Quantification of Grid Resource Heterogeneity effects on Performance

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Abstract:
Grid computing enables sharing, selection and aggregation of large collections of geographically and organizationally distributed heterogeneous resources to increase computational, and storage power, resource accessibility and utilization for solving large-scale data intensive problems in science, engineering and commerce. One of the distinct characteristics of grid system is resource heterogeneity. The effective use of a Grid requires the definition of an approach to manage the heterogeneity of the involved resources that can include computers, data, network etc. In order to develop an efficient resource management and scheduling strategies for grid environments, how heterogeneity affects performance of systems and applications is to be well understood. In this study, the potential impact that heterogeneity of grid resources has on the performance and reliability achieved by grid applications and system is analyzed. We have made an attempt to categorize and quantitatively characterize heterogeneity based on various resource characteristics. We quantify the heterogeneity impact of varying computational power, communication bandwidth, usage policies and, reliability based on user and system centric performance metrics. To this end, simulations will be performed for systematic and in depth investigation and results will be verified using different grid configurations, workload and usage policies. This is the initial status report of the exchange visit from KTH to UCY.

Introduction:

High Performance grid computing aims seamless aggregation of large collections of geographically and organizationally distributed heterogeneous computing and storage resources to increase computational, and storage power, resource utilization, and resource accessibility. Issues that characterize high performance grid systems are heterogeneity, scalability, dynamicity, non-determinism and complexity. However, one of the distinct characteristics is resource heterogeneity [1] as compared to dedicated multiprocessor system. Resource heterogeneity arises mainly from the computers with widely varying performance capacity which could range from a supercomputers to clusters, and to a workstations, residing in different administrative domains, be subject to different access control and usage policies, running different software tools, and communication stratum coupling these diverse resources could range from a very high speed optical link to relatively slow intra-resource communication for a loosely coupled network of workstations serving as a single grid resource. The reverse is also possible where inter-node communication is slower than intra-node links. As more diverse resources are added, the Grid scales to larger capability and greater heterogeneity. Therefore, we have a purely true heterogeneous system model with widely varying performance and system characteristics among grid resources. It means that users and applications will be faced with environments that have an even greater level of heterogeneity. While this potential includes the flexible harnessing of resources on a scale not previously considered for individual applications, it also means that achieving efficient use of those resources will be harder than ever.

How are we to effectively and efficiently utilize such an infrastructure? Clearly an effective approach is to require for managing the heterogeneity of the involved resources. Typically, resource management and scheduling strategies are used for this purpose. In order to develop such efficient strategies for grid environments, how heterogeneity affects performance of systems and applications is to be well understood.

Grid heterogeneity can be seen as an abstract model with wide manifestations. Diverse heterogeneity models based on certain resource characteristics have been adopted by researchers for developing resource selection algorithms. We need to categorize these heterogeneity models and quantitatively characterize heterogeneity based on computational capacity, communication bandwidth, and usage policies. So that, to have better understanding for the design of optimal and performance-aware resource selection and scheduling algorithms.

In our study, we focus only on heterogeneity aspects of varying computational power, communication bandwidth and usage policies and try to analyze the potential impact of these resource characteristics on the performance and reliability achieved by grid applications and systems. In detail, we categorize and characterise resource heterogeneity and then depending on type and extent of heterogeneity, the effects on the machine utilization and the average response time for the user or application is analyzed based on user and system centric performance metrics. To this end, simulations will be performed for systematic and in depth investigation and results will be verified using different grid configurations, workload and usage policies.

This is a status report for the first two and half months of the exchange from KTH to UCY. Therefore, the remainder of this report is organized as follows: In Section 2 we discuss the related work; Section 3 describes the Grid System model and application model; and Section 4 discusses the ongoing and future work.

Related Work:

Heterogeneity among computers in cluster environments has been addressed from various viewpoints of high performance computing, including modelling (heterogeneity of) the system [3], reliability [4], scalability and efficiency [5, 6], scheduling [9, 10, 11, 12] and load balancing [7, 8] etc. Little prior work has been for heterogeneous Grid computing environments. Few studies have been made for partitioning applications when system architecture exhibits heterogeneity in resource characteristics. In particular, Kumar and Biswas [15] considered heterogeneity in the system as well as in the workload graph to optimize application execution time but they assume homogeneity between the resources of a single site. Schnekenburger [14] considered network of workstations with varying processor speed, but did not take into account the network heterogeneity. Walshaw and Cross [13] studied the partitioning problem by modelling heterogeneous communication network for the homogeneous set of resources. Martin [16] studied the effects of communication latency, overhead, and bandwidth in cluster architecture to observe the impact on applications performance.

Computational grids have the potential for solving large-scale scientific problems using heterogeneous and geographically distributed resources. However, heterogeneity of resources and dynamic nature are the major technical hurdles that must be overcome before this potential can be realized. One problem that is critical to effective utilization of computational grids is the efficient scheduling of jobs. Many job scheduling algorithms [11,12,19,18] have been proposed to deal with the heterogeneity and dynamicity so as to optimize some figure of merit, for instance, a shorter response time and better system utilization. These algorithms model only certain heterogeneity characteristics and hence adopted diverse heterogeneity models. Ernemann and Hamscher [20] examined the benefit of participating by individual sites in a grid environment and usage of multi-site jobs to study the effects on average response time. In their recent study [21], they examine the impact of global grid computing on the scheduling quality for computational jobs. In detail, the effect of the geographical distribution of the resources in different time zones, on the machine utilization and the average response time for the user is analyzed. In both studies, they assumed same type of resources at the different sites where resources only differ in the number of nodes. Clearly, it is exactly inter resource heterogeneity that has the significant impact on performance and need to quantify its effects on the average response time and system utilization.

It is also important to define metrics which can be used to characterize the system's behaviour affected by type and extend of heterogeneity. However, few works has been conducted in grid performance evaluation by taking into account the heterogeneity of involved resources. This is due to the lack of appropriate grid performance metrics, high complexity and dynamism nature of the grids. Shan et al [17] evaluated grid job scheduling strategies and job super scheduler performance in computational grid environment respectively by defining performance metrics.

Grid System Model:

A System model of grid computing environment appears to be distant to account the heterogeneity of the computing resources which could be a single pc, a massively parallel supercomputer or a network of workstations. Each resource thus has different resource characteristics. The communication stratum coupling these diverse resources is also heterogeneous in terms of the network topology and the communication latency/bandwidth. We adopt a model for the basic grid infrastructure architecture that is representative of the EGEE testbed and is quite similar with most grid testbeds. Figure 1 depicts such Grid Infrastructure in which resources are modelled as sites. Sites could be heterogeneous in terms of computation, storage, usage and access policies. Each site contains several resources, e.g., a site is a *cluster* of resources. Resources can be computational and storage resources or both at the same time. Each site contains a computing element that manages a set of worker nodes for performing computation, and an optional “storage element” which is an interface to mass storage. Computing element has direct (local area network) access to mass storage on the storage element that is close to it. Typically, a grid virtual organization is made of a set of geographically distributed sites. A VO defines the resources available for the participants and the rules for accessing and using the resources. A VO also provides tools and mechanisms for applications to determine the suitability and accessibility of available resources. The sites are connected by shared wide-area links over the internet.

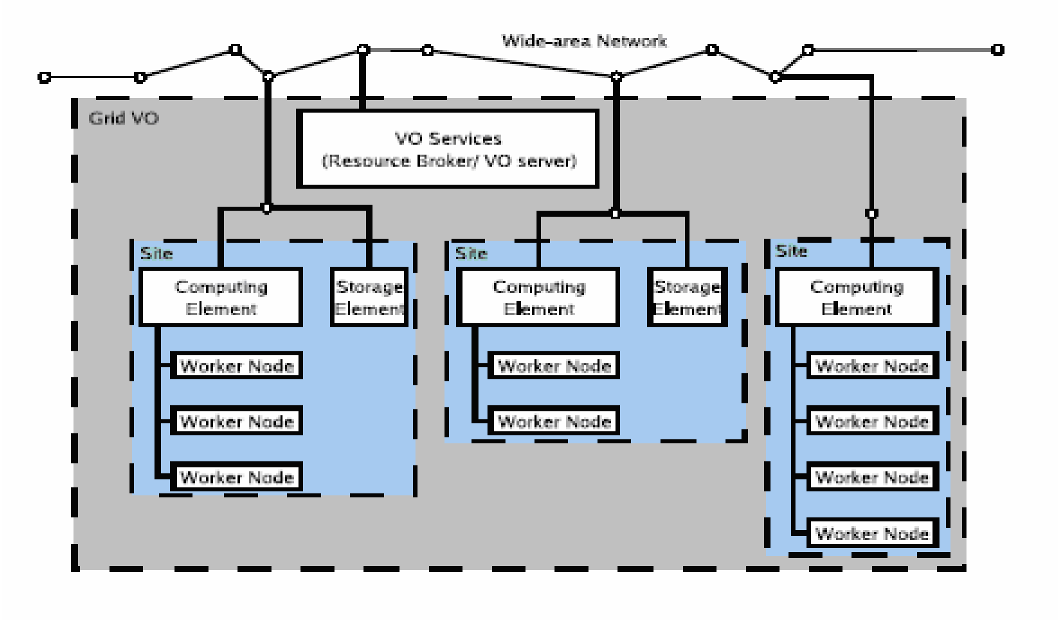

Figure1. Basic Grid Infrastructure Architecture

Application Model:

The application model we consider in this study is a directed acyclic graph (DAG). Each node in the graph represents an executable task. Each directed edge represents a precedence constraint (or simply dependence) between two tasks; the sink node cannot start execution until the source node has finished and the transmission of the required amount of data from the source node to the sink node has been completed. A task with no parent node in the DAG is called an entry task and a task with no child node in the DAG is called an exit task. Without loss of generality, we assume that the DAG has exactly one entry task entry and one exit task.

Work Progress:

In this section, we describe briefly the work which has been done in first two and half months and which has to be done in remaining time within this research exchange from KTH to UCY. First, we investigated the problem to define more specifically, the objectives and goals. We then defined the set of activities and work plan which will be carried out during this exchange period to accomplished these goals and objectives. The set of activities are: Defining the scope and objectives; Preliminary study of the concern areas; Identification of the related work; Exposure of production grid systems such that EGEE; Modeling and characterization heterogeneity; Identification of the appropriate performance metrics to evaluate system and application performance against defined types and extent of heterogeneity; Perform simulation experiments by exercising different resource configurations, workloads and usage policies. Analysis of the experimental results obtained by simulation; Use these measures of heterogeneity to develop efficient resource selection algorithm to improve grid and application performance; analyze and characterize dependability in grid environments.

So far, we have completed the preliminary study of the concerned areas. Much of the efforts have gone into the identification and study of the related work which provided us the basis for our own work. Get exposure of the Production Grid System such as, EGEE by running jobs and benchmarking experiments on such a true heterogeneous grid infrastructure. We are also evaluating different simulation tools to choose best for our experiments and to study the effects of resources heterogeneity on performance.

We are in the process of modeling heterogeneity and defining performance metrics to quantifying and analysis of the simulated results. Characterization of heterogeneity and defining performance metrics is essential parts of our work. Defining good and appropriate performance metrics would help us in obtaining accurate measurements and analysis of the data.

In the next phase, we will extend our measures of resource heterogeneity sensitive to grid and application performance, to develop scheduling algorithms for the performance aware resource selection by taking into account the heterogeneity effects of involved resources.

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