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Design and implementation of economics-based resource management system in ad hoc grid

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ABSTRACT

The ad hoc grid is a spontaneous organization of cooperating heterogeneous nodes into a logical community without a fixed infrastructure and with only minimal administrative requirements. Resource management for ad hoc grids is challenging due to the participation of heterogeneous, dynamic, autonomous and ephemeral grid nodes. The paper proposes an ad hoc grid resource management system, the producers and consumers of ad hoc grid resource are modeled as the self-interested decision-makers described in microeconomic theory. All market participants in the ad hoc grid environment including grid resources and services can be represented as agents. We apply economic agents to build ad hoc grid resource management, where ad hoc grid resource consumers and providers can buy and sell ad hoc grid resource based on an underlying economic architecture. The main processes involved in ad hoc grid resource management are resource registration, discovery, and resource allocation. The experiments are conducted to compare ad hoc grid resource allocation algorithm with other ad hoc grid resource allocation algorithm. Simulation results show that our proposed algorithm is more efficient than compared allocation scheme.

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1. Introduction

The ad hoc grid is a spontaneous organization of cooperating heterogeneous nodes into a logical community without a fixed infrastructure and with only minimal administrative requirements [1]. The main goal of an ad hoc grid is to provide computing resources on demand to every participant. Unlike traditional grid systems, the number of nondedicated grid nodes is much higher, demanding non-intrusive operation of the ad hoc grid middleware. Ad hoc grids allow a group of individuals to accomplish a mission that involves computation and communication among the grid components, often without fixed structure. Examples of applications of ad hoc grids include: disaster management, wild fire fighting, and defense operations. An ad hoc grid allows grid entities, also referred to as ad hoc grid peers, to spontaneously establish an ad hoc relationship, join existing grids, dynamically contribute services to the grid, and invoke services offered by other peers in the grid. Ad hoc grids facilitate interaction in an autonomous fashion without requiring pre-configured environments or management policies. They support a large class of applications that cannot be conventionally supported by traditional grid environments. These applications include market-oriented applications, transient collaborations, sporadic interactions, and other community applications that require on-the-fly grid establishment and deployment. In an ad hoc grid, every node in the network can spontaneously arise as a resource consumer or a resource producer at any time when it needs a resource or it possesses an idle resource. Ad hoc grids are highly heterogeneous and dynamic, one of the main challenges of resource allocation in such environments is to find mechanisms which do not rely on the global information and are robust to the changes in resource availability in grid. Ad hoc grids are characterized by heterogeneity, autonomy, and volatility [2]. These characteristics result in varying workload of the resource manager in the ad hoc grid. Therefore it is required to develop a resource allocation mechanism that can balance the workload of the resource, and can enable the ad hoc grid to self-organize itself.

Resource management for ad hoc grids is challenging due to the participation of heterogeneous, dynamic, autonomous and ephemeral grid nodes. Due to limited resources (energy, bandwidth, etc.), user preferences may lead to an unfair load distribution in ad hoc grids. The situation worsens, in cases where ad hoc grid nodes act both as grid clients and grid resources from time to time but refuse to contribute resources. The paper proposes an ad hoc grid resource management system, the producers and consumers of ad hoc grid resource are modeled as the self-interested decision-makers described in microeconomic theory. All market participants in the ad hoc grid environment including grid resources and services can be represented as agents. We apply economic agents to build

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ad hoc grid resource management, where ad hoc grid resource consumers and providers can buy and sell ad hoc grid resource based on an underlying economic architecture. The agents of the ad hoc grid system interact by offering to buy or sell resources at given prices. The main processes involved in ad hoc grid resource management are resource registration, discovery, and resource allocation. The experiments are conducted to compare ad hoc grid resource allocation algorithm with other ad hoc grid resource allocation algorithm.

The rest of the paper is structured as followings. Section 2 discusses the related works. Section 3 gives the overview of system model. Section 4 presents economics based ad hoc grid resource management. Section 5 describes ad hoc grid resource allocation algorithm. In section 6 the experiments are conducted and discussed. Section 7 gives the conclusions to the paper.

2. Related works

Currently, ad hoc grid is hot research topic. Shivle et al. [1] studied assigning resources in an ad hoc grid to an application composed of communicating subtasks. Their goal of the allocation is to minimize the average percentage of energy consumed by the application to execute across the machines in the ad hoc grid, while meeting an application execution time constraint. Six different heuristic approaches of varying time complexities have been designed and compared via simulations to solve this ad hoc grid allocation problem. Pourebrahimi and Bertels [3] presented a learning algorithm in a market-based resource allocation in ad hoc grid. Using this algorithm, consumer and producer agents learn the current condition of the network through their previous reward from the grid and decide the preferred prices only based on their local knowledge. Aggressive and conservative bidding strategies reinforce adaptation to the variations of resource availability in the ad hoc grids. Kim et al. [4] proposed parsimonious resource usage and job migration to lesser overloaded nodes, in order to balance the overall workload in a decentralized ad hoc grid. Moreno-Vozmediano [5] focused on the problem of resource discovery in ad hoc grids; they study the existing resource and service discovery architectures, analyzing the main limitations of these systems (scalability, discovery delay, adaptation to changing conditions, etc.). Hummel and Jelleschitz [6] proposed a robust decentralized job scheduling approach for mobile peers forming an ad hoc grid. The scheduling approach is based on a first come first serve strategy executed locally by each peer. The peer performs matchmaking between a job's requirements and the device's capabilities autonomously. Pourebrahimi et al. [7,16] presented a market formulation for resource allocation in ad hoc grids where the availability of tasks and resources are dynamic. They discussed different market models and bidding mechanisms that can be employed in a market formulation for ad hoc grids. Abdullah et al. [8] presented a resource management mechanism that will enable the ad hoc grid to self-organize according to the workload of the resource manager. The proposed mechanism is based on the emergent behavior of the participating nodes and adapts with respect to changes in the ad hoc grid environment. Smith et al. [9] presented the idea of a spontaneously formed, service-oriented ad hoc grid to harness the unused resources of idle networked workstations and high-performance computing nodes on demand. They discuss the requirements of an ad hoc grid, show how the service-oriented computing paradigm can be used to realize it and present a proof-of-concept implementation based on the Globus Toolkit 3.0. Scriven et al. [10] addresses a resource evaluation and allocation system, which allows grid developers to accurately specify the requirements of their grid job to ensure the most suitable nodes are used when creating the ad hoc grid, and a node monitoring and error recovery system, which allows grid applications to detect and recover from errors and complete successfully. Abdullah et al. [11] defined a mechanism that dynamically promotes and demotes nodes as matchmaker(s) and matchmakers back to the normal nodes in an ad hoc grid environment. The proposed mechanism uses the matchmaker workload as the basic criterion for promotion and demotion of the matchmaker(s). Herrmann [12] proposed a new self-organizing infrastructure called Ad hoc Service Grid (ASG) that is based on a mobile ad hoc network. They concentrate on the service distribution in ASGs and present a new algorithm for replicating and migrating services to optimize network bandwidth usage and client response times. Vetri Selvi et al. [13] presented trace based mobility model in mobile ad hoc grid to obtain the probable position and stability time of a node in order to build a stable grid. They analyzed the performance of mobile ad hoc grid both by using a theoretical model and by simulation. Khan and Ahmad [14] study the problem of allocation of tasks onto a computational grid, with the aim to simultaneously minimize the energy consumption and the makespan subject to the constraints of deadlines and tasks' architectural requirements. They propose a solution from cooperative game theory based on the concept of Nash Bargaining Solution (NBS). In [15], Katsaros and Polyzos formulated the problem of job scheduling in a Mobile Grid environment considering the problems incurred by intermittent connectivity. They proposed the installments scheduling policy specifically tailored for the constrained mobile and wireless networking environment. The works [17–21] mainly deal with resource allocation, QoS optimization in the computational grid and do not consider resource selection scheme in ad hoc grid environments.

3. Overview of system model

3.1. Model description

The overall ad hoc grid resource management system model consists of three layers (Fig. 1). The lower layer is the underlying ad hoc grid resource. Ad hoc grid resources on this layer are owned and allocated by ad hoc grid resource agents deployed at the nodes in the ad hoc grid. The top layer is the system's interface to ad hoc grid user. The middle layer is the agent-based ad hoc grid resource management system. It consists of two types of agent and market institution that allocates resources in response to the selling of ad hoc grid resource agent and buying behavior of ad hoc grid task agents. The third layer is the user layer at which ad hoc grid request agents provide interfaces to the grid user' request. Ad hoc grid resource agents sell the underlying resources of the ad hoc grid. Ad hoc grid task agent that represents the ad hoc grid user makes buying decisions within budget constraints to acquire grid resources.

The system model makes use of two economic agent types: (1) the ad hoc grid resource agents that represent the economic interests of the underlying resources of the ad hoc grid, (2) the ad hoc grid task agents that represent the interests of ad hoc grid user using the grid to achieve goals. Ad hoc grid resource agent is used at the source node in the ad hoc grid and is deployed at the entry node. The ad hoc grid resource agents have varied grid resource capacity, and the ad hoc grid resource capacity is shared among the ad hoc grid task agents. The ad hoc grid resource agents charge the grid task agents for the portion of the grid resource capacity occupies. The ad hoc grid resource agents compete among each other to serve the ad hoc grid task agents. The ad hoc task agents do not collaborate, and try to purchase as much grid resource as possible with the objective of maximizing their net benefit. The agents communicate by means of a simple set of signals that encapsulate offers, bids, commitments, and payments for resources. We couple the resources and payments with the offers and requests respectively. This reduces the number of steps in-

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