Economic Workflow Scheduling Strategy in Mobile Grid*

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Abstract. A wired Grid recognizes resources connected with a fixed network as shared resources. But the present computing environment is evolving to mobile computing environment that involves mobile devices and wireless network. Therefore, the next generation Grids should offer an environment that uses a mobile device as a Grid resource not recognized in wired Grids. It is necessary to develop a system model and a scheduling algorithm for economic scheduling paradigm and load-balancing, which consider both wired and wireless environment. In this paper, we propose a service based architecture that integrates wireless resources with wired resources using proxy-based method to be a resource consumer and a resource producer and suggest an adaptive scheduling strategy considering economy in Mobile Grid. Experimental results show that the performance of our proposed scheduling strategy is scalable in wired and wireless environments.

Keywords: economic scheduling, workflow, mobile grid, maximum flow

1 Introduction

A wired Grid recognizes resources connected with a fixed network as shared resources. But the present computing environment is evolving to mobile computing environment that involves mobile devices and wireless network. Mobile devices will be used in Grid application because of keeping pace with fixed device and wired network in performance and supporting mobility. Therefore, the next generation Grids should offer an environment that uses a mobile device as a Grid resource not recognized in wired Grids. But because Mobile Grid has more constrained than a wired Grid, researches for the use of a mobile device in Grids have considered the mobile device as a resource consumer rather than a resource producer. Generally, mobile devices depend on battery power, and are paid to communicate with other devices. Therefore, a power-balancing for availability of mobile devices and an

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economic model between a resource producer and a resource consumer have to be considered in Mobile Grid.

A wired Grid assumes fast and reliable network connections but a wireless Grid doesn't. A proxy-based environment provides mobile devices with a delegation system that solves a constraint that mobile devices are not always online. Therefore, a proxy-based environment is an alternative for mobile devices to integrate with a wired Grid environment. In this paper, we propose a service based architecture that integrates wireless resources with wired resources using proxy-based method to be a resource consumer and a resource producer and suggest an adaptive workflow scheduling strategy considering economy in Mobile Grid.

2 Related works

Some of researches for integrating mobile devices with Grid have been achieved with the use of a proxy. They had conducted researches for mobile devices to use wired resources through proxy[1]. But they have gradually studied a proxy as an integration environment that mobile devices and wired resources use as Grid resources irrespective of wired or wireless[2][3]. In this paper, we propose an architecture that constructs middleware for proxy-based Mobile Grid environments with Globus in wired environments and JXTA in wireless environments. That is, we integrate P2P with Grid environments by means of a proxy. A research for integrating P2P with Grid is discussed in [4][5]. Researches for scheduling in Mobile Grid have considered mobile environments such as pricing model, energy model[6][7]. In this paper, we propose an economic workflow scheduling that is concerned with the performance, cost and load-balancing of dynamic resources and is adapted to Mobile Grid environment.

3 Proposed Architecture & Economic Workflow Scheduling

The existing Wired Grid model is a centralized or hierarchical structure based on reliable communication such as WSRF(Web Services Resource Framework). If mobile devices that have an intermittent communication are applied to this architecture, we cannot get an expected performance. Therefore, we use a proxy-based three-tier architecture for convergence of wired and wireless Grid resources. A first layer of wired resource is managed by service-based environment using WSRF, a third layer of wireless resource is managed by P2P-based environment using JXTA, and a second layer of middle proxy enables interaction between first and third layer.

We limit user's QoS parameters to deadline and cost, and our goal is to propose an economic workflow scheduling that optimizes time-cost and cost-time. Although there are various workflow types, in this paper, we assume that an application takes the form of only sequential workflow that has one process flow and can execute several data in parallel.

For the economic workflow scheduling, we use a maximum flow algorithm that finds a maximum flow value in flow Network with source *s* and sink *t*. The economic workflow scheduling algorithm presented in Algorithm 1 works as follows. In Algorithm 1, the input parameters of *EconomicWorkflowScheduling* are task graph G_T and *SLA*(Service Level Agreement). This *SLA* involves QoS for physical criteria of compute nodes and data nodes, deadline, and cost. According to the result of

MaximumFlow in Algorithm 2, it inspects whether user's QoS is satisfied before job execution. If user's QoS is not satisfied, the user has to readjust deadline and cost.

- Deadline: Because the edge of service graph is throughput per unit time, the unit time of sequential workflow *wut* is presented as a multiply of the unit time of edge and the service count of sequential workflow. For completion of all jobs within deadline, a multiply of the value that divides the count of all jobs by maximum flow *mf* and *wut* must be less than user's deadline.
- Cost: We can know the unit cost of workflow after *MaximumFlow* execution. This is the cost when executing jobs as much as maximum flow per unit time. Therefore, a multiply of the value that divides the count of all jobs by *mf* and unit cost must be less than user's cost.

If user's QoS is satisfied, it fetches jobs and allocates jobs to services according to the order of services in Algorithm 1. Otherwise, it is rescheduled by *MaximumFlow* again. *FindanAugmentingPath* in Algorithms 2 is based on breadth-first search to find augmenting path in residual network of G_S. The adjacency lists of *FindanAugmentingPath* are sorted by ascending order or descending order of sufferage value of cost and capacity for searching-priorities of nodes. After all tasks are executed, scheduler updates the makespan of services for use of service performance criteria in the future.

```
EconomicWorkflowScheduling(G_T, SLA)
 G_S ← Identify available services satisfied SLA about G_T
 MaximumFlow(G_S, SLA)
 wut = UNIT_TIME * SLA.SERVICE_COUNT_IN_WORKFLOW
 if (SLA.OPTIMIZING_TYPE == DEADLINE &&
    SLA.DEADLINE <= wut * (SLA.TOTAL_JOB_COUNT / mf))
    then it's impossible to finish all jobs by deadline
 if (SLA.OPTIMIZING_TYPE == COST &&
    SLA.COST >= wuc * (SLA.TOTAL_JOB_COUNT / mf))
    then it's impossible to satisfy cost
 while all tasks not executed
    do Fetch task according to the order of services' execution Os
       if the QoS guarantee is violated
          then do update V_S[G_S] // rescheduling
             G_Sprev = G_S
             MaximumFlow(G_S, SLA)
             Migration(G_S, G_Sprev)
 update service's makespan
```

Algorithm. 1. Economic Workflow Scheduling Algorithm

```
MaximumFlow(G_S, SLA)
 for each edge (u, v) ∈ E_S[G_S]
    do flow[u, v] ← 0,  flow[u, v] ← 0
 // there exists a path p from start service to end service
    in the residual network G_S
 while (FindanAugmentingPath(G_S, SLA.OPTIMIZING_TYPE))
    c_f(p) ← min{c_f(u, v) : (u, v) is in p} // residual capacity
    for each edge (u, v) in p
       do flow[u, v] ← flow[u, v] + c_f(p), flow[v, u] ← -flow[u, v]
       for each vertex v in p
          do store path trace π to Lm
      mf ← mf+ c_f(p)
      wuc ← wuc + sum{cost(u, v) : (u, v) is in p} // total cost
      if (SLA.TOTAL_JOB_COUNT <= mf) then break
      if (SLA.COST <= wuc) then break
```

Algorithm. 2. Maximum Flow Algorithm

4 Experiments

We simulate our scheduling algorithm using SimGrid toolkit. Simulation scenario is classified into three categories according to the ratio of wired and wireless node. In this paper, we compare our scheduling with scheduling without optimizing which is previous work[8]. As shown in Fig. 1, the cost per a job is scalable in all scenarios and our scheduling is more economical than scheduling without optimizing.

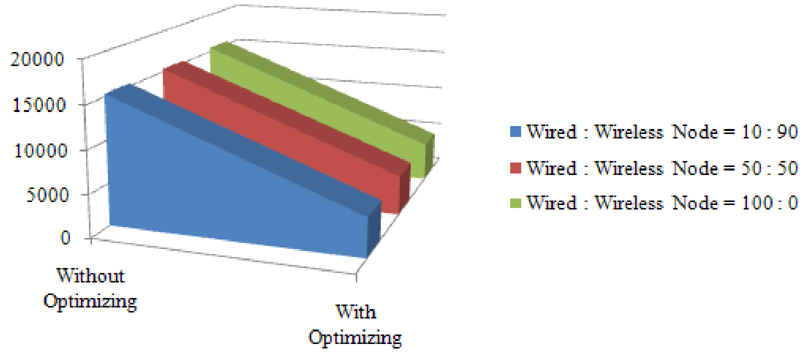

Fig. 1. Result of simulation according to the ratio of wired and wireless node

5 Conclusion

In this paper, we proposed a proxy-based wired-wireless convergence architecture and an economic workflow scheduling strategy in Mobile Grid. Our experiments showed that our scheduling optimized results according to user's QoS and was better than previous work in performance. In the future, we plan to apply to real grid applications and work on applying not only sequential workflows but also complex workflows.

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