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Towards the Exploration of Task and Workflow Scheduling Methods and Mechanisms in Cloud Computing Environment

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Abstract— Cloud computing sets a domain and application-specific distributed environment to distribute the services and resources among users. There are numerous heterogeneous VMs available in the environment to handle user requests. The user requests are defined with a specific deadline. The scheduling methods are defined to set up the order of request execution in the cloud environment. The scheduling methods in a cloud environment are divided into two main categories called Task and Workflow Scheduling. This paper, is a study of work performed on task and workflow scheduling. Various feature processing, constraints-restricted, and priority-driven methods are discussed in this research. The paper also discussed various optimization methods to improve scheduling performance and reliability in the cloud environment. Various constraints and performance parameters are discussed in this research.

Keywords- Cloud Computing; Task Scheduling; Workflow Scheduling; Virtual Machines; Resource Allocation

I. INTRODUCTION

Cloud systems [1] allow users to access shared, virtualized resources whenever they need them. This setup distributes the service across multiple nodes with minimal administration and fast provisioning. Queries or a standard interface let users access services and resources. It's a mixed-media setting. The environment's implicit service allocation models consider multiple attributes. The cloud system has public-facing, generic, and domain- and application-specific definitions. Figure 1 shows the functional architecture of cloud computing that defines the responsibilities and tasks performed by different layers and components of cloud computing. The functional responsibilities of cloud computing are divided into three layers called application layer, resource layer and platform layer. The resource layer is the actual server-side infrastructure layer that contains different resources including storage and networking components [18]. The platform layer provides an interactive connection with other layers and works as a middle layer. The resource allocation, resource provisioning, and scheduling algorithms are defined in this layer. Various servers and virtual machines are connected to this layer and provide interactive and flexible communication. The application layer is the client-side layer that accepts the user request and enables interaction with the cloud environment. Cloud computing can be private, public, or hybrid depending on the audience. The middle layer architecture lets users request access or services. This framework contains metadata about cloud services and cloud hosts. Low-cost cloud server services, ICT devices, and resources meet customers' flexible needs. Cost-benefit analysis improves service and uptime [3][5].

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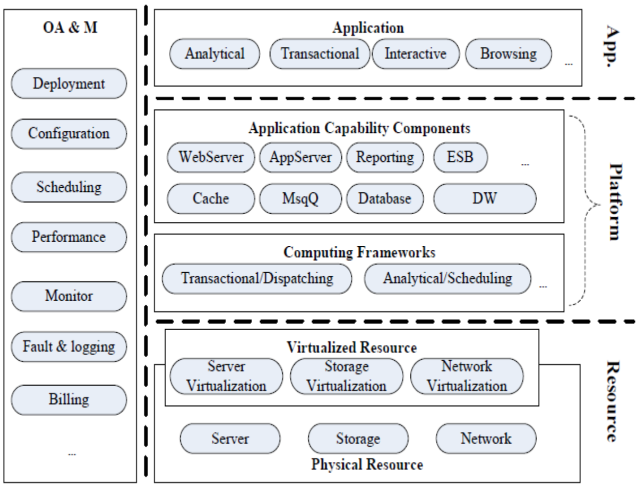

Figure 1: Functional Architecture of Cloud Computing[1]

In recent years, most of work and home environments are converted towards automation and using smart devices and equipment. These environments are equipped with a large number of IoT devices to capture the user or environmental inputs and requests. These IoT devices are now a significant part of Health care systems, industrial environments etc. A large volume of requests and data flow in these IoT-based cloud networks increases the load on the cloud environment[6].

Several cloud users/clients/customers ask for services/resources. All users have the same interface on the cloud platform. This unified environment has numerous user and customer entry points. Individual users make database and service requests. Text or graphical interfaces can be used to submit requests. The server saves information about client accessibility. For dependable services, users must be verified. When choosing a server, clients frequently specify criteria. The cloud can be accessed by thin clients, mobile devices, and PCs. Client-side computation organizes users and processes requests. To optimize service access and usage, the distributed middle layer architecture processes user characteristics and behavior. To improve customer satisfaction, we consider user and service sensitivity[9][10].

This infrastructure is supported by cloud servers. Memory, processing power, and safety measures are all built into each physical entity. Cloud server meta-data is defined by master servers. Cloud servers are divided into virtual machines. Requests are processed by virtual machines. Cloud servers can store both general and specialized resources. Service execution is improved by cloud system architectures and scheduling algorithms. Using resources and services more efficiently improves the efficiency of cloud service distribution. Cloud archives are kept in data centers. Critical data is stored in the cloud by businesses and customers. The environment has been designed to maximize data storage and dissemination. The data center stores user, transaction, and meta-data. Data centers can be virtualized or run entirely on a single server. During transactions and requests, data centers safeguard user data and communications. Data center processing has been plagued by scalability, load, and real-time request execution[8].

In distributed cloud environments, where users request services and resources, scheduling tasks can be difficult. The scheduling approach is a layered architecture that efficiently allocates and schedules services at the middle layer. Optimization techniques are used to fine-tune its many parameters, constraints, and control schemes. Researchers have looked into a variety of scheduling approaches, each of which is defined by a unique set of controllable functional capabilities and objectives[41].

In this paper, an exploration of cloud computing along with its function behavior is provided. In this section, the architectural behavior of cloud computing, its relative challenges, and its characteristics are defined. A brief description of resource allocation and scheduling methods of cloud computing are discussed. In section II, the work done in the directions of workflow scheduling is discussed. Earlier research contributions and issues related to earlier work are provided in this work. In section III, the requirement and challenges of task scheduling are discussed. The architectures and methods proposed by researchers are discussed. In section IV, the optimization methods used by the researchers to optimize the performance and reliability of different scheduling methods are defined. In section V, the conclusion and future scope of work are provided.

II. WORKFLOW SCHEDULING

Workflow Scheduling is a critical scheduling technique that is defined under consideration of deadline and budget constraints. In workflow scheduling, the processes are defined under dependency sequence so that the particular process should be executed after or before other specific processes. The arrival time and deadline-based conditions are applied to define the scientific workflow. Figure 2(a) and 2(b) is showing a simple example of workflow scheduling. Workflow scheduling is a NP-Hard optimization problem that is required for which an effective schedule generation is difficult. In workflow scheduling, there are various virtual machines in the cloud environment to achieve the required objectives. The main objective of workflow scheduling is to minimize the execution delay and make span. The effective utilization of available resources is also the objective of workflow scheduling. The tasks should be executed before the deadline and dependency constraints. Some more common issues of workflow scheduling are heavy load situations, resource utilization, and availability of resources[11][37].

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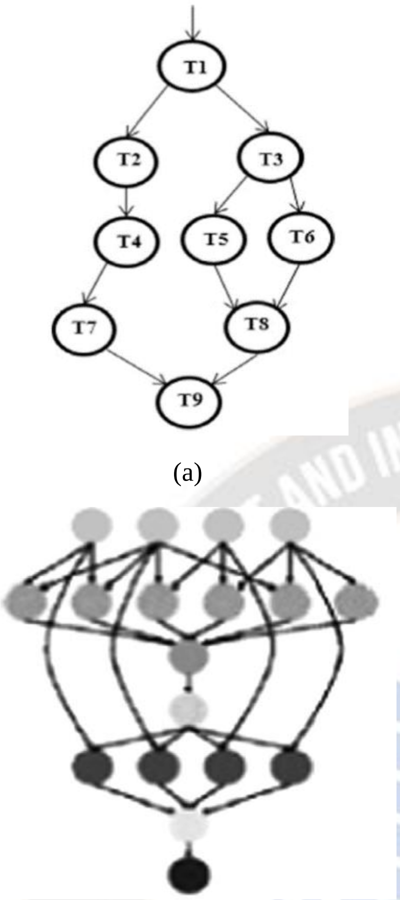

(a)

(b)

Figure 2: Work Flow Scheduling[11]

Workflow scheduling is a critical middle-layer task that comes under the NP-complete problem. It provides an effective way of resource utilization and quality improvement with reduced cost. The workflow scheduling faces various challenges such as dynamic load and high failure rate. Resource management in the cloud is a big challenge in such time-sequenced applications[46]. Various algorithms and models were proposed by the researchers to optimize the performance and reliability of work scheduling. Some of these effective models are listed in Table 1.

Table 1 : Methods and Models Proposed by Earlier Researchers on Workflow Scheduling

Author	Approach/ Algorithm	Significance of Work	Limitations
Wang et al.[47]	Dynamic Group Learning based Distributed Particle Swarm Optimization	A resource characteristics analysis based optimized algorithm was proposed. Improved the performance against existing methods	The method was not tested against heavy load situations.
Zhou et al.[48]	Deadline constraint based multi-objective optimization approach	Reduced the cost of workflow scheduling and optimized the make span. The profit driven method was defined under deadline constraint.	Varied load situations were not handled in this work. The swarm or genetic based algorithm were not applied
Abrishami et al.[49]	A Deadline constraint based two pass algorithm was defined to generate Partial critical path	Algorithm was defined to optimize the performance and complexity for clod computing. Promising results were achieved against existing algorithms	The load situation was not handled in this work and experiments were not conducted on different load situation.
Fard et al.[50]	Multi-Objective Approach for Workflow Scheduling	The constraint specific approximation algorithm was implemented to optimize the environment against energy, reliability cost and make span parameters	The task failure rate and VM scheduling based analysis was not considered. The analysis against different load situation was not handled.
Bittencourt et al.[51]	Hybrid Cloud Optimized Cost Scheduling	A aggregative analysis based method was defined to optimize the resource usage and cost. reduced the executing time and power consumption	Load situation were not handled in this work. The switching between different machines and failure rates were not handled.

III. TASK SCHEDULING

The cloud scheduling approach is specified in terms of a control behavior with constraints. User and server characteristics are

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used heavily in determining how services are distributed and requests are processed. Different scheduling behaviors can be managed by assigning weights, scores, or priorities to various client and server level features. In this section, we provide some of the criteria and behavioral features that were taken into account when designing the middle layer. The functional architecture of task scheduling and related issues are discussed. The contribution of researchers for handling the task scheduling issues and improving its behavior against various challenges are discussed[36][38]. The work provided by the earlier researchers for optimizing the task scheduling are also discussed in this section.

Any scheduling strategy must adhere to the primary criterion or constraint of the request completion time or the make span. In some cases, requests specify a deadline for the completion of time-sensitive work. Failure is defined as work that is submitted or completed past its due date. It is widely agreed that the make span is the best metric by which to judge the efficiency of any given scheduling technique. The deadline or time level restriction is defined according to the importance of the service or resource requested by the user. Cost vector is also used to estimate the efficiency with which cloud services are executed. Using monetary limits, workflow scheduling can be evaluated. Cost vector allows for disaggregated analysis of component utilization, resource allocation, service selection, and data transfer. To lower service modelling and execution costs, the scheduling must be optimized. With the definition of resource provisioning, we can process the cloud component and lower the cost of service allocation and execution by using a cost-aware scheduling approach[2][39].

Scheduling approaches take reliability into account when optimizing task execution in the cloud. When all requests are processed without error, the cloud environment and service execution are said to be reliable. Reliability is the factor that guarantees requests are carried out within the allotted time frame and within the parameters you set. This function specifies the efficiency with which tasks are completed and the resources used. The server is just one example of a cloud resource; others are defined with either a battery backup or a constant energy supply. Any time a service is run on a given server or any time an energy-intensive resource is accessed, some amount of power is used. The cloud scheduling system is also in charge of regulating the amount of power used by each node. Energy efficiency must come first when choosing which cloud server to send a user's request to. The direction of energy is also a factor in the cost analysis. Workflow-based methods for managing user requests' execution and implementing cloud-based workflow scheduling are also defined[2][40].

When it comes to the cloud, data privacy and security are of paramount importance. User requests' criticalities in terms of the environment's security can be determined in real-time. There is a wide variety of security options for cloud servers that can be used. Improving data integrity and reliability also necessitates efficient user request mapping on cloud systems. Scheduling strategies at the task and workflow levels are defined to regulate service execution in a cloud setting. To achieve trusted execution in a distributed environment, multi-level security methods are defined in both public and private cloud environments. When evaluating the safety of a cloud server, many factors, including data security, file security, and user security, must be taken into account[4][7][34][35].

Figure 3 shows the architecture of request processing and scheduling in cloud computing environment. At the lowest layer of this architecture, the functional resources are present in the form of virtual machines (VMs). At the upper most layer, the users are presented and generating the requests. These requests are processed by the Base request handler. The prior check, parametric check is performed by this handler. It perform high level isolation of requests to identify the priority and constraints. This handler is connected to the data center. The handler identify the request queries generated by the user. These queries are processed by the intermediate layer and resource allocation algorithm is applied. The constraint and resource driven estimation is performed for allocating the virtual machine. The scheduling algorithm is also integrated in the same layer for setting up the order of request execution. The load balancing algorithm are also integrating in this stage for allocating the resources[25].

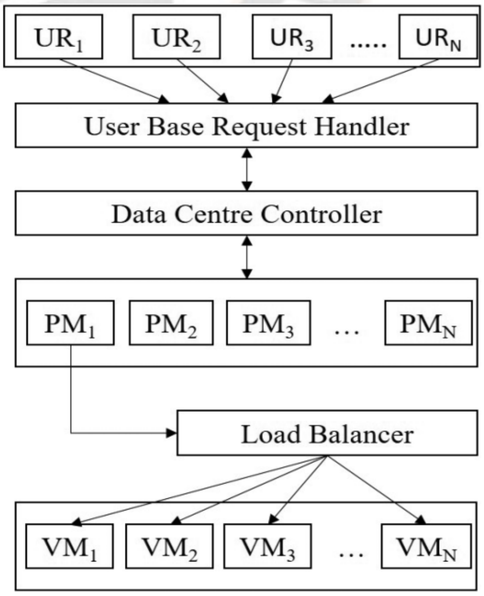

Figure 3 : A Resource Allocation and Scheduling Architecture for Cloud Computing[25]

Task scheduling involves effective resource allocation. Load balancing is one of the critical issue of resource allocation and task scheduling in cloud environment. The load balancing is a

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region specific issue in which the smaller network or region can have large number of users or queries. The availability of limited number of VMs or controllers in a region can cause the heavy load situations. The heavy load situation can increase the execution failure or non-execution of task within the deadline. The migration is a way to handle the load situation. In case of migration, the allocated request can be reallocated to other virtual machine. The robustness against scalability and heterogeneity also affects the load balancing algorithms in cloud environment[25].Panwar et al.[28] proposed a scheduling method to handle the load balancing problem in cloud computing. The workload analysis was performed by generating the group of virtual machines. The modified throttled load balancer was defined for effective allocation of virtual machines. The method improved the resource utilization and performance of the distributed network was improved. Kapoor et al.[29] used a clustering method for achieving the load balancing in heterogenous cloud network. The resource specific demand tasks were categorized. The clustered method improved the scheduling behavior and improved the performance in terms of execution time, turnaround time and waiting time. Patel et al.[31] presented load balanced Min-Min algorithm for optimizing the Meta-task scheduling. The improved algorithm achieved the robustness against heavy load situation. This task scheduling method improved the resource utilization and reduced the make span. A finish time[33] analysis based load balancing algorithm was proposed to improve the performance of task scheduling. A ratio based estimation was performed on capacity and load parameters and to control the size the queue. The method improved the performance and response time and improved the reliability.

Table 2: Limitations and Benefits of Recent Task Scheduling Methods

Author	Scheduling Algorithm/ Method	Features /Constraints/ Benefits	Limitations/ Drawback
Agarwal et al.[12]	Generalized Priority Algorithm used on tasks based on process size and on VMs based on MIPS	Reduce the Execution and Turn Around time in comparison with FCFS and Round Robin Methods	Load condition was not handled, Analysis based on delay is not provided, Deadline consideration is not present
Selvaraniet al.[13]	Activity based Cost (ABC) scheduling under resource cost consideration	Cost Minimizing, resource optimization and Machine utilization were the constraints to optimize scheduling method. Reduced the turn around time and cost	Load situation was not handled, The constraint based method is defined, optimization method was not included
Wang et al.[16]	Bayesian network based Trust model was defined for dynamic scheduling	Model improved the trust value and accuracy of service execution. Reduced the execution and make span in cloud environment	The probability failure and security constraints were not analyzed. Load situation was not handled
Ghanbariet al.[19]	A priority based scheduling algorithm was defined with multi-criteria decision making	Algorithm reduced the execution time, make span time and Reliability of task execution and Scheduling	Load situations were not handled. The optimization method is not integrated.
Lin et al.[23]	A bandwidth aware divisible task scheduling method was proposed for effective resource allocation	The load balancing was achieved and the performance was improved. Reduced makespan and improved reliability	Optimization method was not included to improve the performance. Failure rate not computed or analyzed

IV. OPTIMIZATION ALGORITHMS

Optimization refers to the process of selecting the optimal solution from among those that are possible. Parameters like cost, distance, error, etc., are used to define the optimization process and must be specified before the optimization process can begin. The objective function is defined within the context of this primary constraint, and additional constraints are applied to regulate the optimization process. The optimal solution provided by the optimization method must be more precise and time-saving than the typical heuristic-based solution[43]. Swarm[45] is a new technology that takes its cues from bio computing. It is applicable to any system that is both dynamic and adaptive. It's seen as a natural progression from previous evolutionary computation methods. Here, the genetic system is extended to account for variations in social behavior among organisms. As can be seen from the foregoing definitions, swarm intelligence is a form of collective intelligence used on

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groups of agents. Swarms, which are made up of real-world insects, have their behavior analyzed in order to figure out how to solve problems more efficiently. The real-time behavior of these organisms is used to apply their movement over the problem space[42][44]. Genetic algorithms (GA) are introduced, based on a natural selection process that mimics biological evolution, to solve both constrained and unconstrained optimization problems. Genetic is the evolutionary function specified in terms of a sample population and their possible outcomes. The algorithm then iteratively improves upon a population of previously found solutions.

Singh et al.[26] proposed an autonomous agent based load balancing and scheduling algorithm. Ants were deployed in the network as agent to analyze the virtual machine. Load analysis was performed to allocate the resources and optimize the scheduling in cloud computing environment. Pradhan et al.[27] used a particle swarm optimization based load balancing technique and scheduling technique to increase the resource utilization. The proposed method reduced the makespan and improved the behavior of scheduling for cloud computing. Jena et al.[30] proposed a hybrid optimization method for improving the load balancing. The hybridization was performed on an improved Q-learning and Particle swarm optimization algorithms. The method analyzed the local and global best measured along with improved Q-learning. This hybrid method maximize the throughput and achieved the balanced priorities in cloud environment. Gamal et al.[32] combined two swarm based optimization methods for improving the effectiveness of task scheduling method to handle load balancing situations. The optimization methods considered in this work are ant colony and artificial bee colony algorits. The method covered the drawbacks of existing optimization methos and reduced the energy consumption. The resource utilization and performance of distributed network were improved against existing algorithms.

Table 3 : Optimization Algorithms in Cloud Computing to Optimize Scheduling Methods

Author	Scheduling Method	Optimization Method	Benefit/ Effectiveness of Work
Zhao et al.[14]	Task Scheduling	Genetics Algorithm	Genetic method was applied on heterogenous cloud computing system. Resource and communication features were analyzed for optimizing scheduling behavior.
			Improved the resource utilization and cost of service execution
Awadet al.[15]	Task Scheduling	Particle Swarm Optimization	Load balancing adaptive PSO was proposed to optimize resource allocation and scheduling. Reduce execution time, make span and transmission cost.
Kaur et al.[17]	Task Scheduling	Genetics Algorithm	A meta-heuristic based scheduling method with improved genetic algorithm was defined to minimize the execution cost and time. Utilize the computational complexity in heavy load situation
Guo et al.[20]	Task Scheduling	Particle Swarm Optimization (PSO)	PSO based task scheduling and rule based evaluation were combined to minimize the cost and performance of task scheduling.
Chen et al.[21]	Task Scheduling	Whale Optimization Algorithm	An advanced and improved whale optimization algorithm was proposed to optimize task scheduling. Achieved better performance results against ACO and PSO-based scheduling methods.
Gu et al.[22]	Resource Scheduling	Genetics Algorithm	A load balancing method with genetic method was defined. The historical data and current state of system were analyzed for obtaining least affective solution.

Mezmazet al.[24]	Task Scheduling	Parallel bi-objective hybrid Genetic Algorithm	A parallel bi-objective hybrid and energy adaptive scheduling method was defined. Dynamic voltage scaling to minimize energy consumption.

V. CONCLUSION

Cloud computing provides a distributed environment for various IoT based real time applications. These applications are service driven and defined with time restriction to execute the services. The performance in such environment is a critical issue. The task scheduling and resource allocation are the key processes of task execution of cloud environment. The makespan optimization, resource utilization and reliability are the key challenges in cloud environment. In this paper, a detailed exploration of cloud computing architecture and various challenges of the environment are provided. In this paper, a detail study is provided on various algorithms and models proposed by the researchers to optimize the performance of various workflow and task scheduling methods. The paper include the analysis work on various optimization algorithms.

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