Review of Workflow Scheduling Algorithms in Cloud Computing

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ABSTRACT

Cloud computing is a parallel and distributed framework computation by the information technology resources and which are further characterized by the demand services through the Internet. The cloud providers also use a typical model such as "pay-as-you-go" to access the network services. Due to its wide popularity, a huge number of applications and organizations are on Cloud platforms. The performance of the Cloud depends on the number of applications run at a given point of time and resources available at Cloud to execute these applications. Hence, improper utilization of computational resources may result in a compromise in the overall performance of the Cloud. This issue becomes critical for real-time applications where performance in form of throughput and response time is of utmost importance. Here comes the role of scheduling algorithms that appropriately plan the task on a given resource. Proper scheduling mechanism can avoid the problem of performance as well as resource utilization. Through this research, various scheduling mechanisms being used for Cloud computing is extensively surveyed and evaluated them based on various parameters such as throughput, latency, makespan, etc for typical task execution and also discuss their benefits and challenges.

Keywords: Cloud computing, workflow scheduling, cost, makespan, performance, optimization, latency

1. INTRODUCTION

Cloud computing offers scalable computing repository and services to its users through the Internet [1]. Users' requirements specified by service level agreement (SLA) are satisfied through different services by making use of non-uniform computing resources. Amazon EC2 [2], Google App Engine [4], Dropbox [3], and Microsoft Azure [5] are a few of the popular Cloud computing platforms. Based on the visibility (what is available to whom) and access control (who can access what), there are three principle classifications of cloud facilitating such as public, hybrid, and private to meet the requirements of federal and state regarding the data controls. Any type of subscriber can access the cloud publicly but private Cloud and their infrastructure are owned and accessed by the entities within an organization. Few organizations with some common interest collaboratively share and maintain community Cloud services. The private and the public clouds are connected with the hybrid clouds with the assistance of the resources. Besides, the receptiveness issues faced by the single cloud are tackled by merging with the multi-Cloud, which leads to converges on the federation.

Cloud plaforms offers various services among them the three major services which plays a vital role are termed as Platform as a Service (PaaS), Software as a Service (SaaS), and Infrastructure as a Service (IaaS). SaaS provider offers enterprise software as a service on a rental basis so that the user does not need to buy the license of the software and use this rented option for a limited period of time on a subscription basis. PaaS is a wonderful concept where the developer does not need to buy and install the software development platform. Here, the developer uses the platform on a rental basis to write/test the code. Once the development part is over, the subscription can be relinquished. Here, the developer does not need to face the hassle of installation and maintenance of the platform. The third and most interesting category is IaaS wherein the physical resources such as microprocessors' computing power, main memory (RAM), secondary memory (for storage), internet bandwidth, etc. are offered on a pay as you go basis. This concept of renting computing resources is merely possible without a technology called virtualization where a physical resource can be offered as multiple virtual machines (VMs) by considering the peak utilization of that physical machine at any point in time. Theoretically, a virtual machine is just an instance of the physical machine designed to serve a particular user or to execute a specific task. Using virtualization, the same physical machine can be utilized by multiple users/tasks at the same time without compromising the performance of the system. Users can execute their tasks or run their applications on the virtual machines allotted to them. This allotment is scalable or elastic i.e. depending on the requirement the amount of virtual machine allocated can grow or shrink. Virtual Machine Monitor (VMM) software are also called as hypervisor, is utilized to manage all types of Virtual Machines (VMs). Hypervisor acts as an interface between the physical and logical/virtual resources.

Though virtually the Cloud owns infinite resources, sometimes users face problems while accessing their data or application due to heavy workload at Cloud service providers' site. This happens mainly due to the reason of unbalancing in allocating computational resources to the tasks. This results in improper utilization of existing virtual resources and also into compromise in the performance of the end user's application. Scheduling mechanisms are used to overcome the issue of inappropriate mapping of tasks and virtual resources. In scientific or other industrial applications wherein a huge amount of computation is required, the entire process is divided among small pieces of work from beginning to end. Depending on the inter-connectivity among these pieces, they are executed in parallel or sequentially. This process is called workflow. Hence, a workflow is nothing but a container containing a bunch of tasks that are in/dependent on each other. These tasks communicate with each other through data or function and can have data dependency or functional dependency among them. Each part of the work process is termed as workflow scheduling. In Cloud Computing, workflow scheduling is one of the most challenging areas and the main objective of scheduling is to allocate the task ina sequential order so that throughput(response time) and the resources can be further improved in the overall system. Another issue faced by workflow scheduling is to perform the optimal scheduling which is handled by the NP-hard optimization problem.

The work process measure application W= (T, E) is shown as an organized Directed Acyclic Graph (DAG) where T= {t1, t2,… ..tn} is a bunch of an errand and E is the collection of directed edges. An edge eij of the formation (ti,tj) survives only if there is dependence among ti and tj, in the case in which ti is supposed to be the parent responsibility of tj and tj should be the child task of ti. The child task starts after the completion of the parent tasks. If any of the tasks start from scratch without any predecessor, it is termed as an entry task, and if any of the task end without a successor is termed an exit task. Where in the case of the DAG, it has more number of entry and exit tasks. The size of the work process is represented by the total number of tasks. The association between the tasks represented by the workflow structure which are classified into non-DAG and DAG. The other kinds of classification, such as Choices in the DAG-based structure, Parallelism, and Sequence. In the Sequence structure, the execution of the current task depends on the effective completion of the previous task. In the Parallelism Structure, two or more tasks are executed concurrently. And in the Choice-based Structure, the tasks are executed in sequential order according to the selection manner.The two sorts of workflows are scientific and simple. Fig 1(a) describes a DAG-based simple workflow where (A, D, F) represents the sequence structure, and (B, C, D) depicts a parallel structure. Fig 1 (b) exhibits the traditional model, where the workflow accompanies the conventional master-worker architecture. The workflow engine is executed inside a master node and initiates the task by waiting for the queue. The worker nodes perform their tasks independently on the Virtual Machine(VM). The master node can further progress outside or inside of the Cloud server as a kind of Virtual Machine.

The worker node is dispatched according to the requirement and can be flexible based on the assets of the Virtual Machine instance. Some customized or dynamic resources reliant on the provisioning strategy incompatible with the Virtual Machine instances. The traditional Cloud model similarly requires a limited device to store the data of each work process. There are different options for data storage in the cloud but the most typically used information stockpiling is Amazon S3 or Google Cloud store. The pieces of information are stored at all times and aids to complete the workflow.

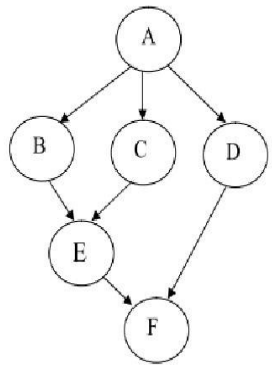

Fig1.(a) Simple workflow[7] (b) Traditional workflow[8]

2. LITERATURE SURVEY

In this area of our exploration, comprehensively alluded a few papers which are later or present continuous in the space of workflow planning for Cloud registering. Thinking about the writing on different estimating boundaries, for example, users budget for their task, priority, deadlines, load balancing, computational cost, energy consumption, resource utilization etc.
Junlong et al. [21] distinguish the issue of handling resource configuration and development of hybrid Cloud in traditional distributed computing. They pick two QoS boundaries for examination/ improvement viz. makespan and cost. Utilizing Genetic algorithm, authors propose two algorithms, one single objective DCOH (Deadline constrained cost optimization for hybrid Cloud) to lessen money related expense and second multi-objective MOH (Multi-objective optimization for hybrid Cloud) to reduce expense and makespan, they do reproduction experimentation to help their cases utilizing Amazon EC2. The authors have expected the assignment execution time to be fixed which may not be a genuine case. Further, the impact of DVFS on makespan, cost, and reliability are yet to be estimated.

Zonget al. [22] distinguish the issue of the enormous size of workflow flexibility and heterogeneity of the Cloud. The two commonly found issues in the Cloud Computing(CC) are the execution cost and the execution time. A novel multi-objective and ant colony system(MOACS) based in co-evolutionary multiple populations for multiple objective frameworks are proposed, which deal two colonies to manage these two objectives. They pick two QoS boundaries for correlation execution time and cost. MOACS approach depends on the ACS analyzer and MPMO system that utilizes different provinces to enhance diverse goal. They complete recreation experimentation utilizing Amazon EC2Cloud platform. Further, other Cloud condition or even multi-clouds condition ought to test the with MOACS.

Emmanuel et al.[23] recognize the issues in single or bi-objective optimization issue of the workflow scheduling for Cloud computing. They picked two QoS boundaries for development ar cost and Makespan. They proposed WSABD (workflow scheduling algorithm based on decomposition) to aids the tuning of the CPU recurrence for each assignment with the goal that both Makespan and cost can be minimized. They have done experimentation utilizing Cloudsim 1.0. Future works Cloud consider distinctive evaluating models, study the effect of various setting like the number of the machine, number of cycle to the advancement result. The proficiency of the proposed calculation could be tried through a genuine Cloud stage.

Vaheb et al [24] take a dataset in a dynamic big data environment to check the issues and concerns in processing multitasks workload to study overhead due to the effect of scheduling in a large search space. They choose QoS parameters to minimize the search space. Using Ordinal Optimization, they propose two scheduling mechanism. One is an adaptive workflow control machine that makes use of ordinal optimization to collect suboptimal schedules in an awful lot leaser time and second prediction based workflow scheduler version that predicts the execution time of the next coming workflow by using SVM (support vector machine). They carry out experimentation using Amazon EC2 Cloud platform. Many of the scientific workflow applications are highly data-dependent that may represent a reduction in the parallelism of the workflow. Further, introducing a mechanism for the separation of conditional independence tasks to increase the parallelism.

Vahidet al. [25] distinguish the issues of the big-scale clinical computation is based on the runtime and workflow scheduling. The issues of the cloud framework completely depend on the dynamic concept of the Cloud. This happens when handling the dynamic and static non-homogeneous asset along with the virtualization and management. These are chosen by the QoS boundaries in funds and deadlines. The proposed Budget and Deadline Aware Scheduling (BDAS) is for planning the workflow forced by both funds and deadlines. They did experimentation utilizing Cloudsim. The planning execution accomplished by the BDAS calculation is promising particularly considering the time required to register a schedule. Future, explore the utilization the BDAS heuristic calculation is close to genuine-time, multiple work processes, and dynamic planning circumstances.

Na wuet al. [26] identify the issues To it is critical to configure a value-powerful fault-tolerant scheduling method for a large-scale workflow. They pick QoS boundaries like spatial worldly re-execution of the work process for unwavering quality and cost. The proposed Dynamic Fault-Tolerant Workflow Scheduling (DFTWS) method along with the fleeting and the crossover spatial, reactivate the plans in three steps, first ascertain the time characteristics of the assignment and recognizes the basic way of the work process ahead of time, second, allot virtual machine adversary each errand as per task earnestness and spending share and third, execute Online scheduling which males actual time fault tolerant selection depend on failure kind and project criticality in the course of workflow execution. They did experimentation utilizing Amazon EC2. They found that there is diverse execution measurement for getting to say the least open-minded workflow booking the approach which is commonly

conflicting like dependability and cost. Future, design a flexible tolerant plan choosing or looking over the methodology for workflow planning for distributed computing situations.

Ali Abdaliet al. [27] distinguishes the issues that security is demonstrated to have the option to empower the importance between two elements for a long time. They pick QoS boundaries execution time, load adjusting, and security. Using Genetic calculation, they proposed CPSO (chaotic particle swarm optimization) algorithm to upgrades the booking execution and limit complete execution cost and equalization the heap on the asset while fulfilling limitations budget and deadline. Further, extend propose calculation with limit Makespan and unwavering quality QoS boundaries to furnish the peruser with the pattern in the obtaining of the method, appealing to a more productive system of streamlining to take care of the errand asset planning issue.

Zhongjin Li et al [28] describes the inspection to track the troubles that the cloud data faced using the Amazon EC2 Cloud platform. The Cloud data undergo the malicious attack and external breakdown frequently and consider the scientific execution of the workflow in the Cloud. The Fault-Tolerant Scheduling (FTS) algorithm supports the clinical workflow of the cloud context. The main aim of the workflow is to rectify the external and internal failures according to the cutoff date. The FTS primary set of the rules are corresponding to the obligations replication method that is broadly categorized under the faults tolerant mechanisms.

Ahmad M. Manasrah et al [29] recognizes the problems in the business approaches where the workflow is managed over cloud computing. The demanding conditions with the utilization of useful resources in a growing manner due to the provinces among responsibilities. A hybrid GA-PSO contains a set of rules to be followed for the tasks. The objective of this algorithm is to reduce the time span and the value of the load based on the heterogonous resources in CC. They finished experimentation making use of Amazon EC2. The evaluation result display that the GA-PSO calculation declines the all-out execution season of the workflow assignment, in examination with exceptional algorithms. It decreases the execution price. Future, the work can be reached out to multiple server farms in a heterogeneous area. The transmission of the workflow relationship can be extended out into two-level such as when the workflow projects the arrival of the administrative agent and when the workflow tasks are dispatched to the available VMs. And each DC depends on the size and speed of the VM. The performance can be enhanced by employing a dynamic workflow that authorizes greater flexibility for the customers to adjust the characteristics of the work process distribution throughout the runtime.

ShahinGhasemi et al [30] distinguish the issues to ideal planning of undertaking on the accessible preparing resource in such a manner some subjective rules when executing the whole workflows are fulfilled. They proposed another planning calculation for work processes in the Cloud condition utilizing Cuckoo Optimization Algorithm (COA). The point of the proposed calculation is lessening the handling and transmission cost just as keeping up an attractive burden adjusting among the preparing assets. The proposed calculation prevails with regards to finding a better arrangement, in lower ages.
The following Table I summarize the literature review, have been carried out so far. It bifurcates the research papers among various facets such as the authors' contribution, parameters are taken for measurement, tools used for experimentation, etc.

TABLE I. LITERATURE SURVEY OF WORKFLOW SCHEDULING IN CLOUD COMPUTING

Paper Title	Algorithm	Description	Parameter	Tool
Cost and Makespan aware workflow scheduling in hybrid Clouds[21]	Deadline constrained cost optimization and Multi-Objective optimization	single objective to reduce monetary cost and second multi-objective to optimize cost and Makespan	Makespan and cost	Amazon EC2
Multi-Objective Cloud workflow scheduling: A Multiple Population Ant Colony System Approach[22]	Multi-Objective and Ant Colony System	MOACS dependent on different populaces for various target systems is proposed, which receives two states to manage destinations. MOACS approach depends on the ACS optimizer and MPMO structure that utilizes numerous provinces to improve various destinations.	Time and Cost	Amazon EC2
Decomposition Based Multi-Objective Workflow Scheduling for Cloud Environments[23]	Workflow scheduling algorithm based on decomposition	WSABD to assists in the tuning of CPU frequency for each task.	Cost and Makespan	CloudSim-1.0
Workflow Scheduling in Cloud computing environment with classification on ordinal optimization on using SVM[24]	Classification Ordinal Optimization	Authors propose two scheduling mechanisms (i) An adaptive workflow management gadget that makes use of ordinal optimization to accumulate suboptimal schedule in lots leaser time (ii) prediction based workflow scheduler model that expects the execution time using SVM.	Minimize Search Space	Amazon EC2
Budget and Deadline Aware E Science Workflow Scheduling in Clouds[25]	Budget and Deadline Aware Scheduling	The proposed Budget and Deadline Aware Scheduling (BDAS) for the planning work process is compelled by both deadline and budgets.	Budget and Deadline	CloudSim

Dynamic Fault-Tolerant Workflow Scheduling with Hybrid Spatial-Temporal Re execution in Cloud[26]	Dynamic Fault-Tolerant Workflow Scheduling	The crossover spatial and fleeting reactivates the plans in three stages of the DFTWS method to determine the tasks. The First stage defines the time attributes of tasks and basic course of work process ahead of time. The Second stage allots the virtual gadget for every task during difficult circumstances and range quantity. The Third stage performs web-based planning at the time of fault-tolerant selection.	Reliability and Cost	Amazon EC2
A new Optimization Method For Security Constrained Workflow Scheduling[27]	Chaotic Particle Swarm Optimization	The Chaotic Particle Swarm Optimization(CPSO) algorithm aids to optimize the scheduling execution, decrease total execution cost, and adjust the load on the resource with the funds and deadlines.	Execution Time, Load Balancing and Security	Amazon EC2
Fault-Tolerant Scheduling for Scientific Workflow with Task Replication Method in Cloud[28]	Fault-Tolerant Scheduling	FTS Algorithm is to depreciate the workflow task with the deadline assignment that is based on the task replication method.	Cost and Deadline	Amazon EC2
Workflow Scheduling Using Hybrid GA-PSO Algorithm in Cloud Computing[29]	GA-PSO	The recommended algorithm aids to allot the duties to the resources. It diminishes the timespan and cost covering the heterogonous resources in Cloud.	Cost and Makespan	WorkflowSim
A Cuckoo based Workflow Scheduling Algorithm to Reduce Cost and Increase Load Balance in the Cloud Environment[30]	Cuckoo Optimization Algorithm	This algorithm support to overcome the time constraints and transmission costs that are maintained by a load balancing method amongst the resources.	Cost and Load Balancing	MATLAB

In the following Table II, the research gap identified for each paper has been listed which could be useful for the research community to finalize path for their prospective work.

TABLE II RESEARCH GAPE FOR LITERATURE SURVEY

Paper Title	**Research Gap**
Cost and Makespan aware workflow scheduling in hybrid Clouds[21]	They assumed the task execution time to be fixed which may not be the real case. The effect of DVFS on Makespan, cost, and reliability are yet to be measured.

Multi-Objective Cloud workflow scheduling: A Multiple Population Ant Colony System Approach[22]	Multi-Cloud Environment should be adopted to test the performance of MOACS.
Decomposition Based Multi-Objective Workflow Scheduling for Cloud Environments[23]	The efficiency of the proposed algorithm could be tested through a real Cloud platform.
Workflow Scheduling in Cloud computing environment with classification on ordinal optimization on using SVM[24]	Introduce a mechanism for conditional independence tasks to increase parallelism.
Budget and Deadline Aware E Science Workflow Scheduling in Clouds[25]	BDAS algorithm is employed in real-time applications, concurrent workflows, and dynamic scheduling circumstances.
Dynamic Fault-Tolerant Workflow Scheduling with Hybrid Spatial-Temporal Re execution in Cloud[26]	This is to design a manageable tolerant scheme based on selection and used to connect the approaches for workflow scheduling.
A new Optimization Method For Security Constrained Workflow Scheduling[27]	Extend propose an algorithm to minimize Makespan and reliability Parameters.
Fault-Tolerant Scheduling for Scientific Workflow with Task Replication Method in Cloud[28]	An unstable computing environment is considered to originate an energy-efficient fault-tolerant task scheduling algorithm from the prospect of Cloud providers.
Workflow Scheduling Using Hybrid GA-PSO Algorithm in Cloud Computing[29]	The transmission of the workflow relationship can be extended out into two-level such as when the workflow projects the arrival of the administrative agent and when the workflow tasks are dispatched to the available VMs. And each DC depends on the size and speed of the VM.
A Cuckoo based Workflow Scheduling Algorithm to Reduce Cost and Increase Load Balance in the Cloud Environment[30]	The CSO performs better than the proposed algorithm when involved in identifying the optimal solutions.

3. CONCLUSION AND FUTURE SCOPE

Cloud computing provides excellent scalability to workflow systems and assists in the process of transferring and recognized operations. Many researchers have investigated workflow scheduling to produce optimized solutions. This article proposes an evaluation of various present workflow scheduling algorithms, queries, and difficulties of scheduling workflow in the cloud context. These algorithms are based on target achievements. Most of the works are affected due to the budgeting, and other issues are energy, reliability, security, and scalability to be addressed. The main objective of the work is to obtain efficient scheduling. When working with the multi-cloud environment, there is the existence of complexity of workflows where this is not experienced in a single cloud environment. Numerous algorithms are utilized in the single cloud, whereas, in the case of a multi-cloud limited number of algorithms are employed. This situation triggers the researchers to promote new scheduling algorithms.

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