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Comparative Study of Workflow Scheduling Algorithms in Cloud Computing

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ABSTRACT: Cloud computing is a new terminology which is achieved by Distributed, Parallel and Grid computing. Cloud computing provides different types of resources like hardware and software as services via internet. Efficient task scheduling mechanism can meet users' requirements, and improve the resource utilization, thereby enhancing the overall performance of the cloud computing environment. In this paper we have considered workflow scheduling and conducted comparative analysis of workflow scheduling algorithms. Here Tasks require minimum completion time, better performance and total cost of execution is considered.

I. INTRODUCTION

Cloud computing now is known as a provider of dynamic, scalable on demand, virtualized resources over the internet. It also makes it possible to access applications and associated data from anywhere. Companies are able to rent resources from cloud for storage and other computational purposes so that their infrastructure cost can be reduced significantly. They can also make use of software, platforms and infrastructures as a services , based on pay-as-you-go model.

INTRODUCTION TO WORKFLOW MANAGEMENT SYSTEM

Workflow Management System (WMS) is used for management of executingthe workflow tasks on the computing resources. The major components of WMS are shown in Figure 1.

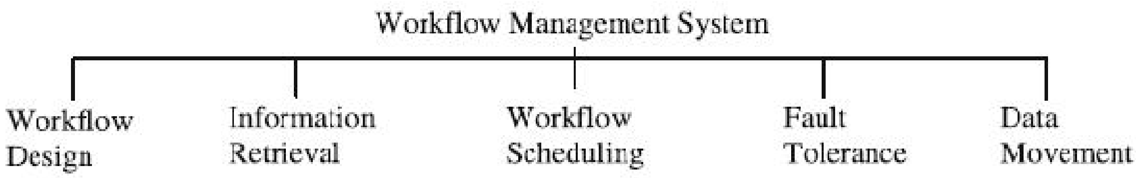

Fig1: Elements of a WMS [1]

Workflow design describes how components of workflow can be defined andcomposed. The elements of workflow design as shown in Figure 2.

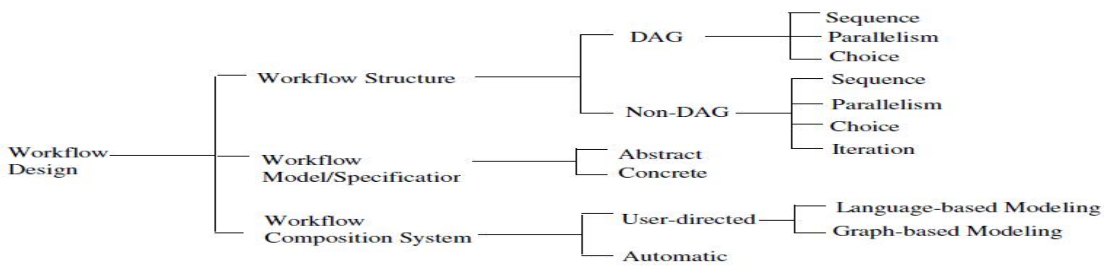

Fig 2: Taxonomy of Workflow Design [2]

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A workflow structure describe the relationship between the tasks of theworkflow. A workflow structure can be of two types Directed Acyclic Graph(DAG) and Non DAG. Workflow structure can further be categorized asSequence, Parallelism and Choice in the DAG based structure. In the sequence structure, the tasks execute in a series. A new task can only be executed if theprevious task has been successfully executed. In parallelism structure, tasks ofworkflow can executes concurrently. In choice structure, the workflow tasks can be executed in series as well as concurrently.The Non DAG based structure, contains all the DAG based patterns along withIteration pattern. In Iteration pattern, the task can executes in an iterativemanner. A complex workflow can be formed with the combination of these fourtypes of patterns in multiple ways.Workflow model defines the workflow, its tasks and its structure. Workflowmodels are of two types; abstract and concrete. Abstract workflow describe theworkflow in an abstract form which means that specific resources are notreferred for task execution. Concrete workflow describes the workflow tasksbinded to specific resources.Workflow composition system allows users to accumulate component to theworkflow. In the user directed system, user can modify the workflow structuredirectly by editing in the workflow. But in automatic, system generatesworkflow automatically. User directed system is further categorized inLanguage based modeling and graph based modeling. In former, user describeworkflow using some markup language such as XML. It is a difficultapproach because user have to remember a lot of language syntax. Graph basedmodeling is simple and easy way to modify the workflow with the help of basicgraph elements [1].

1.1 WORKFLOW SCHEDULING

Mapping and management of workflow task's execution on shared resources is donewith the help of workflow scheduling. So workflow scheduling finds a correctsequences of task execution which obeys the business constraint. The elements ofworkflow scheduling are shown in the Figure 3

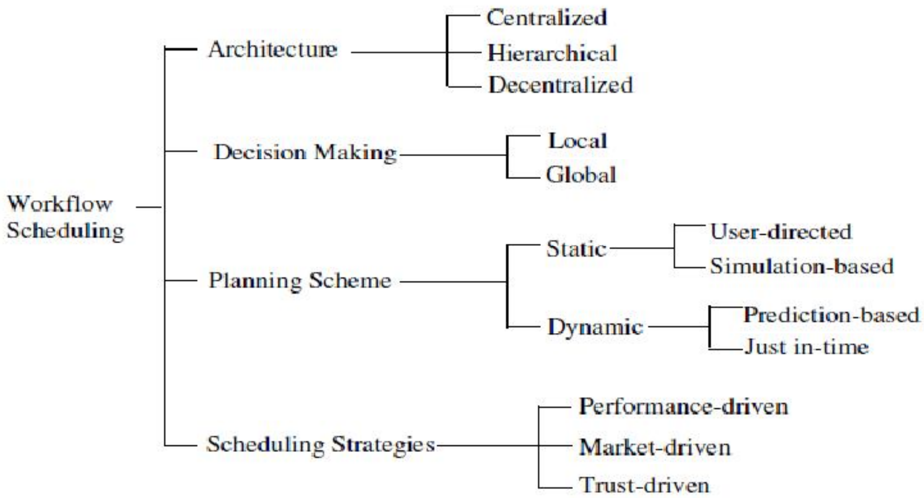

Figure 3: Elements of Workflow Scheduling [2]

Scheduling Architecture is very important in case of quality, performance andscalability of the system. In the centralized workflow environment, schedulingdecisions for all the tasks in the workflow is done by a single central scheduler.There is no central controller for multiple schedulers in decentralized approachbut communication between schedulers is possible. Each scheduler schedulesthe workflow to the resource having less load. On the other hand in hierarchicalscheduling there is a central manager. Not only Workflow execution is controlled by this central manager but also the sub-workflows are assigned tothe lower-level schedulers [1].Scheduling decisions which are taken on the basis of task or sub workflow are known as local decisions and which are taken by keeping in mind the wholeworkflow are called global decisions. Global decisions based scheduling givesbetter overall results because only one task or sub workflow is considered inlocal decision scheduling.

Transformation of abstract models to concrete models is done in two ways:static and dynamic. Concrete models are generated before the execution withthe help of current available information about the execution environment andthe

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dynamic change of resource is not considered in the static scheme. Staticschemes further categorized in two types; user-directed and simulation-based.In the user directed planning scheme, decision about resource mapping andscheduling is done on the basis of user’s knowledge, preferences andperformance criteria. But in case of simulation based, a best schedule can beachieved by simulating task execution on resources before the workflowexecution starts. Both static and dynamic information about resources used formaking scheduling decisions at run-time are consider in case of dynamicscheme. For dynamic scheme, there are two approaches prediction-based andjust-in-time scheduling is used. In prediction-based, dynamic information isused along with some results on basis of prediction and in simulation-based static scheduling, in which prediction of performance of execution of tasksusing resources is done along with generation of optimal schedule before theexecution of task is done. But due to this the initial schedule changed during theexecution. Just in-time scheduling makes decision at execution time.Scheduling strategies are categorized into performance driven, market drivenand trust driven. In case of performance driven strategies, focus is to achieve the highest performance for the user defined QoS parameter. So the workflow’stasks mapped with resources gives the optimal performance. Most of theperformance driven scheduling strategies focuses to maximize the makespan ofthe workflow. Market driven Strategies focuses on resource availability,allocation cost and quality for the budget and deadline. A market model is usedto schedule the workflow tasks to the available resource dynamically whichresults in less cost. Trust driven focuses on security and reputation of theresources and tasks are scheduled based on the trust by considering these twoparameters [1].

II. WORKFLOW TASK CLUSTERING

Task clustering is basically used to combine the small sized tasks of the workflow intoa comparatively large sized task to minimize the makespan of the workflow by reducingthe impact of queue wait time. So task clustering restructure the workflow bycombining the small sized tasks into a cluster and execute this cluster as a single task.Due to clustering the number of task in the workflow is reduced and there is less queuewait time as compared to small sized tasks. Task clustering is categorized as level- andlabel based clustering [3], vertical, blocked and balanced clustering [4]. Figure 4represents a simple workflow. Figure 5 describes horizontal clustering in level 2 andlevel 4 with each cluster contains two tasks.

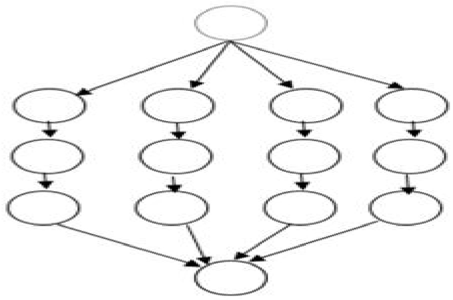

Figure 4 : A simple workflow

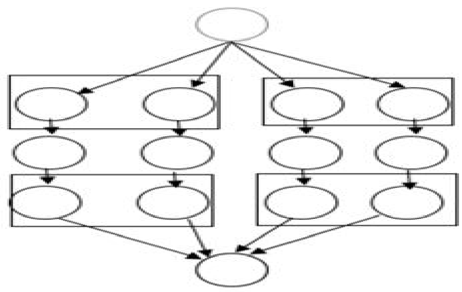

Figure 5 : Horizontal clustering

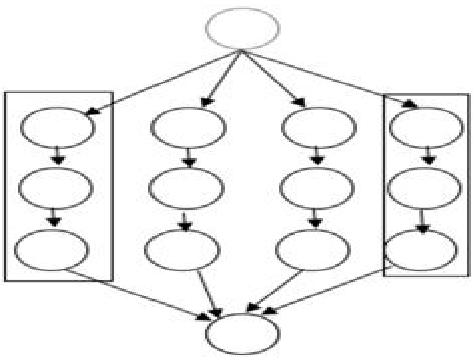

Figure 6 : Vertical clustering

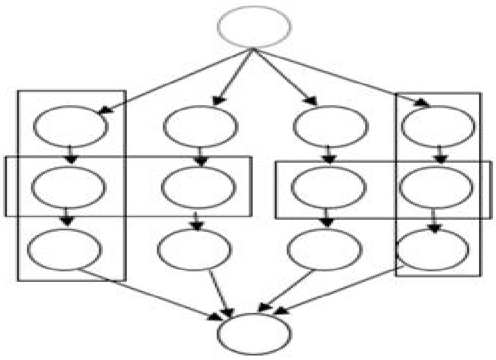

Figure 7 : Blocked Clustering

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Level-based clustering is also called horizontal clustering. In this type ofclustering the tasks are independent and the tasks of the same level of theworkflow can be combined together. In vertical clustering, tasks of the same pipeline can be combined together.Blocked clustering represents the combination of both horizontal and verticalclustering in the same workflow.Figure 6 represents vertical clustering, in which tasks in the same pipeline can be combined together to form a cluster. Each cluster of vertical clustering contains threetasks. Figure 7 shows the blocked clustering, in which horizontal and verticalclustering can be combined together.Tasks in the same level of workflow can have different execution time and wheneverthese tasks are combined without the consideration of their runtime variance then itcauses the problem of load imbalance, i.e., some cluster may contain the smaller tasks
and other may have larger tasks. Due to this inappropriate clustering, workflowoverhead is produced. Another problem is data dependency between the tasks ofworkflow in case of level-based clustering which is called dependency imbalance.

III. SCHEDULING ALGORITHMS

The main objective of scheduling algorithm is to achieve the best system throughputwith proper resource utilization and high performance by obeying the user's specifiedQoS parameter. There are various time comparison based scheduling heuristics existsin the grid and Cloud computing environment, which schedules the tasks by comparingthe arrival time or execution time of the tasks. In the following section these schedulingheuristics are described.

4.1 First Come First Serve (FCFS)

In this algorithm, tasks are compared on the basis of their arrival time and the taskwhich comes first in the ready queue is served first. Advantage of this algorithm is itssimplicity and fast execution behavior. But the main disadvantage of this algorithm isthat sometimes due to the execution of a longer job, which comes in the queue first,small jobs have to wait for its completion. Due to this problem the waiting time of tasksincreased and overall performance of the workflow execution decreases.

4.2 Min-min

In this algorithm, small task is executed first so that large task delays for long time.Algorithm begins with by sorting the set of all unmapped tasks in increasing order oftheir completion time. Then the tasks having the minimum completion is scheduledfrom the unmapped task set and the mapped task has been removed from unmappedtask list, and the process repeats until all the tasks of unmapped list is mapped to thecorresponding available resources [5].

4.3 Max-min

In this algorithm, large task is executed first so that small task delays for long time.This algorithm is very similar to Min-min algorithm, instead of sorting the task in theincreasing order of completion time. This algorithms sorts the tasks in decreasing orderof their completion time. Then the task with the overall maximum completion time isselected from this task list and scheduled to the corresponding available resource. Thenthe scheduled task has been removed from unmapped task set and the process repeatsuntil all tasks of unmapped list is mapped [5].

4.4 Minimum Completion Time (MCT)

In this algorithm, task that takes least time to complete is allocated to a machinerandomly. So MCT behaves somewhat like Min-min. However, Min-min algorithmconsiders all the unmapped tasks during each mapping decision but on the other handMCT considers only one task at a time [6].

IV. EXPERIMENTAL RESULTS

The paper uses simulation to test and verify the efficiency and correctness of the scheduling algorithm presented in this paper.

5.1 Simulation setup

The proposed algorithm is simulated in a simulation toolkit workflowsim[7].We have created a datacenter with the following properties and created 20 virtual machines.

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Arch	Os	Vmm	time_zone	cost	costPerMem	CostPerStorage	costPerBw
x86	Linux	Xen	10.0	0.3	0.05	0.1	0.1

5.2 Analysis of results

The fig 8 shows workflow of task dependency in CyberShake_50 and fig 9 shows simulation results when MINMIN simulation algorithm is used. Here the total cost is calculated using the formula

cost= (communication cost + computation cost) = (data (both input and output) *

* unit cost of data + runtime * cpu cost) for each task

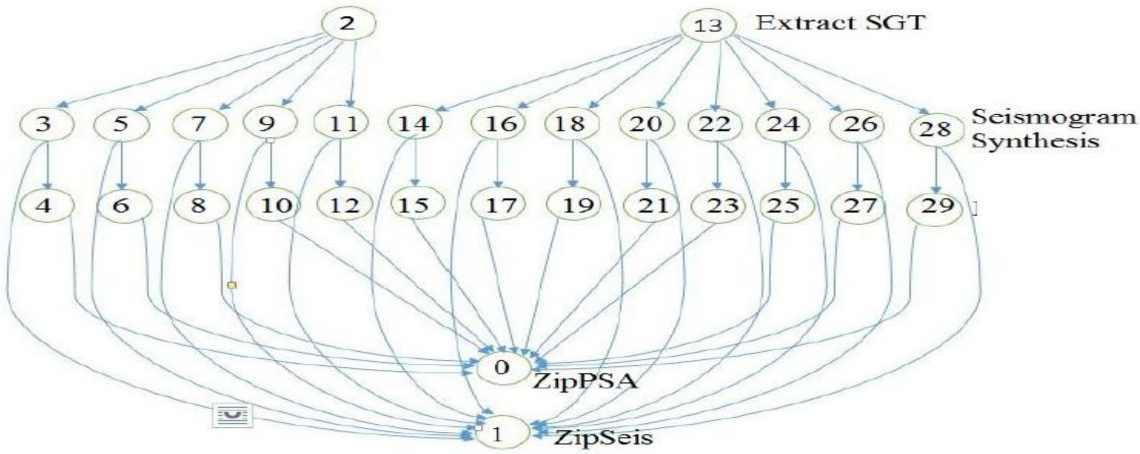

Fig 8: CyberShake_50 task dependency graph

---------- OUTPUT ----------

Cloudlet ID	STATUS	Data center ID	VM ID	Time	Start Time	Finish Time	Depth	Cost
50	SUCCESS	2	0	0.11	0.1	0.21	0	1724.83
2	SUCCESS	2	0	646.21	0.21	646.42	1	678.16
22	SUCCESS	2	1	663.51	0.21	663.72	1	687.65
5	SUCCESS	2	0	40.64	646.42	687.06	2	67.29
6	SUCCESS	2	0	1.01	687.06	688.07	3	0.3
25	SUCCESS	2	1	30.11	663.72	693.83	2	68.33
26	SUCCESS	2	0	0.77	693.83	694.6	3	0.23
35	SUCCESS	2	2	697.94	0.21	698.15	1	668.38
46	SUCCESS	2	2	40.27	698.15	738.42	2	41.68
47	SUCCESS	2	2	1.29	738.42	739.71	3	0.39
36	SUCCESS	2	0	43.08	698.15	741.23	2	42.42
37	SUCCESS	2	0	0.77	741.23	742	3	0.23
27	SUCCESS	2	7	79.03	663.72	742.74	2	82.91
3	SUCCESS	2	4	96.39	646.42	742.81	2	83.72
28	SUCCESS	2	0	1.38	742.74	744.12	3	0.41
4	SUCCESS	2	2	1.4	742.81	744.21	3	0.42
9	SUCCESS	2	5	97.94	646.42	744.36	2	84.28
10	SUCCESS	2	0	0.99	744.36	745.35	3	0.3
31	SUCCESS	2	8	81.89	663.72	745.6	2	84.07
32	SUCCESS	2	0	0.68	745.6	746.28	3	0.2
23	SUCCESS	2	9	82.84	663.72	746.55	2	84.25
24	SUCCESS	2	0	1.03	746.55	747.58	3	0.31
7	SUCCESS	2	6	101.39	646.42	747.81	2	85.42
8	SUCCESS	2	0	1.32	747.81	749.13	3	0.4
40	SUCCESS	2	1	57.68	698.15	755.83	2	46.7
41	SUCCESS	2	0	1.54	755.83	757.37	3	0.46
29	SUCCESS	2	10	94.1	663.72	757.82	2	87.53
30	SUCCESS	2	0	1.31	757.82	759.13	3	0.39
11	SUCCESS	2	3	759.23	0.21	759.44	1	709.17
38	SUCCESS	2	12	63.64	698.15	761.79	2	48.59
44	SUCCESS	2	13	64.38	698.15	762.53	2	48.82
39	SUCCESS	2	5	1.37	761.79	763.17	3	0.41
45	SUCCESS	2	6	1.25	762.53	763.79	3	0.38
48	SUCCESS	2	14	66.03	698.15	764.18	2	49.41
49	SUCCESS	2	5	1.21	764.18	765.39	3	0.36
33	SUCCESS	2	11	103.66	663.72	767.38	2	90.3
34	SUCCESS	2	5	1.28	767.38	768.66	3	0.38
42	SUCCESS	2	15	78.04	698.15	776.19	2	53.01
43	SUCCESS	2	5	1.36	776.19	777.55	3	0.41

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18   SUCCESS   2   3   51.38   759.44   810.82   2   67.31
19   SUCCESS   2   3   1.44    810.82   812.26   3   0.43
20   SUCCESS   2   0   71.39   759.44   830.83   2   73.42
21   SUCCESS   2   0   1.56    830.83   832.39   3   0.47
14   SUCCESS   2   1   76.33   759.44   835.78   2   74.8
15   SUCCESS   2   0   1.3     835.78   837.08   3   0.39
12   SUCCESS   2   2   84.47   759.44   843.91   2   77.34
13   SUCCESS   2   0   0.88    843.91   844.79   3   0.26
16   SUCCESS   2   4   89.94   759.44   849.38   2   78.78
1    SUCCESS   2   0   0.17    849.38   849.55   3   0.05
17   SUCCESS   2   1   1.57    849.38   850.96   3   0.47
0    SUCCESS   2   0   0.24    850.96   851.2    4   0.07
The total cost is 5996.73
BUILD SUCCESSFUL (total time: 1 second)
```

Fig 9: simulation results when MINMIN simulation is used

The table shows the makespan and total cost of scheduling of tasks using the algorithms FCFS,MCT,MAXMIN and MINMIN with Montage_100 and CyberShake_50 datasets

Scheduling Algorithms	Data set	Make span time	Total cost
FCFS	Montage_100	114.2	533.58
MCT	Montage_100	114.2	533.58
MINMIIN	Montage_100	115.19	534.56
MAXMIN	Montage_100	113.55	534.7
FCFS	CyberShake_50	851.2	5996.73
MCT	CyberShake_50	851.2	5996.73
MINMIIN	CyberShake_50	851.2	5996.73
MAXMIN	CyberShake_50	846.95	5996.69

Table 1 : Results of various scheduling algorithms with different datasets

Our experiment shows that MAXMIN is the most efficient with respect to the makespan and total cost in comparison to the other algorithms FCFS,MCT,MINMIN

V. CONCLUSIONS

Minimizing Makspan is one of the objective in scheduling algorithm. TheExperiments shown MAXMIN is the most efficient with respect to the makespan and total cost in comparison to the other algorithms FCFS,MCT,MINMIN. These algorithm still can be improved by considering multiple objective functions, fault tolerance. because after a job is submitted to the resource , if the resource becomes unavailable it may affect the makespan and cost of execution.

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