportunity to take advantage of the large amounts of data generated from cloud infrastructure, which provides room for predicting when components may fail or fail (Peng & Ho, 2018). Currently, mathematical and statistical modelling are the prominent approaches used for failure predictions, these are based on equipment degradation, physical models and machine learning techniques respectively (Mollajafari & Shahhoseini, 2016), (Mohammed et al., 2018), (Xu, Chen, & Alcaraz Calero, 2017), (Chawki, Ahmed, & Zakariae, 2018).

To ensure the security of business-sensitive data and information, organizations must understand the type of cloud used (Vogel, Griebler, Maron, Schepke, & Fernandes, 2016). In terms of data storage and access security (Jain, Tyagi, & Kalra, 2016), (Rahouti

& Xiong, 2019) or cloudStack (Abdulhamid, Abd Latiff, Abdul-Salaam, & Madni, 2016). Regarding optimization and cost minimization, we can also build smartphones to release SDKs for Apple iOS or Android (Ilyas, Khan, Saleem, & Alowibdi, 2019).

On a comprehensive basis, current technological advancements play a key role in the development of formal education by providing a variety of learning delivery and communication modes that can meet the needs of continuing education at low cost. Ultimately, the issue of interest to decision makers is how to use modern technology to attract distance learners to participate in collaborative learning courses. In addition, given the continuing need for universities to build capacity to take advantage of technological and teaching advances in the formal education sector.

Information security in the cloud is based on the fact that no one can access client information from the cloud, so they will not be able to understand the essence of the information. These lines ensure information security, which is the most important prerequisite for cloud clients, and can actually avoid hardware costs, and there is little understanding of configuration software. When using cloud computing in the education sector, transparency and audit control are still not working optimally, so we need a system that can use innovative technologies to read business performance requirements.

5 CONCLUSION

The aim of this work was to present a comprehensive overview of cloud computing implementation research in the education field. A systemmatic review has been conducted which included planning, implementation, and reporting phases. Various technique of cloud computing infrastructure as a service implementation in education field have been identified from 53 selected literatures. In this study also identified the challenges, such as security, data server complexity, and financial problems in educational sector.

To take on these challenges, there are several solutions are proposed, such as the selection of the best technology approach for effective and efficient use, regular and routine checks and backups, and infrastructure management to manage as effectively and efficiently as possible as needed. So that, the costs incurred will be optimal.

However, the author only about technical aspects such as security, complexity, or financial. Meanwhile, non-technical aspects also need to be considered (eg human factors). Development can continue when people can have a lot of professional experience for cloud computing adoption maximal. So, the next study deeply discusses user interest and user research on cloud computing issues.

REFERENCES

A. M. Ibrahim, F., & Hemayed, E. E. (2019). Trusted Cloud Computing Architectures for infrastructure as a service: Survey and systematic literature review. *Computers and Security*, *82*, 196–226. https://doi.org/10.1016/j.cose.2018.12.014

Abdulhamid, S. M., Abd Latiff, M. S., Abdul-Salaam, G., & Madni, S. H. H. (2016). Secure scientific applications scheduling technique for cloud computing environment using global league championship algorithm. *PLoS ONE*, *11*(7). https://doi.org/10.1371/journal.pone.0158102

Ahmed, E. A., & Ahmed, H. A. (2019). A Proposed Model for Education System Using Cloud Computing. *2018 3rd International Conference on Emerging Trends in Engineering, Sciences and Technology, ICEEST 2018*, 2018–2021. https://doi.org/10.1109/ICEEST.2018.8643331

Ahmed, F. F. (2015). Comparative Analysis for Cloud Based e-learning. *Procedia Computer Science*, *65*, 368–376. https://doi.org/https://doi.org/10.1016/j.procs.2015.09.098

Al-Samarraie, H., & Saeed, N. (2018). A systematic review of cloud computing tools for collaborative learning: Opportunities and challenges to the blended-learning environment. *Computers and Education*, *124*(March), 77–91. https://doi.org/10.1016/j.compedu.2018.05.016

Allison, M., Turner, S., & Allen, A. A. (2015). Towards interpreting models to orchestrate IaaS multi-cloud infrastructures. In *10th International Conference on Computer Science and Education, ICCSE 2015* (pp. 80–85). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ICCSE.2015.7250222

Alqahtany, S., Clarke, N., Furnell, S., & Reich, C. (2016). A forensic acquisition and analysis system for IaaS: Architectural model and experiment. In *Proceedings - 2016 11th International Conference on Availability, Reliability and Security, ARES 2016* (pp. 345–354). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ARES.2016.58

Alshamrani, S. (2018). An Efficient Allocation of Cloud Computing Resources. In *Proceedings of the 2018 Artificial Intelligence and Cloud Computing Conference* (pp. 68–75). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3299819.3299828

Amron, M. T., Ibrahim, R., & Chuprat, S. (2017). A Review on Cloud Computing Acceptance Factors. *Procedia Computer Science*, *124*, 639–646. https://doi.org/10.1016/j.procs.2017.12.200

Ashouraie, M., & Jafari Navimipour, N. (2015). Priority-based task scheduling on heterogeneous resources in the Expert Cloud. *Kybernetes*, *44*(10), 1455–1471. https://doi.org/10.1108/K-12-2014-0293

Ataie, E., Entezari-Maleki, R., Rashidi, L., Trivedi, K. S., Ardagna, D., & Movaghar, A. (2019). Hierarchical Stochastic Models for Performance, Availability, and Power Consumption Analysis of IaaS Clouds. *IEEE Transactions on Cloud Computing*, *7*(4), 1039–1056. https://doi.org/10.1109/TCC.2017.2760836

Atiewi, S., Abuhussein, A., & Saleh, M. A. (2018). Impact of Virtualization on Cloud Computing Energy Consumption: Empirical Study. In *Proceedings of the 2nd International Symposium on Computer Science and Intelligent Control*. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3284557.3284738

Cerroni, W., Gharbaoui, M., Martini, B., Campi, A., Castoldi P., P., & Callegati F., P. (2015). Cross-layer resource orchestration for cloud service delivery: A seamless SDN approach. *Computer Networks*, *87*, 16–32. https://doi.org/10.1016/j.comnet.2015.05.008

Chao, K.-M., James, A. E., Nanos, A. G., Chen, J.-H., Stan, S.-D., Muntean, I., Capelle], J. [van. (2015). Cloud E-learning for Mechatronics: CLEM. *Future Generation Computer Systems*, *48*, 46–59. https://doi.org/10.1016/j.future.2014.10.033

Chaufournier, L., Ali-Eldin, A., Sharma, P., Shenoy, P., & Towsley, D. (2019). Performance Evaluation of Multi-Path TCP for Data Center and Cloud Workloads. In *Proceedings of the 2019 ACM/SPEC International Conference on Performance Engineering* (pp. 13–24). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3297663.3310295

Chawki, E. B., Ahmed, A., & Zakariae, T. (2018). IaaS Cloud Model Security Issues on Behalf Cloud Provider and User Security Behaviors. *Procedia Computer Science*, *134*, 328–333. https://doi.org/10.1016/j.procs.2018.07.180

Cheng, S., Cao, C., Yu, P., & Ma, X. (2017). SLA-Aware and Green Resource Management of IaaS Clouds. In C. J. Yang L.T. (Ed.), *Proceedings - 18th IEEE International Conference on High Performance Computing and Communications, 14th IEEE International Conference on Smart City and 2nd IEEE International Conference on Data Science and Systems, HPCC/SmartCity/DSS 2016* (pp. 457–464). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/HPCC-SmartCity-DSS.2016.0072

Chiba, Z., Abghour, N., Moussaid, K., omri], A. [El, & Rida, M. (2019). Intelligent approach to build a Deep Neural Network based IDS for cloud environment using combination of machine learning algorithms. *Computers & Security*, *86*, 291–317. https://doi.org/10.1016/j.cose.2019.06.013

Couto, R. S., Sadok, H., Cruz, P., da Silva, F. F., Sciammarella, T., Campista, M. E. M., … Rubinstein, M. G. (2018). Building an IaaS cloud with droplets: a collaborative experience with OpenStack. *Journal of Network and Computer Applications*, *117*, 59–71. https://doi.org/10.1016/j.jnca.2018.05.016

Diouani, S., & Medromi, H. (2019). Trade-off between Performance and Energy Management in Autonomic and Green Data Centers. In *Proceedings of the 2nd International Conference on Networking, Information Systems & Security*. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3320326.3320332

Dykstra, J., & Sherman, A. T. (2012). Acquiring forensic evidence from infrastructure-as-a-service cloud computing: Exploring and evaluating tools, trust, and techniques. *Proceedings of the Digital Forensic Research Conference, DFRWS 2012 USA*, *9*, S90–S98. https://doi.org/10.1016/j.diin.2012.05.001

Elamir, A. M., Jailani, N., & Bakar, M. A. (2013). Framework and Architecture for Programming Education Environment as a Cloud Computing Service. *Procedia Technology*, *11*(Iceei), 1299–1308. https://doi.org/10.1016/j.protcy.2013.12.328

Farzai, S., Shirvani, M. H., & Rabbani, M. (2020). Multi-Objective Communication-Aware Optimization for Virtual Machine Placement in Cloud Datacenters. *Sustainable Computing: Informatics and Systems*, 100374. https://doi.org/https://doi.org/10.1016/j.suscom.2020.100374

Gao, Y., & Yu, L. (2017). Energy-Aware Load Balancing in Heterogeneous Cloud Data Centers. In *Proceedings of the 2017 International Conference on Management Engineering, Software Engineering and Service Sciences* (pp. 80–84). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3034950.3035000

Hamza, S., Abderaouf, G., Abdelhak, M., & Okba, K. (2017). A New Cloud Computing Approach Based SVM for Relevant Data Extraction. In *Proceedings of the 2nd International Conference on Big Data, Cloud and Applications*. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3090354.3090355

He, J., & Zhang, D. (2017). A Structure of Intelligent Grain Network Information Platform Based on Cloud Computing. In *Proceedings of the Second International Conference on Internet of Things, Data and Cloud Computing*. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3018896.3018978

He, X., & Tian, J. (2017). A trusted VM live migration protocol in IaaS. *Communications in Computer and Information Science*, *704*, 41–52. https://doi.org/10.1007/978-981-10-7080-8_4

Ilyas, M. U., Khan, M. M., Saleem, S., & Alowibdi, J. S. (2019). IoT-IaaS: A new public cloud service to unleash innovation in the IoT space. In L. M. D. Visvizi A. (Ed.), *Springer Proceedings in Complexity* (pp. 487–493). Springer. https://doi.org/10.1007/978-3-030-30809-4_45

Jain, S., Tyagi, P., & Kalra, S. (2016). A novel approach to cloud computing: Infrastructure as a service security. In K. P. K. Shukla B. Khatri S.K. (Ed.), *2016 5th*

International Conference on Reliability, Infocom Technologies and Optimization, ICRITO 2016: Trends and Future Directions (pp. 501–504). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ICRITO.2016.7785007

Jayanetti, A., & Buyya, R. (2019). J-OPT: A Joint Host and Network Optimization Algorithm for Energy-Efficient Workflow Scheduling in Cloud Data Centers. In *Proceedings of the 12th IEEE/ACM International Conference on Utility and Cloud Computing* (pp. 199–208). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3344341.3368822

Juma, M. K., & Tjahyanto, A. (2019). Challenges of cloud computing adoption model for higher education level in Zanzibar (the case study of Suza and Zu). *Procedia Computer Science*, *161*, 1046–1054. https://doi.org/10.1016/j.procs.2019.11.215

Jun, L., Jie, Z., & DingHong, P. (2019). Cloud Computing Virtual Machine Migration Energy Measuring Research. In *Proceedings of the 3rd International Conference on Vision, Image and Signal Processing*. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3387168.3387192

Kertesz, A., Dombi, J. D., & Benyi, A. (2016). A Pliant-based Virtual Machine Scheduling Solution to Improve the Energy Efficiency of IaaS Clouds. *Journal of Grid Computing*, *14*(1), 41–53. https://doi.org/10.1007/s10723-015-9336-9

Kumar, J., Goomer, R., & Singh, A. K. (2018). Long Short Term Memory Recurrent Neural Network (LSTM-RNN) Based Workload Forecasting Model For Cloud Datacenters. *Procedia Computer Science*, *125*, 676–682. https://doi.org/10.1016/j.procs.2017.12.087

Lin, W., Wang, J. Z., Liang, C., & Qi, D. (2011). A threshold-based dynamic resource allocation scheme for cloud computing. *Procedia Engineering*, *23*, 695–703. https://doi.org/10.1016/j.proeng.2011.11.2568

Lis, T., & Paula, B. (2015). The Use of Cloud Computing by Students from Technical University - The Current State and Perspectives. *Procedia Computer Science*, *65*(Iccmit), 1075–1084. https://doi.org/10.1016/j.procs.2015.09.050

Makori, E. O. (2016). Exploration of cloud computing practices in university libraries in Kenya. *Library Hi Tech News*, *33*(9), 16–22. https://doi.org/10.1108/LHTN-11-2015-0077

Manvi, S. S., & Krishna Shyam, G. (2014). Resource management for Infrastructure as a Service (IaaS) in cloud computing: A survey. *Journal of Network and Computer Applications*, *41*(1), 424–440. https://doi.org/10.1016/j.jnca.2013.10.004

Metwally, K., Jarray, A., & Karmouch, A. (2015). A cost-efficient QoS-aware model for cloud IaaS resource allocation in large datacenters. In *2015 IEEE 4th International Conference on Cloud Networking, CloudNet 2015* (pp. 38–43). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/CloudNet.2015.7335277

Mohammed, B., Modu, B., Maiyama, K. M., Ugail, H., Awan, I., & Kiran, M. (2018). Failure Analysis Modelling in an Infrastructure as a Service (Iaas) Environment. *Electronic Notes in Theoretical Computer Science*, *340*, 41–54. https://doi.org/10.1016/j.entcs.2018.09.004

Mollajafari, M., & Shahhoseini, H. S. (2016). A cost-optimized GA-based heuristic for scheduling time-constrained workflow applications in infrastructure clouds using an innovative feasibility-assured decoding mechanism. *Journal of Information Science and Engineering*, *32*(6), 1541–1560. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84992431104&partnerID=40&md5=40adcbdcdbf9943be1f1065e5ac5dddd

Nesi, L. L., Pillon, M. A., de Assunção, M. D., & Koslovski, G. P. (2018). GPU-Accelerated Algorithms for Allocating Virtual Infrastructure in Cloud Data Centers. In *Proceedings of the 18th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing* (pp. 364–365). IEEE Press. https://doi.org/10.1109/CCGRID.2018.00057

Njenga, K., Garg, L., Bhardwaj, A. K., Prakash, V., & Bawa, S. (2019). The cloud computing adoption in higher learning institutions in Kenya: Hindering factors and recommendations for the way forward. *Telematics and Informatics*, *38*, 225–246. https://doi.org/10.1016/j.tele.2018.10.007

Patel, K., Patel, N., & Patel, H. (2016). Efficient resource allocation strategy to improve energy consumption in cloud data centers. In *ACM International Conference Proceeding Series* (Vol. 04-05-Marc). Association for Computing Machinery. https://doi.org/10.1145/2905055.2905135

Peng, L., & Ho, P.-H. (2018). A Novel Framework of Distributed Datacenter Networks to Support Intelligent Services: Architecture, Operation, and Solutions. *IEEE Access*, *6*, 77485–77493. https://doi.org/10.1109/ACCESS.2018.2883252

Peniak, P., Franekova, M., & Zolotova, I. (2016). Model of cloud computing realisation on the base of infrastructure IaaS. *Advances in Electrical and Electronic Engineering*, *14*(2), 122–128. https://doi.org/10.15598/aeee.v14i2.1565

Psychas, A., Violos, J., Aisopos, F., Evangelinou, A., Kousiouris, G., Bouras, I., Stavroulas, Y. (2020). Cloud toolkit for Provider assessment, optimized Application Cloudification and deployment on IaaS. *Future Generation Computer Systems*, *109*, 657–667. https://doi.org/10.1016/j.future.2018.09.016

Rahouti, M., & Xiong, K. (2019). Understanding global environment for network innovations (GENI) and software-defined networking (SDN) for computer networking and security education. In *ASEE Annual Conference and Exposition, Conference Proceedings*. American Society for Engineering Education. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85078769886&partnerID=40&md5=eb009b12f66c4a868fb7731fea522f8f

Rajabion, L., Wakil, K., Badfar, A., Nazif, M., & Ehsani, A. (2019). A new model for evaluating the effect of cloud computing on the e-learning development.

Journal of Workplace Learning, *31*(5), 324–344. https://doi.org/10.1108/JWL-12-2018-0156

Rao, N. S. V, Ma, C. Y. T., & He, F. (2018). Defense Strategies for Multi-Site Cloud Computing Server Infrastructures. In *Proceedings of the 19th International Conference on Distributed Computing and Networking*. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3154273.3154344

Shaik, S., & Baskiyar, S. (2018). Resource and service management for fog infrastructure as a service. In *Proceedings - 3rd IEEE International Conference on Smart Cloud, SmartCloud 2018* (pp. 64–69). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/SmartCloud.2018.00019

Sharma, Y., Javadi, B., Si, W., & Sun, D. (2017). Reliable and Energy Efficient Resource Provisioning and Allocation in Cloud Computing. In *Proceedings of The10th International Conference on Utility and Cloud Computing* (pp. 57–66). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3147213.3147218

Shorfuzzaman, M., Alelaiwi, A., Masud, M., Hassan, M. M., & Hossain, M. S. (2015). Usability of a cloud-based collaborative learning framework to improve learners' experience. *Computers in Human Behavior*, *51*, 967–976. https://doi.org/https://doi.org/10.1016/j.chb.2014.10.002

Singh, J., & Chen, J. (2019). Optimizing Energy Consumption for Cloud Computing: A Cluster and Migration Based Approach (CMBA). In *Proceedings of the 2019 3rd International Conference on Computer Science and Artificial Intelligence* (pp. 28–32). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3374587.3374594

Sun, P. J. (2020). Security and privacy protection in cloud computing: Discussions and challenges. *Journal of Network and Computer Applications*, *160*(August 2019), 102642. https://doi.org/10.1016/j.jnca.2020.102642

Suryono, R. R., Purwandari, B., & Budi, I. (2019). Peer to peer (P2P) lending problems and potential solutions: A systematic literature review. *Procedia Computer Science*, *161*, 204–214. https://doi.org/10.1016/j.procs.2019.11.116

Tashkandi, A. N., & Al-Jabri, I. M. (2015). Cloud computing adoption by higher education institutions in Saudi Arabia: An exploratory study. *Cluster Computing*, *18*(4), 1527–1537. https://doi.org/10.1007/s10586-015-0490-4

Vogel, A., Griebler, D., Maron, C. A. F., Schepke, C., & Fernandes, L. G. (2016). Private IaaS Clouds: A Comparative Analysis of OpenNebula, CloudStack and OpenStack. In P. G. A. Cotronis Y. Daneshtalab M. (Ed.), *Proceedings - 24th Euromicro International Conference on Parallel, Distributed, and Network-Based Processing, PDP 2016* (pp. 672–679). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/PDP.2016.75

Xu, X., Chen, Y., & Alcaraz Calero, J. M. (2017). Distributed decentralized collaborative monitoring architecture for cloud infrastructures. *Cluster Computing*, *20*(3), 2451–2463. https://doi.org/10.1007/s10586-016-0675-5

Yazidi, A., Abdi, H., & Feng, B. (2018). Data Center Traffic Scheduling with Hot-Cold Link Detection Capabilities. In *Proceedings of the 2018 Conference on Research in Adaptive and Convergent Systems* (pp. 268–275). New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3264746.3264797

Yong, B., Zhang, G., Chen, H., & Zhou, Q. (2017). Intelligent monitor system based on cloud and convolutional neural networks. *Journal of Supercomputing*, *73*(7), 3260–3276. https://doi.org/10.1007/s11227-016-1934-1

Yuvaraj, M. (2015). Problems and prospects of implementing cloud computing in university libraries: A case study of Banaras Hindu University library system. *Library Review*, *64*(8–9), 567–582. https://doi.org/10.1108/LR-01-2015-0007

Yuvaraj, M. (2016). Perception of cloud computing in developing countries: A case study of Indian academic libraries. *Library Review*, *65*(1–2), 33–51. https://doi.org/10.1108/LR-02-2015-0015