Chapter XII

Bio-Inspired Grid Resource Management

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ABSTRACT

The need for a dynamic and scalable expansion of the grid infrastructure and resources and other scalability issues in terms of execution efficiency and fault tolerance present centralized management techniques with numerous difficulties. In this chapter we present the case for biologically inspired grid resource management techniques that are decentralized and self organized in nature. To achieve the desired de-centralized resource management, these techniques model the self-organization observed in many natural complex adaptive systems. Using a few representative techniques, we review the literature on Bio-inspired Grid Resource Management. Based on this review we conclude that many such techniques have been successfully applied to resource discovery, service placement, scheduling and load balancing.

INTRODUCTION

In computational grids resources vary in complexity and type. They may include computers, storage space, sensors, software applications, and data. A Grid is a collection of heterogeneous resources and can be characterized by its large scale and dynamic nature. In most existing grid systems, management of these resources is centralized. Due to the heterogeneous and dynamic nature of grid resources, fluctuating resource demands, and the presence of different control policies in different domains the centralized management has its limitations. Further, the need for a dynamic and
scalable expansion of the grid infrastructure and resources and other scalability issues in terms of execution efficiency and fault tolerance present these centralized management techniques with numerous difficulties. These limitations have been identified by many researchers (Iamnitchi and Foster, 2001; Lamehamedi, 2005; Pavani and Waldman, 2006; Wolskı et al., 2003) in the past.

Resource discovery, for instance, is significantly difficult for traditional centralized services because resources are owned by various administrative organizations and are shared under local policies that define which resources are to be shared when (e.g. dependent on local computing load) and with whom (Iamnitchi and Foster, 2001). Lamehamedi (2005) notes that, in most cases, system administrators are responsible for installing software, granting and controlling access to resources. It is argued that such configurations are not suitable for dynamic and scalable expansion of the grid infrastructure and resources. Addition of new nodes is dependant on the intervention of system administrators. Similarly, a node cannot leave without system pre-configuration. Enabling dynamic node addition and deletion while providing efficient access to resources on the data grid presents considerable challenges to system designers. Centralized grid resources allocation and scheduling is also proving to be a performance bottleneck. It is argued (Wolskı et al., 2003) that it is not a scalable solution either in terms of execution efficiency (the resource broker or scheduler can become a bottleneck) or fault tolerance (the allocation mechanism is a single point of failure).

These traditional and centralized resource management mechanisms work well within single grid clusters but are not suitable for multiple Grids (Ching et al., 2002). Provision of services across such platforms requires a distributed resource management mechanism with capabilities beyond traditional centralized management. A self-organized approach to resource management can provide the infrastructure for a reliable and a consistent Grid.

BACKGROUND

The universe is full of systems that are complex and constantly adapting to their environment. Examples of these systems include human economies, the ecosystem and the weather system. These, so called complex adaptive systems (CAS), are characterised by the absence of a centralised control, dynamism and large scales. The components (or agents) of these complex adaptive systems interact with each other according to some simple local rules. These simple interactions, however, result in self-organisation and complex behaviors.

The Grid As A Complex Adaptive System

A grid computing system can also be seen as a CAS. It is by nature a complex combination of hardware, software and network components. Geographically distributed nature of resources that make up the grid infrastructure, along with their heterogeneity and different control policies in different domains, make the availability of these resources dynamic and conditional upon local constraints. The consumers of the resources are the users who have specific requirements which are expressed in terms of CPU speed, storage capacity, network bandwidth, etc. To achieve the desired de-centralized resource management the self-organization observed in many natural CAS systems can be modeled in the context of grid computing.

Emergent Behavior in Nature

Foraging in ant and bee colonies, predator and obstacle avoidance in fish schools, bird flocks and animal herds are examples of emergent behavior observed in nature. The behavior of individual
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