2013

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Advanced Networks and Telecommuncations Systems (ANTS), 2013 IEEE International Conference on
Pages: 1 - 3, DOI: 10.1109/ANTS.2013.6802891

A Tabu Search Based Heuristic for Optimized Joint Resource Allocation and Task Scheduling in Grid/Clouds

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***Abstract*—Nowadays the development of Grid/Cloud networks has accelerated to meet the increasing requirements for large-scale computing, storage and network capabilities by consumers. Therefore how to improve the resource utilization in the Grid/Cloud to satisfy more task requests from users is becoming important. The objective of our investigation in this paper is to minimize the expense the consumers incur while obtaining the resources they request from Grid/Cloud networks. We propose a Tabu search based heuristic to solve joint resource allocation and task scheduling problem in Grid/Cloud networks, and examine the performance of the proposed method. The experimental results are analyzed and compared with the Best-Fit method we proposed in our earlier work. The results show that the Tabu search based heuristic method will equal or outperform the Best-Fit heuristic, and both can achieve approximate optimal solutions to the corresponding MILP (Mixed Integer Linear Programming) solutions. In addition, compared to the Best-Fit method, the Tabu search based heuristic will reduce the traffic blocking rate by 4%∼30% generally under different job scheduling policies.**

I. Introduction and Related Work

Grid/Cloud networks provide dynamically scalable resources as a service over the Internet. Resource allocation in distributed Grid/Clouds has become an important problem involving resource modeling, resource selection and optimization, resource offering and treatment, resource discovery and monitoring [1]. For the resource selection and optimization challenges, the provider needs to fulfill all requirements and optimize the usage of the infrastructure when given the information regarding Grid/Cloud resource availability at hand. We will focus on the resource selection and optimization problem in the Grid/Cloud network from the customer's perspective in this paper.

Several research studies have been carried out on the resource allocation problems for the Grid/Cloud networks with various distinct objectives or approaches [2][3]. Different from other works, our contributions in this paper are based on a new resource allocation model we designed in our previous work [4]. New job structures are supported in the model, in which each job consists of a number of sequential tasks or parallel tasks or both. In addition, temporal parameters were introduced in the Grid/Cloud resource scheduling model. The objective of our model is to minimize the expenditure for each user while obtaining enough joint resources to execute their submitted jobs, while making the Grid/Cloud providers accept as many job requests from users as possible.

The rest of this paper is organized as follows. Section II presents the model of the joint resource allocation problem concisely. Section III describes the proposed Tabu search based heuristic for solving our problem. In Section IV we evaluates the performance of Tabu search algorithms on two network topologies, and compare the performance with the Best-Fit method and MILP results obtained in IBM ILOG CPLEX in our previous work. Section V provides the conclusion.

This work is supported by the National Science Foundation under Grant No. CNS-1040765 and Department of Energy (DOE) project award No. DE-SC0001277.

II. Problem Modeling

A. Definitions and Assumptions

The resources in the Grid/Cloud networks are distributed among the various physical hosts or virtual machines. How to select and allocate the available resources to the submitted jobs reasonably and guarantee the minimum expenditure for the users is the problem we investigate.

We consider the scheduling of computational resources (processor, storage), and network resources (optical transponder (OT), physical links such as optical fibers) in the DWDM (Dense Wavelength Division Multiplexing) layer of network in our problem model. Users submit the jobs which consist of several tasks to the scheduler in the Grid/Cloud network. The scheduler will assign the required computational resources from the nodes, and also the physical links to transport data between tasks of each job. OTs connected to the ports of ROADM (reconfigurable optical add-drop multiplexers) are used to set up physical links to transmit in DWDM layer. We make the followings assumptions to simplify our model and keep it reasonable for realistic joint scheduling in Grid/Cloud networks as well.

- Each node has potentially, different computational capacities; each link has the same bandwidth capacity.
- Jobs arrive one by one and are collected in the scheduler node first, then the scheduler will schedule them together.

- The computational resources for each task, must be allocated from the same node.
- Execution cycle, noted as S_{max}, is slotted. Each time slot is of fixed length and equal size, noted as s. Jobs should be completed within one execution cycle.
- A job consists of dependent or independent tasks. Independent tasks in one job can be executed in parallel, while dependent tasks must be executed sequentially. If task B is dependent on A, and we note A as **parent** task and B as **child** task.
- Resources will be released once the execution of a job is completed.
- Transponder Mapping. OTs, used to set up optical circuits between two nodes in the network, must appear in pairs.

B. Price Model

Our price model is based on the “pay-as-you-go” criterion, in which users pay the bills according to how many resources they use and how long they hold the resources. We define three price models (for processer, storage and network resource) based on the study of Amazon EC2, Google GCE and GoGrid price models.

For the processor price model, we decide the processor unit cost on a node according to the compute power of this node, which is related with the CPU capacity of current node. For the storage price model, the more storage resources a node has, the less storage unit cost it will have. For the network price model, the OT and physical link unit price is related with the geographic location of the data-center in the network topology (We divide network topology into three regions: US-east, US-west and US-central). Due to the space limitation, the detailed price model information and problem definition are not included here and can be found in [4].

III. Tabu Search Based Heuristic

In the previous studies, we implemented the Best-Fit algorithm, which is a greedy method, to solve the optimal joint resource scheduling problem in Grid/Cloud networks. The Best-Fit method performs well, but as we know Tabu search is a “high level” meta-heuristic procedure for solving optimization problems, designed to guide other methods to escape the trap of local optimality [5], and has been applied to solve resource allocation and other optimization problems [6]. So we proposed Tabu search based heuristic to solve our optimization problem with the hope of obtaining better solutions and improving the traffic blocking rate for the input demands.

Based on the study of basic idea of Tabu search, we need to pay attention to several key points in our design, such as initial solution, neighborhoods generation, aspiration satisfaction and termination conditions. The pseudocode of the proposed Tabu search based heuristic is shown in Algorithm 1. In Algorithm 1, C_j is the cost of job j. The four job scheduling policies are FCFS (first come first serve), SJF (shortest time first), ESTF (earlier start time first), SSF (simpler structure first).

Algorithm 1 Tabu Search Based Algorithm

Input and Initializations:
$G = (V, E)$;
Current traffic in network;
$J = j_1, j_2, ..., j_M$; //Input job requests
$T_j = t_1, ..., t_k$, $j \in J$; //set of tasks belong to job j
$VT_j = vt_1, ...vt_k$, $j \in J$; //set of virtual tasks belong to job j
$C_j = 0$; //initial job cost is 0
Output: Minimize $\sum_{j \in J} C_j$.

Update current available resources in the network;
Select job scheduling policy from: FCFS, STF, Random, ESTF, SSF;
Sort the topology nodes according to resource unit cost;
InitialSol := solution by Best-Fit algorithm;
OptSol := InitialSol; //set optimal solution
Generate solutions pool;
Set Tabulist;
while not-termination conditions **do**
    Random move to generate neighbor solution: Neighbor;
    if Neighbor $\in$ Tabulist **then**
        Move operation, generate new neighbor;
    else
        CurrSol := Neighbor; //set current solution
        if CurrSol $<$ OptSol **then**
            OptSol := CurrSol;
            Update Tabulist;
            Continue; //move on search
        else
            Move operation, generate new neighbor;
        end if
    end if
end while
Return OptSol;

IV. Results and Analysis

The simulation with proposed Tabu search based heuristic are carried out on two network topologies: a 10-node network topology and a real 20-node GCE (Google Compute Engine) data-centers topology in US [7].

For our joint resource allocation model, we compare the total expense generated by IBM CPLEX (for solving MILP problems), Best-Fit heuristic and Tabu search based heuristic. For the 10-node topology, with distinct input job numbers, the optimal solutions obtained through Tabu search method are as good as those obtained by Best-Fit method, and are approximate with the accurate solutions obtained by CPLEX. Figure.1 compares the total expense of Tabu search and Best-Fit heuristic with 15 input jobs, under different job scheduling policies on the GCE topology. Here we did not compare the results with those of CPLEX since it is very slow when solving our problem for a larger network topology. We can see from the figure that when the number of input jobs is 15, the Tabu search results are a little bit better than Best-Fit results under the SJF, ESTF, SSF job scheduling policies.

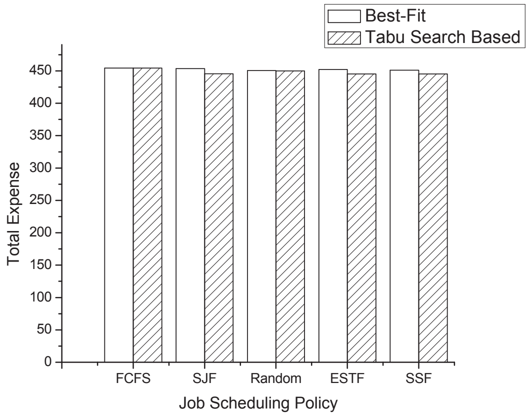

Fig. 1: The total expense comparison of Best-Fit heuristic and Tabu search heuristic with 15 job inputs on GCE topology

We also examine the blocking rate (BR) of our proposed Tabu search heuristic for the optimization problem. The results show that, similar to Best-Fit method, the Tabu search method with SSF job scheduling policy also performs much better in the BR aspect, and has lowest BR than other job scheduling policies. Figure.2 shows us the BR results for various job scheduling policies for the GCE network topology with Tabu search method (Experiment results on 10-node topology are similar and we do not include the figure here due to space limitations). We can see that the BR under SSF is 50% better than that under ESTF when number of input jobs is 130.

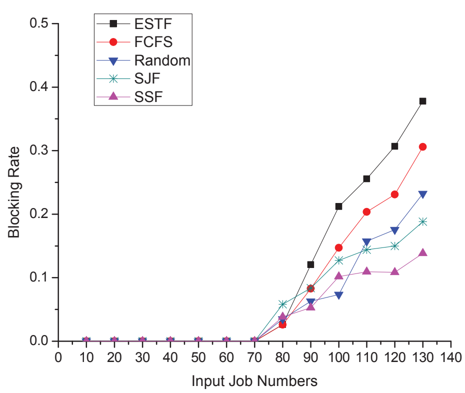

Fig. 2: The blocking rate of Tabu search method under distinct job scheduling policies on GCE topology

In addition, the Tabu search method reduces the BR significantly compared with the Best-Fit method for our problem. In Fig. 3 we compare the BR of Best-Fit and Tabu search methods under SSF job scheduling policy for the GCE topology. The BR is reduced by 4%∼25% than the Best-Fit method. According to the statistics of all the simulation results, the Tabu search method can reduce the BR by 4%∼30% than the Best-Fit method under different job scheduling policies.

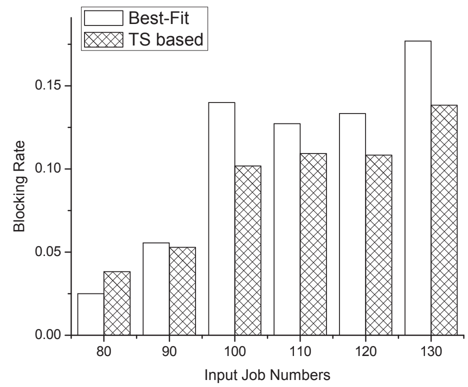

Fig. 3: Blocking rate comparison by Best-Fit and tabu search under SSF job scheduling poliy on GCE topology

V. Conclusion

In this paper, we propose a Tabu search based heuristic based on several distinct job scheduling policies to solve the joint resource allocation in the Grid/Cloud network. The Tabu search based heuristic method will equal or outperform the Best-Fit heuristic, and both can achieve approximate optimal solutions to the corresponding MILP solver results. The experiment results show that the Tabu search based method with SSF job scheduling policy has a better performance on the traffic blocking rate; it has a lower blocking rate than other job scheduling policies. In addition, the Tabu search based method also reduces the blocking rate by 4%∼30% compared with Best-Fit method under any job scheduling policy.

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