Chapter II
Dynamic Network Optimization for Effective QoS Support in Large Grid Infrastructures

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ABSTRACT

In the past decade there has been a remarkable change from mainframe-based centralized computing to a distributed client/server approach. In the coming decade this trend is likely to continue with further shifts towards network centric collaborative computing. At the state of the art, the key technology in collaborative computing is the computational grid paradigm. Like an electrical power grid, the computational Grid will aim to provide a steady, reliable source of computing power. More precisely, the term grid is now adopted to designate a common computational and/or data processing infrastructure built on distributed resources, highly heterogeneous (in their role, computing power and architecture), interconnected by heterogeneous communication networks and communicating through some basic services realized by a middleware stratum that offers a reliable, simple, uniform and often transparent interface to its resources such that an unaware user can submit jobs to the Grid just as if he/she was facing a large virtual supercomputer, so that large computing endeavors, consisting of one or more related jobs or tasks, are then transparently distributed over the network on the available computing resources. Such a workload distribution strategy, that is, to balance the tasks on different idle computers on the underlying networks, is the most important functionality in computational Grids, usually provided at the service level of the grid software infrastructure.
INTRODUCTION

In the past years there has been a remarkable change from mainframe-based centralized computing to a distributed client/server approach and now, this trend is likely to evolve with further shifts towards network centric collaborative computing. At the state of the art, the key technology in collaborative computing is the computational grid paradigm. Like an electrical power grid, the computational Grid will aim to provide a steady, reliable source of computing power. More precisely, the term grid is now adopted to designate a common computational and/or data processing infrastructure built on distributed resources, highly heterogeneous (in their role, computing power and architecture), interconnected by various communication networks and communicating through some basic services realized by a middleware stratum that offers a reliable, simple, uniform, and often transparent interface to its resources. An unaware user can submit jobs to the Grid just as if he/she was facing a large virtual computing cluster, so that large computing endeavors, consisting of one or more related jobs or tasks, are then transparently distributed over the network on the available computing resources. Such a workload distribution strategy, that is, to balance the tasks on different idle computers on the underlying networks, is the most important functionality in computational Grids, usually provided at the resource management services layer of the grid software infrastructure. Although much progress has been made towards grid scheduling and resource management technologies, the area that is still underdeveloped is the link between grid applications and underlying network technologies which is now the most compelling requirement to make grids truly effective. In fact, the quality and consistency of the underlying transport network services become critical success factors for the overall Grid infrastructure, since many up-to-date Grid applications are now highly network-dependent with more demanding requirements in areas such as data access or interactivity, and hence the submitted jobs can be subject to failure if the network connections between the computing and service nodes do not perform as required. More precisely, modern Grid applications require high bandwidth and quality of service (QoS) guaranteed (low latency, packet loss and jitter) end-to-end connections between Grid resources in different network domains, owned by different providers that have to cooperate in a coordinated manner in order to provide these connections on their fiber optic infrastructures. The bandwidth, delay and/or packet loss guarantees requested in a specific service class can be defined either in a deterministic or statistical way. Deterministic QoS guarantees promise an absolute end-to-end bound for every packet carried by a specific connection. On the other hand, with statistical guarantees, the end-to-end bound is accompanied with a small probability of violation. For applications that can tolerate occasional bound violations, statistical guarantees can help to reduce the resource requirement for each connection. For instance an end-to-end connection carrying sensitive traffic between a couple of Grid applications might require average bandwidth of 10Mbps, and premium service class, defined by near zero packet loss, per-packet delay smaller than 50ms, and probability of violating the delay bound smaller than $10^{-3}$. Traditionally, the Grid control and management logic has been based on a partially or totally network unaware approach in which the computational resources can be chosen from different sites participating to the Grid without inspecting their connectivity characteristics, since Grid service infrastructure had no visibility of the underlying network. This may lead to a virtual cluster with proper computational power, but due to the lack of bandwidth or QoS features, the data distribution may inconsiderately use the network, leading to inefficiency. On the other side, an active network-aware approach needs a strict integration between the Grid job scheduling and resource management logic, the requesting application and the network entities that offer the connectivity services to the involved Grid nodes, to take all the scheduling and
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