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A green energy model for resource allocation in computational grid using dynamic threshold and GA

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ABSTRACT

Computational grid helps compute intensive jobs in faster execution. By virtue of resource provisioning, very high demand of computational power can be facilitated though at the cost of high energy consumption. Many characteristic parameters are intended to be optimized, depending upon the requirements, while making resource allocation for the job execution in computational grid. Most often the green energy aspect, wherein one tries for better energy utilization, is ignored while allocating the grid resources to the jobs. Most of the grid scheduler aims to optimize the makespan, ignoring the energy aspect. Proposed work tries to optimize the energy making it a green energy model while making resource allocation in computational grid. In this, energy saving mechanism is implemented using a dynamic threshold method followed by the use of genetic algorithm which further consolidates the energy saving. It explores how effectively the jobs submitted to the grid can be executed with optimal energy uses and at the same time makes no compromise on other expected characteristic parameters. The proposed green energy model has been experimentally evaluated by its simulation. The result reveals the benefits and gives better insight for effective energy aware resource allocation.

1. Introduction

Grid, a collaborative distributed machine, facilitates execution of complex and compute intensive applications by coordination of a large number of geographically distributed resources. Grid resources, normally heterogeneous, are available to all the grid users and allow possible parallel job execution. The resource usage efficiency of the system also increases considerably. Grid resources are normally under the purview of different administrative domains and thus define varying policies for their usages. These grid resources may have even different capabilities and configurations, making grid resource management a core and important issue for a viable grid system. Resource management in a grid demands efficient mapping of compute jobs to the grid resources making resource allocation a critical work in the grid environment [1,2].

Energy efficiency of Grid systems is an important aspect as it incurs a huge amount of electrical energy for managing its resources. Though, the grid system heterogeneity and the users' constraints make resource allocation in computational grid a difficult problem, this further gets aggravated when energy optimization is also given a heed along with other performance measures.

The energy consumption of a grid may be determined by evaluating the energy consumption of the hardware, the resource configuration policy, and the runtime efficiency of the jobs [3]. Though the objective of a computational grid is to utilize the resources to its fullest extent, it has been observed that not all the resources are used in a continuous manner. The resources that do not contribute in an execution still consume energy [4]. By virtue of the selective connectivity, it is possible to accomplish the users' task with the desired constraints while putting few nodes into sleep mode to conserve energy [5,6]. The resource allocation problem, that normally aims to minimize the makespan for the job by effectively managing the available grid resources, may be extended for energy minimization while meeting the users' and system's constraints.

The proposed model, based on green energy, is designed to suit best both the grid system and the users. The work has been divided in two parts. First part deals with the identification of the best grid cluster as per user's requirements and resource availability. This is done based on the current system's load and jobs' requirements in terms of its specialization, degree of concurrency in the job and the turnaround time expected/offered. In the second part,

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mechanism for energy saving is applied in which all the nodes with the load less than a dynamically evaluated threshold are switched to the sleep mode. The loads, if any, of the sleeping nodes are redistributed among other active nodes while maintaining the execution time constraint. Finally, genetic algorithm (GA) is applied to further consolidate the saving [7].

Outline of the paper is as follows. Section 2 briefs the related work. Section 3 details the formulation of grid resource management problem with minimum energy consumption and then the proposed grid resource management model. The quantification of various parameters and the algorithm is also given in Section 3. Simulation experiments and their observations are presented in Section 4. Concluding remarks appear in Section 5.

2. Related work

The issues involved for solving grid scheduling problem are non-trivial and adding green energy aspect makes it further challenging. In recent, research emphasis has been given to the green aspect of grid computing in addition to traditional issues e.g. resource allocation based performance optimization.

Two approaches, generally applied for the energy management, are Dynamic Voltage and Frequency Scaling (DVFS) and Dynamic Power Management (DPM). The relationship between the supply voltage and the CPU frequency are used by the DVFS approach to explore the energy saving. The DPM approach explores the saving by virtue of coordinated or uncoordinated power down method for job execution in a grid system [8,9].

Most of the existing work, to reduce energy consumption in computational grid, is based on voltage and frequency scaling. Processors define a set of voltage and frequency pair levels. Even otherwise, using a software, the clock speed of processors may be changed dynamically to be utilized for reducing the processor's energy consumption by adjusting its voltage and frequency [10–12]. The processor voltage and frequency is adjusted to its lowest possible level either manually or dynamically. Low speed processor consumes less energy and dissipates lesser heat, meaning thereby the energy consumption will be low if the processor runs at the lower frequency [8,12–14].

The greener aspect in allocation policies are also adopted in other distributed systems like cloud and mobile grid environment. An energy aware resource management technique is proposed in [15] which schedules tasks on an energy constrained heterogeneous computing system while aiming at maximizing the utility of the system based on the completion time of the task. In [16], authors aim at reduced energy consumption and completion time by adopting a centralized scheduling approach in a mobile ad-doc environment. In their work they have used resource selection by controlling the communication overhead between dependent tasks and energy consumption in transmission of data.

In [17,18] authors have evaluated various virtual machine allocation policies to reduce the energy consumption. They observed that by choosing appropriate allocation policies the overall energy consumption may be reduced as the number of active hosts are minimized. From the different approaches adopted in [18] the authors have concluded that the watts per core policy is the most energy efficient and the load balancing policies score well in terms of minimizing CPU load.

In [19], authors have used makespan, flowtime, and energy consumption as the main criteria for scheduling batch of independent tasks in computational grid with different security constraints. They have employed DVFS scaling to reduce the cumulative energy utilized by the system's resources. Although the DVFS approach reduces the energy consumption by scaling down the voltage level, it may not significantly gain in meeting the job deadlines.

A Heterogeneity Aware Meta-scheduling Algorithm is proposed in [20] which can be implemented in any existing scheduler to exploit the heterogeneity of the grid infrastructure for energy reduction of overall grid. The method employed first to identify the most energy efficient grid resources and then uses dynamic voltage scaling method to further reduce the energy consumption.

Any machine, if not in use, may save significant energy by simply keeping itself off [21]. The authors in [14] evaluated the effectiveness of sleeping states and a timeout policy to save energy in grids. They found that the sleeping states and a timeout policy can save energy without harming storage lifetime although with a little expense in terms of the jobs' makespan.

In [22] a theoretical model based on random graph theory is proposed. In this, a potential energy saving applying sleep mode to the network devices (nodes and links) is evaluated. They experimentally establish that the use of sleep mode is very effective in reducing the network energy consumption. This is possible due to the hardware profiling often used now a days where the energy consumption varies very little with the load and thus the use of sleep mode is very effective.

A lot of work has been done on resource allocation problem in computational grids using GA. Some of them use GA for scheduling problems with focus on makespan minimization [23–26] while some other use GA for energy aware scheduling [27,28].

In [29] authors elaborated the energy saving aspect through the devices, network design or embedding through the network protocols. In [30], authors have compared various energy policies. They found that the Simple Job Aggregation with the Switch-off Random policy shows better results. In [31] authors proposed the work for clusters of workstations or PCs to achieve energy conservation. In their algorithm, they make a dynamic decision for making load balancing and un-balancing by putting nodes in *on* state considering the total load imposed on the cluster and nodes to be in *off* state for saving the energy.

A similar approach is adopted in [11] where the unused nodes are switched off by migrating the virtual machines and to concentrate the workload on fewer nodes of the grid. Some work has been done on an energy-scheme for Grid systems [5,6,32,33] where after job scheduling an energy saving strategy is invoked which leverage *on/off* of servers based on the load while avoiding frequent switching of servers for *on/off*.

In an opportunistic grid, the agent controls the switching of a machine to a sleep mode or to bring it back into operation, depending on the state of the machine and the job requirements [6]. In [9], the authors have proposed various auction based strategies for resource allocation in order to attain minimal energy consumption in the grid. They have exhibited that different mechanisms for resource allocation can be used which may significantly alter the energy consumption in execution. Their results show that depending on the characteristics of the task, different auction methods may be explored for the energy conservation.

In [34], a framework to address the objective of minimizing energy consumption by virtue of energy-efficient light-path for computational grid is proposed. Each backbone node maintains two threshold values to adopt *sleep* and *wakeup* cycle and thus saves energy by rejecting transient traffic. The authors in [6] have discussed two strategies, most recent sleeping and the energy awareness to wake up the machines and discussed their impacts on the job makespan. They have also compared the two aspects, standby and hibernate, often used for reducing the energy consumption in the idleness period of any computer system.

In [32,33,35], prediction algorithm for energy-aware model is proposed. There are three steps involved. In the first step, a centralized *on/off* algorithm for the unused resources is used and in second step for subsequent jobs it predicts next use based on the