Cluster based Scheduling of Workflow Applications in Cloud

Ardra V A
Department of Computer Science and Engineering
NSS College of Engineering
Palakkad, Kerala

Sindhu S
Associate Professor
Department of Computer Science and Engineering
NSS College of Engineering
Palakkad, Kerala

ABSTRACT
High Performance Computing (HPC) applications are those that are highly compute and data intensive. They require supercomputers for their execution. Currently the interest in HPC in the cloud has been growing. Cloud computing allows scientists to access supercomputing like features in a pay per use fashion.HPC applications can be represented as workflows because of the existence of dependencies among individual nodes. Scheduling of workflow applications involves mapping of the workflow tasks to individual computing units as the tasks are compute intensive. The schedules should be generated by considering the precedence constraints among the dependent tasks. Minimization of makespan is an important constraint while scheduling workflows. This paper proposes a cluster based scheduling of workflow applications for minimizing the total makespan.

General Terms
Cloud computing, scheduling

Keywords
HPC, workflow, makespan.

1. INTRODUCTION
Cloud computing has referred as one of the most influenced technology trend in the last several years. As the services are delivered and consumed in real time over the internet it has got great amount of attraction from several fields. The main service oriented cloud computing services include SaaS(Software as a service), PaaS(Platform as a service) and IaaS(Infrastructure as a service). Google's Apps and Salesforce's Customer Relation Management (CRM) System belong to SaaS systems, while Google App Engine and Yahoo Pig are PaaS systems, and Amazon's EC2, Amazon's S3, and IBM's Blue Cloud are IaaS systems. These services are deployed either through a public model or through a hybrid or a private deployment model. The services of a cloud computing system can be accessed through internet, while the services of grid and cluster computing takes place in a corporate network. Cloud is an on demand and elastic service, while grid and cluster are not.

A computer is said to be high performance if it uses multiple processors in the range of tens, hundreds or even thousands connected together by some kind of network to achieve well above the performance of a single processor. Calculations can be done many times faster than a conventional computer with HPC. The endless benefits of HPC is that it could increase oil recovery by 50-75% with more accurate seismic modeling of oil reservoirs, it is being used to design efficient wind and wave turbines which helps to harness renewable energy sources, used to model the thread of epidemics so that halting the expansion of life-threatening diseases can be done. HPC is used in image processing also, which helps to get the images of mosaic and montage of sky [1]. Owning HPC machines are expensive in terms of capital and running costs. Traditional HPC centres are available to perform such compute intensive tasks but incur a very large amount.

Other than owning and maintaining our own systems, cloud computing and its pay per use model provides computing as a service. Virtualization flexibility is provided by cloud in addition to traditional HPC systems and supercomputers. Cloud computing offers instantly available and scalable computing resources and almost unlimited storage at low cost. Experiments which need HPC can be characterized as workflows. Workflows describe the relationship of the individual computational components and their input and output data in a declarative way. In astronomy, scientists are using workflows to generate science-grade mosaics of the sky [2], to examine the structure of galaxies [3], and, in general, to understand the structure of the universe. In bioinformatics, researchers are using workflows to understand the underpinnings of complex diseases [4, 5]. In earthquake science, workflows are used to predict the magnitude of earthquakes within a geographic area over a period of time [6]. In physics, workflows are used to search for gravitational waves [7] and model the structure of atoms [8]. In ecology, scientists use workflows to explore the issues of biodiversity [9].Today workflow applications can be run in various national and international infrastructures such as TeraGrid, Open Science Grid etc. However, the challenge is that it's hard to decide which resource to use and how long they will be needed. So cloud systems are a solution for providing on demand computing. Scientific workflows are used to bring together various data and compute resources and answer complex research questions. High Performance Computing applications can be solved efficiently by using cloud and grid systems. Cloud computing is increasingly being explored as a cost effective alternative (and addition) to supercomputers for some HPC applications. While scheduling workflow, we are mapping dependent tasks to computing sites. We consider makespan as QoS constraint while scheduling. Decreasing makespan can be achieved by clustering workflow tasks into clusters and mapping these clusters to computing sites instead of individual tasks.

2. RELATED WORK
Various researches have been taking place on the scheduling of workflow applications in both grid systems and cloud systems. Yu Etal[10] proposed an MDP based workflow scheduling in cloud where the main objective was to minimize deadline. A genetic algorithm based scheduling approach [11] was proposed which was constrained to optimising either execution cost or the overall makespan. Many grid and cluster workflow management tools such as Pegasus, Kepler etc have been successfully executed. In paper [1] the author describes about Amazone's Elastic Compute Cloud(EC2), which is a

part of Amazone Web Services. AWS services provide computational, storage, and communication infrastructure on-demand via web-based APIs. *Elastic Compute Cloud* (*EC2*) is a service for provisioning virtual machines instances from Amazone's compute cluster that allows users to deploy virtual machines. The author of paper [12] describes HPC as a service in cloud like PaaS, SaaS and IaaS. One of the main advantages of HPC clusters is the flexibility and efficiency they bring to their user. With the increasing number of applications being served by HPC systems, new systems need to serve multiple users and multiple applications. In paper [13], the author proposed methods for improving HPC application performance in cloud through VM placement strategies by tailoring with application characteristics. A large scale HPC application would ideally requires a dedicated allocation of cloud resources such as compute resources and network resources.

The authors of paper [14] analyzed the performance of high performance computing applications in Amazone web service cloud. They provide the broadest evaluation to date of application performance on virtualized cloud computing platforms. Their experiences with running on Amazon EC2 and the encountered performance and availability variations also provided an analysis of the impact of virtualization based on the communication characteristics of the application as seen through IPM (Integrated Performance Monitoring). The paper [15] presents a scheme to optimize the mapping of HPC applications to a set of hybrid dedicated and cloud resources. They characterize application performance on dedicated clusters and cloud to obtain application signatures. The paper [16] summarizes the application requirements and business model needed to support the requirements of both existing and emerging science applications, as learned from the early experiences on Magellan and commercial cloud environments. They provide an overview of the capabilities of leading cloud offerings and identify the existent gaps and challenges. In this paper we propose a cluster based scheduling of workflow applications in order to reduce the overall makespan.

3. CLOUD WORKFLOW SCHEDULING

Workflow applications are submitted through an interface. After submission the average execution times of each and every node can be calculated. Clustering of the tasks is performed based on the obtained values of execution time. From this value the overall makespan of the workflow can be calculated.

Workflow applications can be represented as a Directed Acyclic Graph(DAG) G={V,E}. V={V1,...Vn} vertices of the DAG represents tasks and E={E1,...En} edges represents the precedence constraints between tasks. C={C1,...Cn} represents a set of computing sites capable of executing task Vi. The overall makespan M of the workflow is defined as the latest finished time on all the virtual machine. Then total makespan for the workflow is

$$M = \max(Ci)\ \forall i \in C$$

Figure 1 represents a sample workflow DAG containing 7 task nodes. The edge between the nodes represents input and output files between tasks. The objective of the cloud workflow scheduler is to minimize the total makespan of the workflow by finding out an appropriate mapping of each task.

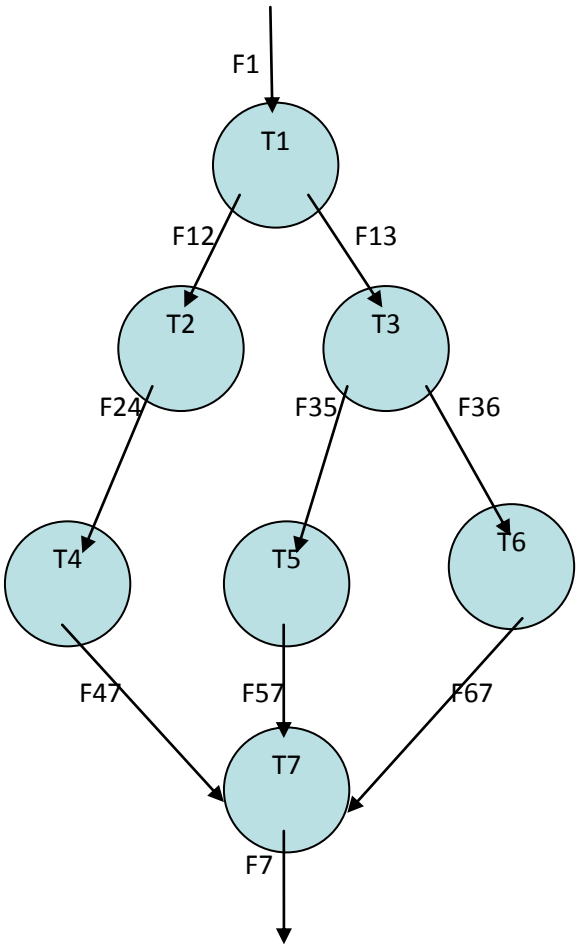

Fig 1: DAG with 7 nodes

Algorithm FIND_CLUSTER

1. *Input:* DAG(V,E)
2. Weighted matrix of DAG
3. Set of processing elements arranged from fastest to slowest
4. Bandwidth matrix for bandwidth between processing elements
5. ETC(Estimated Time for Completion) matrix between tasks(DAG nodes) and processing elements.
6. Begin
7. If(i is an entry node)
8. Cluster(i)={i}, assign i to the fastest processing element.
9. Else
10. While (next node(i)!=null)
11. Check the weighted matrix,
12. If weights between i to all other nodes are different, then assign

the node with largest weight to parents cluster.

13. Other nodes to 2nd and 3rd fastest processing elements according to the bandwidth between processors.
14. Then find out the makespan from the ETC matrix by adding the completion time of each node in the assigned processing elements.
15. End

4. RESULTS AND DISCUSSIONS

4.1 Experimental Setup

To implement the proposed algorithm Cloudsim simulator developed by the CLOUDS group at the University of Melbourne is used. Cloudsim is a cloud simulation tool which helps to model typical cloud scenarios on a single processor. It facilitates the creation of data centres and the deployment of multiple hosts and Virtual machines of varying capacities. In this experiment we simulate two separate data centers each containing two hosts. Each host can create multiple virtual machines. The proposed clustering algorithm was successfully implemented and showed variations from the typical task scheduling policy. The total makespan for scheduling clusters is less than that for the scheduling of individual tasks.

4.2 Result

Table 1. Scheduling without clustering

Job	T1	T2	T3	T4	T5	T6	T7
Time(s)	50	130	190	250	320	400	480

Table 2. Scheduling with clustering

Job	T1	T2	T3	T4	T5	T6	T7
Cluster#	1	2	1	2	1	3	2
Time(s)	50	130	160	220	270	350	410

From table1 and table2 it is clear that the time taken for scheduling clusters is lesser than that of the scheduling of individual tasks.

5. CONCLUSION

Studies were carried about the cloudsim simulation tool as part of the implementation. The proposed algorithm was implemented successfully using simulation tool and results are obtained. As we are scheduling clusters of jobs instead of individual tasks it shows good results in terms of makespan. As a future work we can include more parameters like cost, deadline etc along with makespan for scheduling. Then heuristics can be used to find out optimal scheduling among the generated schedules generated set of schedule.

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