Fault Tolerant and Optimal Task Clustering for Scientific Workflow in Cloud

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ABSTRACT

Scientific workflows are very complex, large-scale applications and require more computational power for data transmission and execution. In this article, the authors address the problem of scheduling scientific workflow on a number of virtual machines (VM) with the objective of reducing the total makespan of workflow and failure. This article implements checkpoints and replication strategies with the parallel task execution (PTE) algorithm to schedule scientific workflow for minimum time and cost. In order to reduce execution overhead and improve performance of the scientific application, the task uses clustering methods. Specifically, Horizontal Reclustering (HR) method were implemented to reduce failure and scheduling overhead. The authors have combined checkpoint, replication and PTE algorithms together and applied it to the HR method. Results show that the proposed strategies and method works efficiently in terms of reducing failure, makespan and execution cost compared to existing methods.

KEYWORDS

Fault Tolerance, Scientific Workflow, Task Clustering, Workflow Scheduling

INTRODUCTION

The scientific workflow is a collection of the number of dependent and interdependent tasks. Scientific workflow is used to model the scientific applications in various fields of astronomy, physics, bioinformatics etc. Since the workflow consists of the large number of computational tasks, hence more computational power required to run. The estimation of performance of workflow technique in real word is more time-consuming and complex, due to large system overhead. Task clustering (Singh et al., 2008) is a technique to consolidate the short tasks into jobs to reduce the system overhead. Existing clustering techniques don't consider the impact of the failure in the system; despite their powerful effect on distributed environment such as clouds, grids, etc. (Sahoo et al., 2004; Schroeder et al., 2010; Gupta et al., 2016; Mohammad et al., 2017; Nasr & Ouf, 2015). Researchers (Zhang et al., 2004; Tang et al., 1990) stressed the significance of fault tolerance planning and showing that the failure rate in distributed environment is important. Deployment of workflow in cloud environment is largely efficient, but more scope is required on fault tolerance (Bagui & Nguyen, 2015; Bhushan & Gupta, 2017). Failure of the workflow tasks consists of many reasons and types. The proposed work focuses to reduce the transient failure, where failure can be recoverable (not permanent failure) (Zhang et al., 2004). Transient failures are divided in two types: job failure and task failure. The task clustering consists of multiple clustered jobs with many tasks. The task from job is failed due to the

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unpredictable event during computation. Then whole job will be in the failed state, even though the other tasks from the same clustered job are executed successfully. Different technique is designed to improve the impact of job failure on scientific workflow execution. One of the techniques is to retry the failed job, but it’s expensive because already executed tasks will also be the part of re-computation (Zhang et al., 2004).

Task failure plays a very important and the most focused problem in workflow execution. Many investigators (Sahoo et al., 2004; Schroeder et al., 2010; Zhang et al., 2004; Tang et al., 1990) point out failure problem and its significance. There are different types of failure such as job failure, task failure, VM failure and many more. The focused research problem entitled on failure, which is not permanent, which can be recoverable (Zhang et al., 2004). The Pegasus Workflow Management System will monitor scientific workflow based on task-level and re-run the job when failure of tasks occurs. Failure data is analyzed to know the reason of failure (Deelman et al., 2015). The (Deelman, et al., 2009), CloudSim is a framework for simulating and modeling cloud computing services. It supports the single execution of workloads.

In literature, few authors focused on the problem of mapping of workflow using Directed Acyclic Graph (DAG) (Blythe et al., 2005; Wieczorek et al., 2005; Kalayci et al., 2010). Author considered matchmaking technique for scheduling tasks to distributed resources (Blythe et al., 2005; Kalayci et al., 2010). Similar approach is taken by author (Chen et al., 2016) to defeat scientific workflow to node computing with high rate of failure. Furthermore, author concentrated on gaining performance of task clustering methods by changing size of the cluster to reduce a cost of re-execution of failed task and reduce makespan of workflow.

In this research work (Chen et al., 2013), they focused on dependency imbalance and runtime imbalance problem. Author proposed balancing task methods to solving these problems. To evaluate performance trace-based simulation is used, and it shows the runtime is improved by these methods.

In (Antony et al., 2012), author addressed the network access problem based on data locality. They proposed algorithm named task scheduling with objective reducing makespan and bandwidth usage. They enhanced Balance Reduce Algorithm (BAR) for effectively handling machine failure. Their results show the comparison of existing and a proposed algorithms, proposed algorithm reduces the makespan when failure occurs.

The management of the task granularity problem is identified in workflow. (Ferreira da Silva, Glatard & Desprez, 2014; Maheshwari, 2012) built algorithms to controlling task granularity in online context and non-clairvoyant, but they didn’t address the fault tolerance issue.

(Pandey et al., 2009, Stergiou et al., 2017), introduced the tasks clustering based upon the execution time and data-transfer time. The tasks having average execution time and good variation, those tasks will not be necessary to cluster for run. A task with an unacceptable execution time and deviation needs to be clustered together. A job contains multiple tasks so that, the chances of task failure rate will high and is the side effect of task clustering. The failure directly effects the performance of workflow. A job, and task failure model focuses on these performance issues in task clustering.

Weiwei Chen, Student Member, Ewa Deelman proposed different methods for the fault tolerance (Chen, et al., 2016). They analyzed these methods for the scientific applications, including Montage, Cybershake, LIGO, SIPHT, Epigenomics in which runtime is captured from real execution traces. They consider the factors such as rate of task failure to find the reliability of their clustering methods and used Trace-based simulation. They used WorkflowSim simulator to control the distributed environment with considering parameters runtime of tasks and fault arrival time to evaluate the performance of proposed fault-tolerant algorithms. Their results show that proposed methods improve the makespan of workflow as compare to existing methods and dynamic re-clustering method is best among all three methods which reduce the makespan and the system overhead (Chen et al., 2016).

(Pandey, et al., 2010) address the problem of minimizing the computation and data transmission cost. To scheduling the workflow application, they proposed the heuristic, Particle Swarm Optimization (PSO). They compare PSO with the Best Resource Selection (BRS) algorithm. Their results indicate
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