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The performance model of dynamic virtual organization (VO) formations within grid computing context

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Abstract

Grid computing aims to enable "resource sharing and coordinated problem solving in dynamic, multi-institutional virtual organizations (VOs)". Within the grid computing context, successful dynamic VO formations mean a number of individuals and institutions associated with certain resources join together and form new VOs in order to effectively execute tasks within given time steps. To date, while the concept of VOs has been accepted, few research has been done on the impact of effective dynamic virtual organization formations.

In this paper, we develop a performance model of dynamic VOs formation and analyze the effect of different complex organizational structures and their various statistic parameter properties on dynamic VO formations from three aspects: (1) the probability of a successful VO formation under different organizational structures and statistic parameters change, e.g. average degree; (2) the effect of task complexity on dynamic VO formations; (3) the impact of network scales on dynamic VO formations. The experimental results show that the proposed model can be used to understand the dynamic VO formation performance of the simulated organizations. The work provides a good path to understand how to effectively schedule and utilize resources based on the complex grid network and therefore improve the overall performance within grid environment.

1. Introduction

Grid computing has emerged as an important model that distributes processing across parallel infrastructure. Grid computing is "predominantly concerned with coordinated resource sharing and problem solving in dynamic, multi-institutional, virtual organizations (VOs)" [4,5]. Since grid strongly focuses on inter-domain resource provision and resource virtualization, the dynamic federating formation of grid environments is dominated by virtual organizations which associate heterogeneous users and resource providers. Users will introduce different tasks or jobs, and a number of different individuals and institutions with different resources join together and form a new VO to complete assigned tasks within given time steps. In fact, the dynamic grid environment can be viewed as the dynamic arrival and leaving of tasks and members of VO with resources. Grids are thus organizationally reflected by typical examples of complex networks.

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Research on virtual organization has received a constantly growing attention [1]. Much of work has been done on the behaviors of virtual organization members and describing rules that govern the behaviors of virtual organization users and resources [2,3]. They normally ignored the effect of network topology of VOs [21]. They assume all of resources can be available for any task or job, which is not realistic. Studies in [23–26] have suggested the importance of organizational structure on the large scale organizational performance. However, little is known about how the impact of virtual organization structure on dynamic VO formations within grid computing environments.

In this paper, we present a performance model of dynamic VO formations for investigating the impact of different well-known organizational structure of complex networks (e.g. lattice, scale free network, random graph (ER model) and small-world (WS model) etc.) and their statistic parameter change on the efficiency of VO formations from three aspects: (1) the probability of a successful VO formation under different organizational structures and statistic parameters change, e.g. average degree (through the paper, a successful formation can be defined as a number of individuals and institutions associated with certain resources join together and form new VOs in order to effectively execute tasks within given time steps.); (2) the effect of task complexity on dynamic VO formations; (3) the impact of network scales on dynamic VO formations.

In the following section we provide an overview of the structure and dynamics of different organizational networks. We then introduce a performance model of dynamic VO formations in Section 3. Experimental results are presented in Section 4. Section 5 makes some conclusion and discusses the future work.

2. Organizational structures of complex networks

The study of most complex networks has been initiated by a desire to understand various real systems, ranging from communication networks to ecological webs.

The last several years have witnessed a hectic activity devoted the characterization and understanding of networked structures as diverse as ecological and biological systems or the internet and the WWW [6–8]. These networks generally exhibit complex topological properties such as the small-world phenomenon [9] and scale free behavior etc.

The structure of networks has been studied by using mathematical graph theories [10–12]. Networks with a complex topology and unknown organizing principles often appear random; thus random graph theory is commonly used in the study of complex networks.

The network that we consider are graphs consisting of vertices (nodes) connected by edges (links). Edges may be directed or undirected (leading to directed or undirected networks, relatively). In this paper, we do not consider networks with unit loops (edges started and terminated at the same vertex) and multiple edges, that is, we assume that only one edge may connect two vertices. Normally, these complex networks can be statistically characterized by several parameters as follows:

Degree: This is the most intensively studied on vertex characteristics. Degree, k, of a vertex is the total number of its connections. In-degree, k_{i}, is the number of incoming edges of a vertex. Out-degree, k_{o}, is the number of its outgoing edges. Hence, $k = k_{\mathrm{i}} + k_{\mathrm{o}}$. Degree is actually the number of the nearest neighbors of a vertex. Total distributions of vertex degrees, $P(k_{\mathrm{i}}, k_{\mathrm{o}})$, the joint in- and out-degree distribution, $P(k)$, the degree distribution, $P_{\mathrm{i}}(k_{\mathrm{i}})$, the in-degree distribution, and $P_{\mathrm{o}}(k_{\mathrm{o}})$, the out-degree distribution, are the basic statistical characteristics of an entire network.

$$p(k) = \sum_{k_{\mathrm{i}}} p(k_{\mathrm{i}}, k - k_{\mathrm{i}}) = \sum_{k_{\mathrm{o}}} p(k - k_{\mathrm{o}}, k_{\mathrm{o}}) p_{\mathrm{i}}(k_{\mathrm{i}}) = \sum_{k_{\mathrm{o}}} p(k_{\mathrm{i}}, k_{\mathrm{o}}),$$
$$p_{\mathrm{o}}(k_{\mathrm{o}}) = \sum_{k_{\mathrm{i}}} p(k_{\mathrm{i}}, k_{\mathrm{o}})$$

Shortest path: The shortest path l can be defined as a geodesic distance between two vertices of a graph with unit length edges, x and y (in this paper, we focus on undirected graph. We have $l_{xy} = l_{yx}$). $\bar{l}$ is the average shortest path. The average means over all pairs of vertices between which a path exists and over all realizations of a network. $\bar{l}$ is often called the "diameter" of a network. It determines the effective "linear size" of a network, the average separation of pairs of vertices. For a lattice of dimension d containing N vertices, obviously, $\bar{l} \sim N^{\frac{1}{d}}$. In a fully connected network, $\bar{l} = 1$. For random networks, if the average number of the nearest neighbors of a vertex is m, then about $m^{\bar{l}}$ vertices of the network are at a distance $\bar{l}$ from the vertex or closer. Then $N \sim m^{\bar{l}}$ and $\bar{l} \sim \ln N / \ln m$, that is, the average shortest path length value is small even for a very large network. This smallness is usually referred to as the small-world effect [9,14].

Clustering coefficients: The clustering coefficient is the probability that two nearest neighbors of a vertex are also the nearest neighbors of one another. The clustering coefficient of the network reflects the "cliquishness" of the mean clos-