# An effective analysis of Metaheuristic optimization algorithms for scheduling in Cloud Computing

M.S.Sudheer Research Scholar

*Department of CSE, Centurion University*

*Parlakhemudi, Odisha India*

*mssudheer2015@gmail.com.*

Dr M Vamsi Krishna

*Professor, Department of CSE*

*Chaitanya Engineering College, Kakinada*

*vkmangalampalli@gmail.com*

Dr. Anurag

*Professor, Department of Computer Science and Engineering,*

*Centurion University,Parlakhemudi, Odisha India*

*anurag@cutm.ac.in*

**Abstract--Cloud Computing is a paradigm which brought revolution in the IT industry. This technology gives on demand services to the users by using pay –as-you-go model in an effective way through virtualization. Cloud computing provides different services based on the user requirement. Scheduling in cloud computing is a NP hard problem so that lot of researchers are using different optimization algorithms. The existing algorithms addressed only few metrics like makepan, resource utilization, execution cost and processing cost. The existing scheduling algorithms failed to meet the metrics like average migration time, electricity price per unit cost and memory utilization. In this paper we have studied about different scheduling algorithms which uses meta heuristic optimization techniques and done a comparison study on the existing algorithms and given a few research directions.**

**Keywords- Electricty price per unit cost, Average Migration Time, Sccheduling, Cloud Computing, Resource utilization, Execution Cost, Processing Cost, makespan, Metaheuristic algorithms.**

## 1. INTRODUCTION

Cloud Computing is a model which provides the services to the users on demand basis with the corresponding Service Level Agreements with the cloud provider. National Institute of Standards and Technology (NIST) defined Cloud Computing can be defined as a paradigm for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources[1]. Cloud Computing have different types of architectures. 1. Layered Architecture 2. Market oriented Architecture.

Layered Architecture- The layered architecture model comprises of different layers like infrastructure, platform and application and these can be posed as services to the users. These services can be provided to the users on demand basis. This architecture focuses on how to provide the services to the users rather than concentrating on the pricing models.Market oriented Architecture- The purpose of Market-oriented architecture is to provide the effective resource allocations to the cloud users based on the Service Level Agreements made with the cloud provider. This architecture consists of Users/brokers, SLA Resource allocator, Virtual Machines (VM) and physical Machines. Cloud provider includes the cost of the resources in the cloud in SLAs. The cost of the resources is calculated based on the pricing model chosen by the cloud provider. Task Scheduling can be defined as assigning the virtualized resources to the particular job for the specified amount of time. The goal of scheduling is to effectively utilize the cloud resources. Task Scheduling is a biggest challenge in Cloud Computing. The traditional Scheduling algorithms are not suitable for scheduling in cloud computing as the resources provisioned and deprovisioned to the cloud is dynamic so that proper scheduling algorithm is necessary in cloud computing.As Cloud Computing is a market oriented uitility. Optimum provision of resources in the cloud computing is a big challenge and it is an issue for the cloud provider to provide the resources to the user in an economic way and from the user perspective it may affect the Quality of services requirements[2].

*Scheduling in Cloud Computing can be done in three layers:*

Scheduling in the Application Layer- To schedule the Virtual Resources to support software and user applications with optimal QOS and efficiency [2].

Scheduling in Virtualization Layer- It is used to map the Virtual Resources to the Physical resources with optimal load balance, energy conservation and Cost effectiveness [2].

Scheduling Deployment Layer- which concerns about the infrastructure, Data Routing and Server Placement [2].

The metrics mainly effecting the performance of the scheduling in cloud computing are

*CPU Utilization*- The percentage of the time CPU is assigned with some resource or process.

*Wait time* - The amount of time a process waits in the Queue.

*Response time* - The amount of time required for a process from the submitted time to output obtained time.

*Turnaround Time* - The amount of time that taken by a process from submission of the input to till the end of the process completion.

*Memory Utilization* – The amount of memory that can be utilized when the process is under execution.

Throughput - Number of Processes finished per unit time.

## 2. LITERATURE REVIEW

In the above section, we have mentioned different metrics like CPU utilization, wait time, Response time and Turnaround time, memory utilization and throughput. In this section we have studied about the existing algorithms with these metrics. Abdullahi, Mohammed, and Md Asri Ngadi et.al, Proposed a Discrete Symbiotic Organism search algorithm[3] is implemented which is a meta heuristic algorithm is used to reduce the makespan and increase the system utilization. The algorithm reduces mutualism, commensalism and parasitic relationship to improve the given function. This algorithm was implemented by using cloudsim toolkit and compared with the PSO and DSOS outperforms than PSO interms of makespan and system utilization. Verma, Amandeep, and Sakshi Kaushal.et.al,[4] proposed a Hybrid Particle swarm optimization technique is implemented which is a meta heuristic algorithm to address the parameters like makespan, cost and energy consumption in the workflow scheduling in IaaS clouds to achieve the multi objective functions using non dominance sorting procedure.

Alboaneen, Dabiah Ahmed, Huaglory Tianfield, and Yan Zhang et.al, [5] proposed an algorithm to minimize the total execution cost of the tasks by keeping the total completion time within the time bound. The authors implemented the algorithm in the cloudsim toolkit and simulated the algorithm and compared it with Shortest Task Scheduling algorithm and Particle Swarm Optimization algorithm and it outperforms both of these algorithms. Keshanchi, Bahman, Alireza Souri, and Nima Jafari Navimipour et.al,[6]proposed a new genetic algorithm which addresses the metrics makepan and execution time of the tasks. Initially they have proposed a model for checking the correctness of the algorithm. They have extracted the required specifications using Linear Temporal Logic (LTL) formulas and to get the best performance they have used Labelled Transition Method(LTS). The algorithm was simulated using NuSMV and PAT model checkers.The proposed algorithm was compared with the HEFt-B, HEFT-T and HEFT-L interms of makespan and execution time. The makespan and execution time comparatively decreased with the above mentioned algorithms. Rodriguez, Maria Alejandra, and Rajkumar Buyya et.al,[7] proposed a resource provisioning and scheduling framework to effectively schedule the resources in IaaS clouds while minimizing the total execution cost. This algorithm was implemented by using cloudsim toolkit by using PSO algorithm and compared with the different algorithms and the proposed method is outperformed by reducing the total execution cost and meeting deadline constraints. Chatterjee, Amlan, et al.[8] proposed an effective resource provisioning algorithm to schedule the tasks in the datacenters. Authors used Particle swarm based optimization technique to get the convergence towards the solution and addressed to minimize the job completion time. They have implemented the algorithm in the cloudsim toolkit and evaluated the performance of the algorithm to schedule the tasks in the datacenters.

Duan, Hancong, et al.[9], proposed to schedule the task in an effective way by reducing the energy consumption and guaranteeing the quality of service (QoS). To do that a predictive mathematical model was developed by the authors to predict whether to schedule the task based on the load trend prediction from the real time workloads from the traces of the Google compute cluster. This algorithm reduces the energy consumption of the system resources and increases the resource utilization. Shojafar, Mohammad, et al.[10], proposed an algorithm to reduce the execution time, cost and average degree of imbalance.They have modified the standard genetic algorithm and used fuzzy theory to devlop the steady state genetic algorithm to reduce the makespan. This FUGE model was implemented by using cloudsim toolkit. Kaur, Parmeet, and Shikha Mehta et.al,[11] proposed an algorithm named as augmented shuffled Frog Leaping algorithm (ASFLA) technique which can be used to effectively provision the resources in the IaaS cloud environments. This algorithm was simulated in the customized java simulator and achieved the minimum execution cost and meeting the workflow deadlines.

Parthasarathy, Sellaperumal, and Chinnasami Jothi Venkateswaran,et.al,[12] proposed an iterative algorithm using the oppositional group search technique to effectively provision the resources in the cloud. The algorithm works based on the iterative approach and the members in the population were separated based on the fitness function they have chosen and perform different operations and gets new members and calculates the fitness for the new members iteratively until they get the stable best member. This algorithm was simulated in the cloudsim simulator and compared with the GSO and PSO algorithms and the proposed algorithm was outperformed on the above mentioned algorithms interms of execution time. Domanal, Shridhar G., and G. Ram Mohana Reddy et.al,[13] proposed modified throttled algorithm which is used to reduce the response time and to distribute the tasks uniformly among the virtual machines. This algorithm was simulated using cloud analyst simulator and compared with the existing algorithms like FCSFS and Round Robin. It outperforms both the FCFS and Round Robin in terms of response time.

Pandey, Suraj, et al.[14],proposed an algorithm which is used to minimize the total cost of execution of workflows of Appliactions. This Can be evaluated by using PSO algorithm and checked the convergence of PSO interms of total cost of execution by varying the communication cost and execution cost of computational resources. It minimizes the total execution cost when using PSO algorithm and it outperforms when compared with the BRS (Best Resource Selection Algorithm). Zhong, Hai, Kun Tao, and Xuejie Zhang et.al [15] proposed an algorithm which addresses the request allocation problem in the IaaS clouds. They have employed an improved genetic algorithm to get the optimization for the resource allocation in the scheduling of VMs. This algorithm was implemented in the JGAP (Java Genetic Algorithm Package) simulator which is developed by the authors. The utilization rate of the computing resources increased twice when compared to the Traditional Genetic Algorithm. Tawfeek, Medhat A., et al [16], proposed an algorithm which is used to reduce the makespan of the given set of tasks. For this the authors chosen ACO (Ant Colony Optimization) technique to address this issue and compared with the traditional algorithms like FCFS and Round Robin. The proposed algorithm minimizes the makespan of the given set of tasks when compared with the traditional scheduling algorithms. This algorithm was simulated in the cloudsim toolkit. Vinothina, V., and R. Sridaran [17], proposed an approach which is used to minimize the makespan, resource cost and increase the resource utilization for heterogeneous workflows in cloud. The algorithm was implemented by using ACO (Ant Colony Optimization) algorithm.

Lal, Arvind, and C. Rama Krishna et.al,[18] proposed an algorithm which is used to minimize the total execution cost and time while meeting the deadline constraints of the workflow. This algorithm was implemented in workflow simulator in which the program was executed in the eclipse to calculate the total execution time and total cost. The proposed algorithm was compared with the existing genetic algorithms and got to know that total execution cost and time were minimized with the proposed algorithm (ACO). Moon, YoungJu, et al.[19], proposed an algorithm to improve the resource utilization in the cloud computing environment by using a slave ants based ant colony optimization algorithm. For this they have used diversification and reinforcement methods with the slave ants to solve the global optimization problem. It is compared with the ACO (Ant Colony Based optimization) algorithm and proved that SACO (Slave Based Ant Colony Optimization) algorithm improves the resource utilization in the Cloud computing environments.

Gupta, Ashish, and Ritu Garg et.al,[20] proposed this algorithm to reduce the makespan of the given taskset and to improve the load balancing among the given virtual machines. They have used Load balancing Ant Colony Optimization algorithm to meet their requirements and they have compared with the Non dominant Sorting Genetic algorithms which shows that reduction in makespan and better load balancing for the given taskset. This algorithm was simulated in the CloudSim toolkit. Sethi, Neha, Surjit Singh, and Gurvinder Singh.et.al,[21] proposed an algorithm which is used to achieve multiple objectives such as effective scheduling and load balancing. Honey Bee behavior Optimization algorithm is used to achieve these requirements as other Meta heuristics algorithms were slow convergent algorithms. With this technique the effective scheduling can be done and load balance among highly loaded High ended servers to under utilized High end servers. This algorithm was implemented in the MATLAB tool with parallel processing toolbox. The results were compared with the existing algorithms like ACO, Game theory and it outperformed over the existing algorithms. Manasrah, Ahmad M., and Hanan Ba Ali et.al,[22] proposed algorithm which reduces the makespan and processing cost and load balancing of the interdependent tasks in the heterogeneous environments. This algorithm was simulated in the Workflow simulator and the results were compared with the existing algorithms like PSO,GA etc. The proposed algorithm has better load balancing and minimizes the processing cost and makespan. Lakra, Atul Vikas, and Dharmendra Kumar Yadav.et.al,[23] proposed this algorithm to increase the throughput and reduce the overall execution time and to optimize the scheduling in cloud computing. This algorithm was simulated in cloudsim and compared with the existing scheduling algorithms which achieve a single objective.

Table 1: Summary of Meta Heuristic Scheduling Algorithms in Cloud Computing

| **Authors** | **Objective** | **Experiment Type** | **Tools Used** |
|---|---|---|---|
| Abdullahi, Mohammed, and Md Asri Ngadi et.al [3] | To reduce the makespan and increases system utilization. | Simulation | Cloudsim |
| Verma, Amandeep, and Sakshi Kaushal. et.al,[4] | To reduce the makespan, Processing cost and energy consumption. | Simulation | Cloudsim |
| Alboaneen, Dabiah Ahmed, Huaglory | To minimize the Total execution | Simulation | Cloudsim |

| | | | |
|---|---|---|---|
| Tianfield, and Yan Zhang et.al,[5] | cost | | |
| Keshanchi, Bahman, Alireza Souri, and Nima Jafari Navimipour et.al,[6] | To reduce the makespan and to minimize the execution cost | Simulation | NuSMV model and PAT checkers |
| Rodriguez, Maria Alejandra, and Rajkumar Buyya et.al,[7] | To minimize the total execution cost | Simulation | Cloudsim |
| Chatterjee, Amlan, et al.[8] | To minimize the job Completion time | Simulation | Cloudsim |
| Duan, Hancong, et al.[9] | To reduce the energy consumption of the system resources and increases resource utilization | Simulation | Google Compute cluster |
| Shojafar, Mohammad, et al.[10] | To reduce the execution time, cost | Simulation | Cloudsim |
| Kaur, Parmeet, and Shikha Mehta,et.al[11] | To achieve the minimum execution cost and meeting the workflow deadlines | Simulation | Customised Java Simulator |
| Parthasarathy, Sellaperumal, and Chinnasami Jothi Venkateswaran.et.al,[12] | To minimize the execution time | Simulation | Cloudsim |
| Domanal, Shridhar G., and G. Ram Mohana Reddy et.al,[13] | To reduce the Response time and uniform distribution of load | Simulation | Cloud Analyst |
| Pandey, Suraj, et al.[14] | To minimize the total execution cost | Mathematical Model | --------- |
| Zhong, Hai, Kun Tao, and Xuejie Zhang et.al,[15] | To effectively allocate the Virtual machines in a flexible manner to improve the resource utilization. | Simulation | JGAP |
| Tawfeek, Medhat A., et al [16] | To minimize the makespan | Simulation | Cloudsim |
| Vinothina, V., and R. Sridaran [17] | To minimize the total execution cost while meeting the deadline | Simulation | Workflowsim |

| | | | |
|---|---|---|---|
| | constraints | | |
| Lal, Arvind, and C. Rama Krishna et.al,[18] | To improve the resource utilization | No Experiments<br>Mathematical model | -- |
| Gupta, Ashish, and Ritu Garg et.al[20] | To reduce the makespan and better load balancing | Simulation | Cloudsim |
| Sethi, Neha, Surjit Singh, and Gurvinder Singh et.al,[21] | Effective scheduling and load balancing | Simulation | MATLAB tool |
| Manasrah, Ahmad M., and Hanan Ba Ali [22] | To reduce the makespan and processing cost | Simulation | Workflowsim |
| Lakra, Atul Vikas, and Dharmendra Kumar Yadav.et.al,[23] | To increase throughput and reduce the overall execution time | Simulation | Cloudsim |

In the table1, we have mentioned the summary of Meta Heuristic Scheduling algorithms in Cloud Computing studied in the literature survey, the way of implementation and the tools used for the implementation.

From the table 2, we can observe that many of the below mentioned algorithms addresses the metrics like makespan, resource utilization, execution time and processing cost. The existing algorithms not addressing the single metrics like Average Migration time and electricity price per unit cost, memory utilization and the combination of the parameters like memory utilization and Response time. From the below table we can clearly state that none of the algorithms doesn't address the metric memory utilization.

Table 2: Comparison of scheduling algorithms

| **Authors** | **Metrics** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Makespan** | **Resource** | **Response** | **Execution time** | **Memory** | **Total Executi** | **Processing** | **Avg Migrati** | **Electricty** |
| Abdullahi, Mohammed, and Md Asri Ngadi et.al | √ | √ | - | - | - | - | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| [3] | | | | | | | | | |
| Verma, Amandeep, and Sakshi Kaushal. et.al,[4] | √ | - | - | - | - | - | √ | - | - |
| Alboaneen, Dabiah Ahmed, Huaglory Tianfield, and Yan Zhang et.al,[5] | - | - | - | - | - | √ | - | - | - |
| Keshanchi, Bahman, Alireza Souri, and Nima Jafari Navimipour et.al,[6] | √ | - | - | - | - | √ | - | - | - |
| Rodriguez, Maria Alejandra, and Rajkumar Buyya et.al,[7] | - | - | - | - | - | √ | - | - | - |
| Duan, Hancong, et al.[9] | - | √ | - | - | - | - | - | - | - |
| Shojafar, Mohammad, et al.[10] | - | - | -- | √ | - | √ | - | - | - |
| Kaur, Parmeet, and Shikha Mehta,et.al[11] | - | - | - | - | - | √ | - | - | - |
| Parthasarathy, Sellaperumal, and Chinnasami Jothi Venkateswaran.et.al,[12] | - | - | - | √ | - | - | - | - | - |
| Domanal, Shridhar G., and G. Ram Mohana Reddy et.al,[13] | - | - | √ | - | - | - | - | - | - |
| Pandey, Suraj, et al.[14] | - | - | - | - | - | √ | - | - | - |
| Zhong, Hai, Kun Tao, and Xuejie Zhang et.al,[15] | - | √ | - | - | - | - | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tawfeek, Medhat A., et al [16] | √ | - | - | - | - | - | - | - | - |
| Lal, Arvind, and C. Rama Krishna et.al,[18] | - | - | - | - | - | √ | - | - | - |
| Moon, YoungJu, et al.[19] | - | √ | - | - | - | - | - | - | - |
| Gupta, Ashish, and Ritu Garg et.al[20] | √ | - | - | - | - | - | - | - | - |
| Manasrah, Ahmad M., and Hanan Ba Ali [22] | √ | - | - | - | - | - | √ | - | - |
| Lakra, Atul Vikas, and Dharmendra Kumar Yadav.et.al,[23] | - | - | - | √ | - | - | - | - | - |

## 3. RESEARCH DIRECTIONS:

Based on the comparison study of the existing scheduling algorithms we can know that lot of researchers are implementing the scheduling algorithms using nature inspired algorithms. We can say that scheduling in the cloud computing is NP hard Problem we can optimize the scheduling in an effective way by using different Meta heuristic algorithms.

We have studied a good number of meta heuristic algorithms for scheduling in the cloud computing in the literature survey. From that we can give some of the research directions inorder to the research work in the area of scheduling in cloud computing using these metaheuristic algorithms.

From the above table 2 no existing algorithms are addressing about the below metrics.

1. *Average Migration time*: This metric is very much important when we want to migrate our workload from one virtual machine to another virtual machine. If the migration time is so high it may impact the response time and as well as the quality of the service of the cloud [24]. If the average migration time is less we can migrate our task to the corresponding Virtual machine with less process cost and less execution time. This metric is to be considered as one of the important metric in cost based scheduling.

2. *Electricty price per unit cost:* As cloud is geographically distributed around the globe [24] the cost of the electricity per unit cost is different from region to region in the cloud. Inorder to benifit both the cloud provider and the cloud user we need to migrate the tasks to the regions where the electricity per unit cost is less.
3. *Memory utilization:* The corresponding factor plays a key role in scheduling. Whenever a task is to be scheduled in the cloud, the resources in the cloud will be in under utilized mode. If the memory is to be utilized in an effective way in cloud we can schedule the tasks in the cloud in an effective way.
4. *Memory utilization and Response time*: If the memory can be utilized in an effective way to schedule the task the Response time also decreases there by resources can be provisioned in an effective way.
5. *Communication cost:* When we are migrating the task to the another virtualized resource where the electricity price per unit cost is less then the communication cost overhead incurs at the time of migration. But it can be optimized when it is to be migrated to the another virtualized resource for effective scheduling.

## 4. CONCLUSION AND FUTURE WORK:

There are good number of task scheduling algorithms was proposed by different authors but as Task scheduling is a NP Hard problem finding the optimal algorithm for task scheduling in the cloud computing is still a hottest research because of the workloads in the cloud. In this Paper, we have studied about the existing scheduling algorithms in the cloud computing. The majority of the existing algorithms address only the metrics like makesspan, resource utilization and they haven’t addressed the metrics like Average migration time, Electricty price per unit cost, memory utilization and the combination of the parameters like memory utilization and Response time. In future, we want to propose a priority based scheduling algorithm in which we want to consider all the metrics like Average Migration time, electricity price per unit cost and Memory utilization.

## REFERENCES

[1] https://www.nist.gov/news.../final-version-nist-cloud-computingdefinition-published.

[2]Zhan, Zhi-Hui, et al. "Cloud computing resource scheduling and a survey of its evolutionary approaches." ACM Computing Surveys (CSUR) 47.4 (2015): 63.

[3] Abdullahi, Mohammed, and Md Asri Ngadi. "Symbiotic Organism Search optimization based task scheduling in cloud computing environment." Future Generation Computer Systems 56 (2016): 640-650

[4] Verma, Amandeep, and Sakshi Kaushal. "A hybrid multi-objective Particle Swarm Optimization for scientific workflow scheduling." Parallel Computing 62 (2017): 1-19

[5] Alboaneen, Dabiah Ahmed, Huaglory Tianfield, and Yan Zhang. "Glowworm swarm optimisation based task scheduling for cloud computing." Proceedings of the Second International Conference on Internet of things and Cloud Computing. ACM, 2017

[6] Keshanchi, Bahman, Alireza Souri, and Nima Jafari Navimipour. "An improved genetic algorithm for task scheduling in the cloud environments using the priority queues: formal verification, simulation, and statistical testing." Journal of Systems and Software 124 (2017): 1-21

[7] Rodriguez, Maria Alejandra, and Rajkumar Buyya. "Deadline based resource provisioningand scheduling algorithm for scientific workflows on clouds." IEEE transactions on Cloud Computing 2.2 (2014): 222-235

[8] Chatterjee, Amlan, et al. "Job scheduling in cloud datacenters using enhanced particle swarm optimization." Convergence in Technology (I2CT), 2017 2nd International Conference for. IEEE, 2017

[9] Duan, Hancong, et al. "Energy-aware scheduling of virtual machines in heterogeneous cloud computing systems." Future Generation Computer Systems 74 (2017): 142-150

[10] Shojafar, Mohammad, et al. "FUGE: A joint meta-heuristic approach to cloud job scheduling algorithm using fuzzy theory and a genetic method." Cluster Computing 18.2 (2015): 829-844

[11] Kaur, Parmeet, and Shikha Mehta. "Resource provisioning and work flow scheduling in clouds using augmented Shuffled Frog Leaping Algorithm." Journal of Parallel and Distributed Computing 101 (2017): 41-50

[12] Parthasarathy, Sellaperumal, and Chinnasami Jothi Venkateswaran. "Scheduling jobs using oppositional-GSO algorithm in cloud computing environment." Wireless Networks23.8 (2017): 2335-2345

[13] Domanal, Shridhar G., and G. Ram Mohana Reddy. "Load balancing in cloud computingusing modified throttled algorithm." Cloud Computing in Emerging Markets (CCEM), 2013 IEEE International Conference on. IEEE, 2013

[14]Pandey, Suraj, et al. "A particle swarm optimization-based heuristic for scheduling workflow applications in cloud computing environments." Advanced information networking and applications (AINA), 2010 24th IEEE international conference on. IEEE, 2010

[15] Zhong, Hai, Kun Tao, and Xuejie Zhang. "An approach to optimized resource scheduling algorithm for open-source cloud systems." ChinaGrid Conference (ChinaGrid), 2010 Fifth Annual. IEEE, 2010

[16] Tawfeek, Medhat A., et al. "Cloud task scheduling based on ant colony optimization." Computer Engineering & Systems (ICCES), 2013 8th International Conference on. IEEE, 2013

[17] Vinothina, V., and R. Sridaran. "An Approach for Workflow Scheduling in Cloud Using ACO." Big Data Analytics. Springer, Singapore, 2018. 525-531

[18] Lal, Arvind, and C. Rama Krishna. "Critical Path-Based Ant Colony Optimization for Scientific Workflow Scheduling in Cloud Computing Under Deadline Constraint." Ambient Communications and Computer Systems. Springer, Singapore, 2018. 447-461

[19] Moon, YoungJu, et al. "A slave ants based ant colony optimization algorithm for task scheduling in cloud computing environments." Human-centric Computing and Information Sciences 7.1 (2017): 28

[20] Gupta, Ashish, and Ritu Garg. "Load balancing based task scheduling with ACO in cloud computing." Computer and Applications (ICCA), 2017 International Conference on. IEEE, 2017

[21] Sethi, Neha, Surjit Singh, and Gurvinder Singh. "Multiobjective Artificial Bee Colony based Job Scheduling for Cloud Computing Environment." (2018)

[22] Manasrah, Ahmad M., and Hanan Ba Ali. "Workflow scheduling using hybrid GA-PSO algorithm in cloud computing." Wireless Communications and Mobile Computing2018 (2018)

[23] Lakra, Atul Vikas, and Dharmendra Kumar Yadav. "Multi-objective tasks scheduling algorithm for cloud computing throughput optimization." Procedia Computer Science 48 (2015): 107-113

[24] Sudheer, M. S., et al. "An effective analysis on various scheduling algorithms in cloud computing." Inventive Computing and Informatics (ICICI), International Conference on. IEEE, 2017.