A Comprehensive review on Task Scheduling Algorithms in Cloud Computing

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Abstract:

Cloud computing is one of the most important technologies now a day that allows user to access different types of computing resources like software, hardware and platform as a services from remote place through the internet. Cloud computing is distinguish services compare to traditional computing service by its implementation costs, reliability, accessibility, scalability, on demand services as per user requirement and pay as usage services. In these services, we can update our software automatically in server side and it is serving services to millions of user simultaneously. Cloudlet is working as intermediate processing device between cloud computing and mobile devices to reduce latency of user request. Number of existing Task scheduling approaches available to boosting the task scheduling in cloudlet computing but it is unresolved issues as per user demand. Therefore, we need to effective task scheduling algorithms to meet this user demand and provide effective service to user as per SLA. Task scheduling is essential part in computing to achieve accuracy and correctness on task completion. In this paper, We gives details survey idea about various task scheduling algorithms used in the cloud computing environment by different researchers and we also study about different parameters like completion time, throughput, and cost to evaluate different scheduling algorithm in cloud computing system

Keywords: Cloud computing, cloudlet Computing, Task scheduling, Effective Scheduling

1. INTRODUCTION

Cloud computing is a new derived technology from grid computing and distributed computing and refers to using computing resources (hardware, software, and platforms) as a service and provided to beneficiaries on demand through the Internet. It is the first technology that uses the concept of commercial implementation of computer science with public users through internet. It relies on sharing resources among users through the use of the virtualization technique. High performance service can be provided by a cloud computing, based on distributing workloads across all various resources fairly and effectively to get less waiting time, execution time, maximum throughput, and exploitation of resources effectively. Still, there are many challenges prevalent in cloud computing, Task scheduling and load balance are the biggest once yet because it is considered the main factors that control other performance criteria such as availability, scalability, and power consumption.

To gain the maximum benefit from cloud computing, developers must design mechanisms that optimize the use of architectural and deployment paradigms. The role of Virtual Machine's (VMs) has emerged as an important issue because, through virtualization technology, it makes cloud computing infrastructures to be scalable as per user demand and pay as per usage of services. Therefore developing on optimal scheduling of virtual machines in cloud computing is an important issue nowadays.

1.2 Cloud Computing Evolution

Cloud computing is basically seen as an evaluation. There are some roots that led to cloud computing. It is because of coming of web services and web service standards that today we can create, package and use

powerful services online. So, it becomes the first root. The next and most important reason for evaluation of cloud is grid computing. Grid computing means to collect all the resources which are distributed in large area and get easy access to them. Since different resources have different software configurations, compilers, libraries and runtime environments which are facing different issues. Virtualization technology did the needful to enable hosting of different software applications on a single physical platform.

Cloud Computing Layers and Types of Cloud

Below is the classification of clouds based on the provided capability and services, at abstraction level. The architecture depicted in the figure is layered, i.e, the higher layer services can be constituted from those at the below layer. The cloud computing architecture has three layers   Figure 1 shows different layers of cloud architecture.

1.   Infrastructure as a Service (IaaS): This layer delivers hardware components (like server ,storage, networking hardware, as well as the virtualization or hypervisor layer) to user

2.   Platform as a Service (PaaS): Cloud application developers are the users of this layer.Automatic scaling, load balancing and integration with other services (e.g. email services) are the major benefits to cloud application developer.

3.   Software as a Service (SaaS): This layer hosts the software and provide to the customer through Internet. It reduces the purchase and maintenance cost of the customer.

Figure 1   Cloud Computing Layers Services

Deployment Models In Cloud Computing

According to the physical location and distribution, there can be four types of deployment models in cloud computing. **Public clouds** are maintained by third party. All the services are available to general public on the basis of pay-as-you-go. Public deployment models in cloud are best for organizations with high and unsteady demands. **Private Cloud** is a cloud model that can be used by a company for its internal/ partner use. It can run within the company's own data center. It provides an organization high security and proper management. **Hybrid deployment** model is when the public and private clouds are used together; i.e., the public cloud services are used when private cloud becomes insufficient. Organization can use private cloud to secure its data and, public cloud can be used for customer interaction. **Community Cloud** model is the one shared by several organizations having common concerns. It is managed and hosted

Figure-2: Cloud Computing Deployment Models

2 RESEARCHES IN SCHEDULING ALGORITHMS FOR CLOUDCOMPUTING

Scheduling in cloud computing is categorized in various ways. **'Task'** is the first category used to classify algorithms. Tasks can be independent tasks or dependent. The tasks which do not communicate each other are known as independent Task. While those Tasks are require a proper sequence for execution are known as dependent tasks. As given in figure 3, and figure 4, task scheduling algorithms can be static or dynamic.

2.1 Classification of Scheduling

Static scheduling

In static scheduling, tasks are simultaneously given to processor and are submitted to available resources, i.e., scheduling decisions are taken before tasks are submitted. The static scheduling algorithms can be further categorized as guided random search based and heuristic based. Random choices are made in guided random search based. On the other way, heuristics algorithms make realistic decisions, not to give optimal schedule but reasonable cost or other resource constraint. **Dynamic Scheduling**

In case of dynamic scheduling, number of tasks, machine resource location, and arrival time of tasks are not known before the tasks are submitted. Dynamic scheduling is further classified into two types: batch mode and online mode. In batch mode, all the tasks are first arranged into a set and then allocated after a fixed periodic time. In online mode task are scheduled as soon as they arrive in the system.

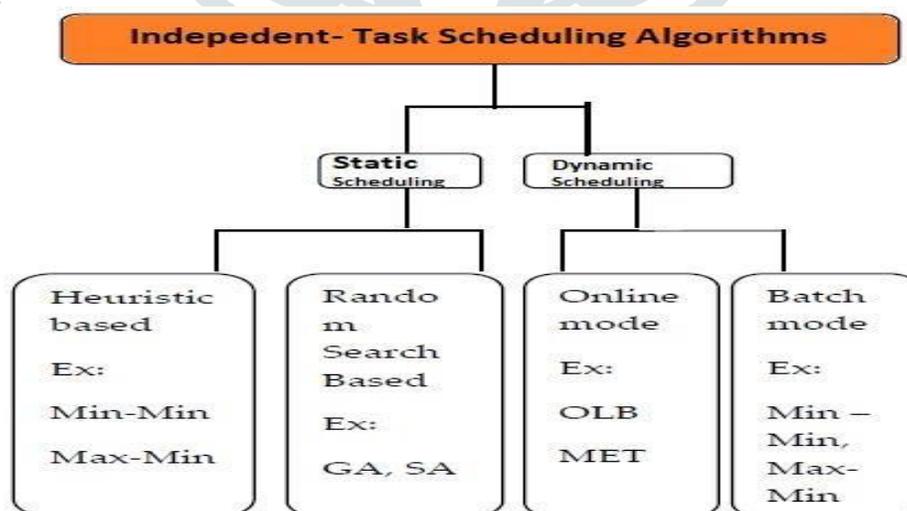### 2.2 Scheduling Independent Tasks

Figure 3 scheduling algorithms for independent tasks.

The Min-Min heuristic: In this algorithm, the first step is to calculate minimum execution time(c) for each task and the consequent tasks with minimum 'c' is assigned to a machine.[10] [11].The Max-Min heuristic: The logic behind the max-min heuristic is just in converse to the min-min heuristic. The task with maximum execution

time is allocated to the best performing machine. Genetic algorithm: GA is a shaped up algorithm that performs population selection, seeding, crossover and mutation to map the tasks to the machines available [12].Simulate annealing. This algorithm uses greedy technique to generate an initial value, and then generates a new value. If the new value is better, it is replaced by original value. This traditional algorithm meets the users' needs and rises system performance [13].**OLB (Opportunistic Load Balancing):** The task assignment in OLB is randomly no matter what the execution time is on the machines. It's implementation is simpler than others, but results in long makespan.. [14] MET (Minimum Execution Time). In contrast to OLB, in MET, task assignment is on the basis of execution time on machine[10], Two-phase hybrid CR-AC algorithm works on MET as it considers makespan to schedule workflows considering tasks independently. A batch refers to a collection of jobs that are processed together.

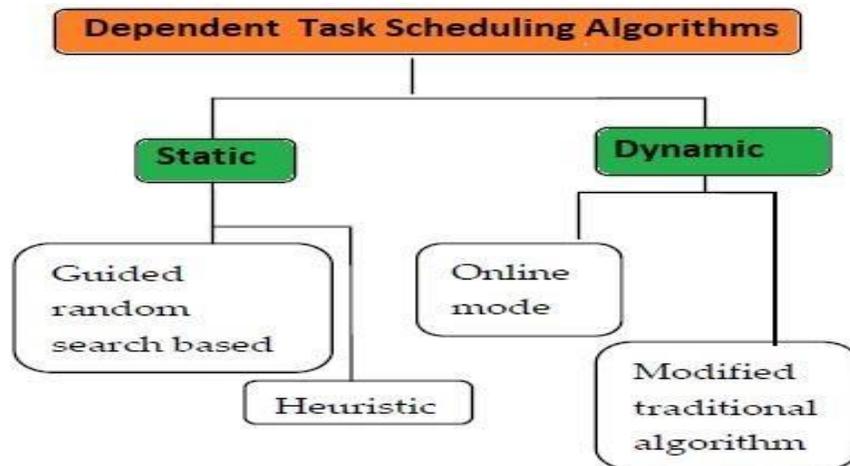## 2.3 Scheduling Dependent Tasks

Figure 4 various static and dynamic scheduling algorithms for dependent tasks.

The static algorithms for dependent tasks are grouped into guided random search based and heuristic based. There can be in depth classification of heuristic based into clustering heuristics and list scheduling heuristics. In [10] Topcuoglu has briefly mentioned static scheduling algorithms for dependent tasks. In list scheduling heuristics, all the tasks are first prioritized and then ordered in list form. Then the tasks are processed to the machine that optimizes cost function. The examples can be: Heterogeneous Earliest Finish Time (HEFT)[10], and Dynamic Critical Path(DCP) scheduling algorithm[9]Clustering Heuristics. These types of algorithms are applied for unbounded number of processors. Examples of this type of algorithms are Dominant Sequence Clustering (DSC) and Linear Clustering Method (LCS).**Dynamic Algorithms for Dependent Tasks**. The online mode scheduling algorithms for scheduling dependent tasks take tasks and assign them at their arrival time instantly. Path selection algorithm [7] and Ant Colony Optimization [13] are the examples of online mode scheduling algorithms (consider table). Hybrid Cloud Optimized Cost(HCOC) [16] is another algorithm working in online mode to schedule workflows; that firstly tries local scheduling using HEFT[6].As we saw, lots of work has been done in task scheduling for cloud computing, however the newest researched algorithms have been finely discussed in next section.

3 LITERATURESURVEY

There are many parameters used to select of algorithms based on user requirement and other scenarios. Scheduling in mobile cloud computing is very important research area to meet demand of user requests. Task scheduler model [1] for mobile cloud computing is one of the algorithm that focused on reducing energy consumption and monetary cost in case of deployment in public cloud and energy consumption parameter in case of deploying in private cloud. The proposed heuristic approach [2] takes bandwidth to load tasks to resources as constraint. Here each task is processed before actual allocation. The algorithm effectively utilizes memory, bandwidth and CPU when compared with the existing algorithms and gives 50% less response time. For scheduling in heterogeneous cloud environment, a map reduce scheduling algorithm [3] was proposed that considered job deadline unlike other map reduce algorithms like FIFO, Fair and capacity schedulers for data-intensive applications. For allocation among slots having different computing power, the job deadline was divided into map and reduces deadlines and

minimum weighted bipartite graph was modeled for finding appropriate slots. Both test bed and simulations results said that there was reduction in job elapsed time 9 by 79%), deadline over job ratio(by 56%) and computational time was just 0.0243 seconds. For a known minimum cost that a user can pay for a particular application on cloud, a cost budgeted algorithm [4] was proposed that obtained minimum energy when experimented on three different applications.

In order to optimize the scheduling decision while satisfying discrete user demands, HEFT-T (heterogeneous earliest finish time and topsis) algorithm [5] considered task priority and processor selection with time deadlines. It proved to be better in deadline achieving and task scalability, but HEFT gave lower total execution time. The proposed algorithm [6], Extended dynamic constraint algorithm(add-on of multiple choice knapsack problemMCKP) was compared with two prevailing scheduling algorithms -Extended Dynamic Constraint Algorithm (EDCA) and Extended Biobjective dynamic level scheduling (EBDLS). It guaranteed that monetary cost is optimized along with secure and reliable operation. It reduced 25% failures while generating the cheapest solutions among three algorithms. Resource allocation for workflow scheduling always persists as a problem. Novel hybrid algorithm CR-AC which is the combination of chemical reaction optimization and ant colony optimization algorithms proposed [7] to optimiz e the workflow scheduling. When compared with traditional CRO, ACO and recent PSO and CEGA; it is observed that the new algorithm gives better results in terms of makespan and cost of scheduling the three workflows, on a number of machines. It achieves a high-standard optimal solution with low cost under the deadline constraint. An optimization algorithm 'Slave ants based ant colony optimization algorithm', based on the population of ant movement was proposed [8]. Results show that SCAO does not exceed ACO when no of tasks is 100, because it involves pre-processing time. With the increase in number of tasks the make span of ACO is always more than SACO. The scheduling in hybrid cloud for heterogeneous workloads [9] followed genetic algorithm to obtain optimal choices of job queues by dividing jobs into I/O intensive and CPU intensive jobs. The algorithm resulted in better job response time and gave higher throughput than private cloud cluster operations. The uncertain execution time of a task on machine, and the random uncertain arrival of workflows resulted in the coming of uncertainty aware Online Scheduling Algorithm [17] abbreviated as ROSA. Being aware of uncertainties, this algorithm optimizes service renting cost, resource utilization, schedule deviation and resource utilization fairness.

TABLE 5: SUMMARIZATION OF VARIOUS SCHEDULING ALGORITHMS

REF	Algorithm	Objective	Optimal parameters	Tool	Result
[6]	Deadline constrained multi Objective task scheduling algorithm (HEFT-T)in MCC[6]	To minimize both total cost and mean load under mobile cloud computing environment	Total cost, mean load, deadline	Matlab 2016a	When no of tasks taken reaches 80, it gives lowest total cost but mean load is high. It gives optimal total cost and mean load than HEFT and CMSACO algorithms.
[7]	Path selection algorithm (workflow scheduling)	Reduce response time and cost to process multimedia data	Response time, cost, along with virtual memory processing speed and user request arrival rate	Matlab scripts	As data rate transmission increases, cost is also increasing. So cost efficient workload scheduling has to be enabled along with pre fetcher in multimedia cloud.

[8]	Two phase hybrid CR-AC algorithm (workflow scheduling algorithm)	combines two traditional algorithms to effectively schedule workflows with lower cost and reduced makespan	makespan, cost	Cloudsim toolkit	CR-AC gives Makespan = 1min, while CRO, ACO take more than 2 min to complete same application; also saves more than 4500$ than traditional CRO and ACO.
[9]	Priority-based process scheduling(PRIPSA) algorithm	load management, energy consumption, reducing the starvation problem of the processes, a maximizing the revenue	waiting time, throughput and starvation of processes	Cloudsim toolkit	The avg waiting time of pre-emptive is increasing exponentially, rather than PRIPSA which gives higher throughput and the starvation increasing rate is very low .
[10]	Extended dynamic constraint algorithm	Reduce total cost along with providing security and reliability	monetar y cost(cost of computing power, data storage and inter-cloud communication)	Workflow Sim and Dynamic CloudSim	Guarantees security, reduces 25% failures, and generates cheapest solution compared to other algorithms.
[25]	(G&PSO) algorithm	Reduce makespan, reduce workload of virtual machine	completion time, workload, resource utilization	Clouds	Compared to the PSO algorithm, it decreases the overall task time completion and balances each virtual machine's workload.
[26]	Multi-Population Genetic Algorithm (MPGA.)	Reduce total cost and time consuming of cloud computing system	Cost and time consuming, load balancing.	Matlab	Better performance in both processing costs and time- consuming than the TCGA and SAGA algorithms balances the load of the inter-nodes well.
[27]	PACO algorithm	Load management and reduce task completion time.	Completion time	Clouds	PACO could enhance task scheduling efficiency. Better than min-min and genetic algorithm for the completion of the task
[28]	IGA (Improvement Genetic Algorithm)	Improve task response time	Task and Completion Time	CloudSim	Improve the performance of a task scheduling compared to SGA (Simple Genetic algo)
[29]	LB-ACO Algorithm	load management in cloudlet system and reduce makespan of system	load balancing, makespan	CloudSim	Better load balance and less makespan compared with the NSGA-II algorithm.

[30]	SAMPGA algorithm	Reduce cost of execution and improve latency of system	completion time, cost, load imbalance, convergence speed	MATLAB	In terms of cost, completion time, convergence speed, and load imbalance, SAMPGA surpasses SAGA, MPGA, and SA.
[31]	TSFPA algorithm	Reduce makespan and improve performance of system	Makespan	CloudSim	In terms of makespan, TSFPA.performance is higher than GA, RR, and FCFS.
[32]	CSM-CSOSA algorithm	Improve performance and Qos of system	execution time, execution cost, QoS	CloudSim	The obtained findings are compared with (MOGA), (MOSACO), and (MOSACO).the proposed method is better performance with improved QoS.
[33]	(GGWO.) Algorithm	Improve performance of task scheduling algorithms	computation time, cost, energy consumption, load utilization	CloudSim	Compared to standard GWO and GA, GGWO will improve task scheduling.
[34]	parallel genetic algorithm	Effective load balance amount vm in cloudlet system and improve fault tolerance	Load balancing, energy usage, migration rate, resource utilization	Matlab	Enhance the load balance level by selecting better tools to execute the arrival tasks at the lower task failure rate in a shorter period.
[35]	VM-ACO algorithm	Improve latency of cloud computing system	task transmission, execution time, and load balancing	CloudSim	It performs better than the ant colony algorithm in task latency, time to finish the task, and load balance.
[36]	LCGA algorithm	Improve load balance among cloudlet and performance of system	load balancing, cost	CloudSim	The LCGA algorithm is compared with LGA, CGA methods, and the results illustrate that the scheduling algorithm is successful and the optimization method is used.

1 CONCLUSION

Without considering scheduling in cloud systems, the outperformance would not be as much as it is now for famous cloud providers like Amazon EC2, Microsoft Azure. In this paper the scheduling algorithms were briefly discuss with different parameter. the comparative analysis provides a detailed understanding. It is seen that various algorithms based on different parameters give different performance. For a scheduling algorithm to be ideal, different parameters are considered sequentially after completing one prioritized parameter. The researchers working in this domain can select one of the studied proposals considering its merits over the others. In the future, the main focus will be on analyzing in deep the uncertainties in scheduling of tasks and improving the uncertainty aware algorithm based on the study provided in this paper. Scheduling in multilevel system will be require more effective and low latency application in cloudlet based cloud computing system

REFERENCES

1. M. Nir, A. Matrawy and M. St-Hilaire, "Economic and Energy Considerations for Resource Augmentation in Mobile Cloud Computing," in IEEE Transactions on Cloud Computing, vol. 6, no. 1, pp. 99-113, 1 Jan.-March 2018.

2. M. Nir, A. Matrawy and M. St-Hilaire, "An energy optimizing scheduler for mobile cloud computing environments," 2014 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), Toronto, ON, 2014, pp. 404-409.

3. W. Zhang and Y. Wen, "Energy-Efficient Task Execution for Application as a General Topology in Mobile Cloud Computing," in IEEE Transactions on Cloud Computing, vol. 6, no. 3, pp. 708-719, 1 July-Sept. 2018.

4. C. Chen, J. Lin and S. Kuo, "MapReduce Scheduling for Deadline-Constrained Jobs in Heterogeneous Cloud Computing Systems," in IEEE Transactions on Cloud Computing, vol. 6, no. 1, pp. 127-140, 1 Jan.-March 2018.

5. Y. Chen, G. Xie and R. Li, "Reducing Energy Consumption With Cost Budget Using Available Budget Preassignment in Heterogeneous Cloud Computing Systems," in IEEE Access, vol. 6, pp. 20572-20583, 2018.

6. Liu, L., Fan, Q., & Buyya, R. (2018). A deadline-constrained multi-objective task scheduling algorithm in Mobile Cloud environments. IEEE Access.

7. Performance of integrated workload scheduling and pre-fetching in multimedia mobile cloud computing. Khorramnejad, K., Ferdouse, L., Guan, L. et al. J Cloud Comp (2018) 7: 13. https://doi.org/10.1186/s13677018-0115-6.

8. Cost-Effective Algorithm for Workflow Scheduling in Cloud Computing Under Deadline Constraint Nasr, A.A., El-Bahnasawy, N.A., Attiya, G. et al. Arab J Sci Eng (2019) 44: 3765. https://doi.org/10.1007/s13369018-3664-6.

9. Haque M., Islam R., Rubayeth Kabir M., Narin Nur F., Nessa Moon N. (2019) A Priority-Based Process Scheduling Algorithm in Cloud Computing. In: Abraham A., Dutta P., Mandal J., Bhattacharya A., Dutta S. (eds) Emerging Technologies in Data Mining and Information Security. Advances in Intelligent Systems and Computing, vol 755. Springer, Singapore.

10. Z. Wen, J. Cała, P. Watson and A. Romanovsky, "Cost Effective, Reliable and Secure Workflow Deployment over Federated Clouds," in IEEE Transactions on Services Computing, vol. 10, no. 6, pp. 929-941, 1 Nov.Dec. 2017.

11. A novel task scheduling scheme in a cloud computing environment using hybrid biogeography-based optimization. Tong, Z., Chen, H., Deng, X. et al. Soft Computing (2018). https://doi.org/10.1007/s00500-0183657-0.

12. Moon, Y., Yu, H., Gil, JM. et al. Hum. Cent. Comput. Inf. Sci. (2017) 7:28 https://doi.org/10.1186/s13673017-0109-2 A slave ants based ant colony optimization algorithm for task scheduling in cloud computing environments.

13. Kaur, S., Bagga, P., Hans, R. et al. Arab J Sci Eng (2019) 44: 2867. https://doi.org/10.1007/s13369-018-36143 Quality of Service (QoS) Aware Workflow Scheduling (WFS) in Cloud Computing.

14. De Souza, F.R., Miers, C.C., Fiorese, A. et al. J Grid Computing (2019). https://doi.org/10.1007/s10723-01909479-x QVIA-SDN: Towards QoS-Aware Virtual Infrastructure Allocation on SDN-based Clouds. Journal of Grid Computing.

15. Chunlin, L., Jianhang, T. & Youlong, L. J Grid Computing (2019). https://doi.org/10.1007/s10723-019-094813 Hybrid Cloud Adaptive Scheduling Strategy for Heterogeneous Workloads. Journal of Grid Computing.

16. Juefu Liu and Gang Li, "An improved MIN-MIN grid tasks scheduling algorithm based on QoS constraints," 2010 International Conference on Optics, Photonics and Energy Engineering (OPEE), Wuhan, 2010, pp. 281283.

17. He, X., Sun, X. & von Laszewski, G. J. Comput. Sci. & Technol. (2003) 18: 442. https://doi.org/10.1007/BF02948918 A QoS Guided Min-Min Heuristic for Grid Task Scheduling.

18. S. Song, Y. -. Kwok and K. Hwang, "Security-driven heuristics and a fast genetic algorithm for trusted grid job scheduling," 19th IEEE International Parallel and Distributed Processing Symposium, Denver, CO, 2005, pp.

19. F. Ying and G. Lei, "Optimal Scheduling Simulation of Software for Multi-tenant in Cloud Computing Environment," 2014 Fifth International Conference on Intelligent Systems Design and Engineering Applications, Hunan, 2014, pp. 688-692.

20. Y. Vijay and B. V. Ghita, "Evaluating cloud computing scheduling algorithms under different environment and scenarios," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Delhi, 2017, pp. 1-5.

21. Y. K. Yu-Kwong Kwok and I. Ahmad, "A Static Scheduling Algorithm Using Dynamic Critical Path for Assigning Parallel Algorithms onto Multiprocessors," 1994 Internatonal Conference on Parallel Processing Vol. 2, North Carolina, USA, 1994, pp. 155-159.

22. HCOC: a cost optimization algorithm for workflow scheduling in hybrid clouds. Journal of Internet Services and Applications, 2011, Volume 2, Number 3, Page 207.

23. H. Chen, X. Zhu, G. Liu and W. Pedrycz, "Uncertainty-Aware Online Scheduling for Real-Time Workflows in Cloud Service Environment," in IEEE Transactions on Services Computing.

24. Ramotra A, Bala A. Task-Aware Priority Based Scheduling in Cloud Computing [master thesis]. Thapar University; 2013.

25. Zhifeng Zhong, K. C., Xiaojun Zhai, Shuange Zhou. (2016). Virtual Machine-Based Task Scheduling Algorithm in a Cloud Computing Environment. *TSINGHUA SCIENCE AND TECHNOLOGY, 21*, 660-667.

26. WANG Bei, L. J. (2016). *Load Balancing Task Scheduling based on Multi-Population Genetic Algorithm in Cloud Computing*. Paper presented at the Proceedings of the 35th Chinese Control Conference, Chengdu, China.

27. Ruonan Lin, Q. L. (2016). *Task Scheduling Algorithm Based on Pre-Allocation Strategy in Cloud Computing*. Paper presented at the International Conference on Cloud Computing and Big Data Analysis.

28. Hu Yao, X. F., Honghui Li, Gaifang Dong, Jianrong Li. (2017). Cloud Task Scheduling Algorithm based on Improved Genetic Algorithm. *International Journal of Performability Engineering, 13*, 1070-1076. doi:10.23940/ijpe.17.07.p9.10701076.

29. Ashish Gupta, R. G. (2017). *Load Balancing Based Task Scheduling with ACO in Cloud Computing*. Paper presented at the International Conference on Computer and Applications.

30. Xing Jia Wei, W. B., Li Jun. (2017). *SAMPGA Task Scheduling Algorithm in Cloud Computing*. Paper presented at the Proceedings of the 36th Chinese Control Conference, Dalian, China.

31. Sidhu, J. K. a. B. K. (2017). *New Flower Pollination based Task Scheduling Algorithm in Cloud Environment*. Paper presented at the 4th International Conference on Signal Processing, Computing and Control, Solan, India.

32. Danlami Gabi, A. S. I., Anazida Zainal, Zalmiyah Zakaria, Ahmad Al-Khasawneh. (2017). *Cloud Scalable Multi-Objective Task Scheduling Algorithm for Cloud Computing Using Cat Swarm Optimization and Simulated Annealing*. Paper presented at the 8th International Conference on Information Technology (ICIT).

33. N. GOBALAKRISHNAN, A. C. A. (2018). A New Multi-Objective Optimal Programming Model for Task Scheduling using Genetic Gray Wolf Optimization in Cloud Computing. *COMPUTER AND COMMUNICATIONS NETWORKS AND SYSTEMS THE COMPUTER JOURNAL*, 1-14.

34. Mehran Ashouraei, S. N. K., Rachid Benlamri, Nima Jafari Navimipour. (2018). *new SLA-aware Load Balancing Method in the Cloud using an Improved Parallel Task Scheduling Algorithm*. Paper presented at the 6th International Conference on Future Internet of Things and Cloud.

35. Fang Yiqiu, L. X. (2018). *Task Scheduling Strategy for Cloud Computing Based on the Improvement of Ant Colony Algorithm*. Paper presented at the International Computers, Signals and Systems Conference (ICOMSSC), Dalian, China.

36. Shuang YIN, P. K., Ling TAO. (2018). *An improved genetic algorithm for task scheduling in cloud computing*. Paper presented at the 13th **IEEE Conference** on Industrial Electronics and Applications (ICIEA).