ENHANCEMENT OF ANT COLONY OPTIMIZATION FOR GRID JOB SCHEDULING AND LOAD BALANCING

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For my lovely parents

Jamal Abdul Nasir and Siti Mariam

and my siblings

Hisyam, Nur Hikmah, and Nur Hidayah

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ABBREVIATION

ACO	Ant Colony Optimization
ACS	Ant Colony System
AHS	Adaptive Hierarchical Scheduling
AS	Ant System
AS_{rank}	Ranked Ant System
BACO	Balanced Ant Colony Optimization
BWAS	Best Worst Ant system
EACO	Enhanced Ant Colony Optimization
EAS	Elitist Ant System
FCFS	First Come First Serve
FIFO	First In First Out
FPLTF	Fastest Processor to Largest Task First
GA	Genetic Algorithm
GJAP	Granularity-based Job Allocation Policy
iACO	Improved Ant Colony Optimization
KPB	K-Percent Best
LBTAS	Local Best Tour Ant System
MCT	Minimum Completion Time
MDS	Metacomputing Directory Services
MET	Minimum Execution Time
MMAS	Max Min Ant System
MOEA	Multi-Objective Evolutionary Algorithm
MPS	Million Instructions per Second
NP	Nondeterministic Polynomial
NWS	Network Weather System
OGSA	Open Grid Services Architecture
OLB	Opportunistic Load Balancing
P2P	Peer-To-Peer
PEs	Processing Elements
PPSO	Parallel Particle Swarm Optimization
PSO	Particle Swarm Optimization
PVM	Pheromone Value Matrix
PVT	Pheromone Value Table
QAP	QoS Access Point
QoS	Quality of Service
QRC	Qualifying Resource Collection
RAS	Rank Based Ant System
RN	Recent Neighbor
SA	Simulated Annealing
SPEC	Standard Performance Evaluation Corporation
SWA	Switching Algorithm
T-RAG	Task Resource Assignment Graph

ABSTRACT

Managing resources in grid computing system is complicated due to the distributed and heterogeneous nature of the resources. Stagnation in grid computing system may occur when all jobs are required or are assigned to the same resources which lead to the resources having high workload or the time taken to process a job is high. This research proposes an Enhanced Ant Colony Optimization (EACO) algorithm that caters dynamic scheduling and load balancing in the grid computing system. The proposed algorithm can overcome stagnation problem, minimize processing time, match jobs with suitable resources, and balance entire resources in grid environment. This research follows the experimental research methodology that consists of problem analysis, developing the proposed framework, constructing the simulation environment, conducting a set of experiments and evaluating the results. There are three new mechanisms in this proposed framework that are used to organize the work of an ant colony i.e. initial pheromone value mechanism, resource selection mechanism and pheromone update mechanism. The resource allocation problem is modeled as a graph that can be used by the ant to deliver its pheromone. This graph consists of four types of vertices which are job, requirement, resource and capacity that are used in constructing the grid job scheduling. The proposed EACO algorithm takes into consideration the capacity of resources and the characteristics of jobs in determining the best resource to process a job. EACO selects the resources based on the pheromone value on each resource which is recorded in a matrix form. The initial pheromone value of each resource for each job is calculated based on the estimated transmission time and execution time of a given job. Resources with high pheromone value are selected to process the submitted jobs. Global pheromone update is performed after the completion of processing the jobs in order to reduce the pheromone value of resources. A simulation environment was developed using Java programming to test the performance of the proposed EACO algorithm against existing grid resource management algorithms such as Antz algorithm, Particle Swarm Optimization algorithm, Space Shared algorithm and Time Shared algorithm, in terms of processing time and resource utilization. Experimental results show that EACO produced better grid resource management solution compared to other algorithms.

ABSTRAK

Mengurus sumber pemproses di dalam sistem pengkomputeran grid adalah rumit kerana sifat teragih dan kepelbagaian keadaannya. Kesesakan dalam sistem pengkomputeran grid boleh berlaku apabila semua tugasan memerlukan atau telah diserahkan kepada sumber pemproses yang sama yang mengakibatkan sumber pemproses tersebut mempunyai beban kerja yang tinggi atau waktu yang diperlukan untuk memproses tugasan menjadi tinggi. Penyelidikan ini mencadangkan algoritma *Enhanced Ant Colony Optimization* (EACO) yang dapat membuat penjadualan dinamik dan mengimbangkan bebanan dalam sistem pengkomputeran grid. Algoritma yang dicadangkan dapat mengatasi masalah kesesakan, meminimumkan waktu memproses tugasan, memproses tugasan dengan sumber pemproses yang bersesuaian, dan mengimbangkan bebanan di dalam pengkomputeran grid. Penyelidikan ini menggunakan kaedah pengujian yang terdiri daripada fasa analisis masalah, pembangunan rangka kerja, membina persekitaran simulasi, melaksanakn pengujian dan menilai hasil. Terdapat tiga mekanisma baru dalam rangka kerja yang dicadangkan untuk mengatur tugasan sebuah koloni semut, iaitu mekanisma nilai awal feromon, mekanisma pemilihan sumber pemproses dan mekanisma pengemaskinian nilai feromon. Masalah menguruskan sumber pemproses telah dimodelkan sebagai graf yang boleh digunakan oleh semut untuk menghantar feromonnya. Graf ini terdiri daripada empat jenis kategori iaitu keperluan, tugasan, sumber pemproses dan keupayaan sumber pemproses dalam membentuk penjadualan tugasan grid. Algoritma EACO yang dicadangkan mempertimbangkan kapasiti sumber pemproses dan ciri-ciri tugasan dalam menentukan sumber pemproses terbaik untuk memproses tugasan. EACO memilih sumber pemproses berdasarkan nilai feromon pada setiap sumber pemproses yang disimpan di dalam bentuk matriks. Nilai awal feromon setiap sumber pemproses untuk setiap tugasan dikira berdasarkan anggaran masa penghantaran dan masa pelaksanaan tugasan yang diberikan. Sumber pemproses dengan nilai feromon tertinggi dipilih untuk memproses tugasan yang baru dihantar. Pengemaskinian nilai feromon secara menyeluruh telah dilakukan setelah tugasan selesai diproses untuk mengurangkan nilai feromon untuk setiap sumber pemproses. Persekitaran simulasi telah dibangunkan dengan menggunakan bahasa pengaturcaraan Java bertujuan menguji prestasi algoritma EACO dan membuat perbandingan dengan algoritma yang sedia ada seperti algoritma *Antz*, algoritma *Particle Swarm Optimization* (PSO), algoritma *Space Shared* dan algoritma *Time Shared* dari segi masa pemprosesan dan penggunaan sumber pemproses. Keputusan pengujian menunjukkan EACO menghasilkan penyelesaian terbaik kepada masalah pengurusan sumber pemproses di dalam pengkomputeran grid berbanding dengan algoritma yang lain.

CHAPTER 1

INTRODUCTION

Grid computing is based on large-scale resources sharing in a widely connected network such as the Internet (Yan et al., 2009). Research by Foster & Kesselman (2004) defined that cluster and grid computing are several ways for establishing a distributed system. A distributed system consists of multiple computers that communicate through a computer network. Several personal computers or workstations in cluster computing are combined through local networks in order to develop distributed applications. In cluster computing, applications are inflexible in variation because they are limited to a fixed area. From this disadvantage, grid computing has been proposed as a solution to this problem. Grid computing is developed through a combination of various resources from different geographic locations. This makes grid computing different from conventional distributed computing and cluster computing. However, computational grid has different constraints and requirements compared to traditional high performance computing systems.

In the mid-1990s, grid computing emerged from metacomputing with the introduction of middleware design as a wide-area infrastructure to support data-intensive applications and diverse online processing (Moallem, 2009). At the same time, systems such as Globus Toolkit (Foster & Kesselman, 1997), Storage Resource

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