Analytical Performance Modeling of the Enterprise Grid Computing

Bahman Javadi
Amirkabir University of Technology
Computer Eng. and IT Department
P.O.Box 19514, Tehran, Iran
javadi@ce.aut.ac.ir

Mohammad K. Akbari
Amirkabir University of Technology
Computer Eng. and IT Department
P.O.Box 19514, Tehran, Iran
akbari@ce.aut.ac.ir

Jemal H. Abawajy
Deakin University
School of Information Technology
Geelong, VIC. 3217, Australia
jemal@deakin.edu.au

Abstract

This paper addresses the problem of performance modeling of large-scale heterogeneous distributed systems with emphases on enterprise grid computing systems. To this end, we present an analytical model that can be employed to explore the effectiveness of different design approaches so that one can have an intelligent choice during design and evaluation a cost-effective large-scale heterogeneous distributed computing system. The model is validated through comprehensive simulation.

1. Introduction

Over the past few years, the trends in parallel processing system design and deployment have been focusing on networked distributed systems such as commodity-based *cluster computing* and *grid computing* systems. Also, advances in computational and communication technologies has made it economically feasible to conglomerate multiple clusters leading to the development of large-scale distributed systems known as multi-cluster systems that is gaining momentum both in academic and commercial sectors. Hence, the focus of this paper is on heterogeneous cluster of clusters computing systems as enterprise grid systems. Theses systems belong to a general class of such systems named as “Multi-Cluster”. The multi-cluster systems are gaining more importance in practice and a wide variety of parallel applications are being hosted on such systems as well. In this paper, a new methodology that is based on probabilistic analysis and queuing network to analytically evaluate the performance of heterogeneous cluster of clusters systems is presented. The model takes into account stochastic quantities as well as processor heterogeneity among clusters of the system. The message latency is used as the primary performance metric. We validated the model through intensive simulation.

2. System Overview

The computational grid architecture used in this paper consists of a cluster of clusters. The driving force and motivation behind this approach is the price/performance ratio. Using PC clusters as in the Beowulf approach is currently one of the most efficient and simple ways to gain supercomputer power for a reasonable price. Combining several of such clusters in a computational grid can improve the cost/performance ratio even further. Fig. 1 presents the overall architecture of the system. The system is made up of *C* clusters, each cluster *i* is composed of N_i processors of type τ_i , $i \in \{0,1,...,C-1\}$. Also, each cluster has two communication networks, an Intra-Communication Network ($ICN1_i$), which is used for the purpose of message passing between processors, and an intEr-Communication Network ($ECN1_i$), which is used to transmit messages between clusters, management of the system, and also for the scalability of the system.

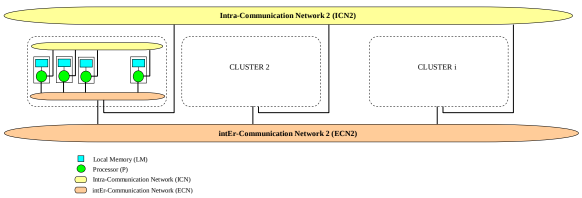

Fig. 1. Cluster of Clusters Structure

3. The Analytical Model

In this section, we try to have an analytic performance modeling for the abovementioned cluster of clusters system in which the processors are heterogeneous and the communication networks are homogenous. The proposed model is built on the basis of the assumptions which are widely used in the similar studies. Unlike most works on heterogeneous parallel systems, we express the speeds of various nodes in each cluster relatively to a fixed reference machine, and not relatively to the fastest node. Since we consider the processor heterogeneity between each cluster, the total relative speed and the average relative speed of the C clusters in the system is as follows, respectively:

$$S = \sum_{i=0}^{C-1} s^{(i)} \qquad (1)$$

$$\bar{s} = \frac{S}{C} \qquad (2)$$

Based on characteristics of the system behavior (see Fig. 1) each communication network is considered as a service center. The queuing network model of the system is shown in Fig. 2, where the path of a flit through various queuing centers is illustrated.

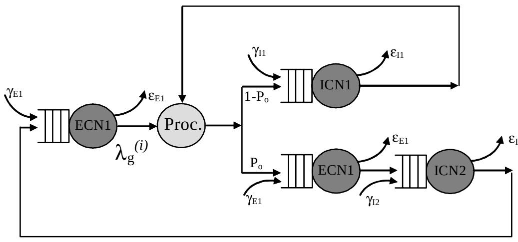

Fig. 2. Queuing model to compute arrival message rate of each communication network

The total requests of the processors received by service centers in the first stage can be calculated as follows:

$$\lambda_{I1}^{(i)} = N_0(1-P_o)\lambda_g^{(i)} \qquad (3)$$

$$\lambda_{E1}^{(i)} = \frac{CN_0P_o\lambda_g^{(i)}}{C} + N_0P_o\lambda_g^{(i)} = 2N_0P_o\lambda_g^{(i)} \qquad (4)$$

In the second stage, the input request rate of ICN2 in forward path can be computed by following equations:

$$\lambda_{I2} = N_0P_o\sum_{j=0}^{C-1}\lambda_g^{(j)} \qquad (5)$$

As it can be seen in the previous equations, the probability P_o has been used as the probability of outgoing request within a cluster and can be computed by the following equation:

$$P_o = \frac{\left(\frac{1}{C-1}\right)\times N_0}{\left(\frac{1}{C\times N_0}\right)-1} = \frac{(C-1)\times N_0}{(C\times N_0)-1} \qquad (6)$$

Consequently, we find the average network latency based on the following equation:

$$\bar{T} = (1-P_o)\times\left(\bar{T}_{ICN1}\right) + P_o\times\left(2\bar{T}_{ECN1}+\bar{T}_{ICN2}\right) \qquad (7)$$

4. Validation of the Model

In order to validate the proposed model and justify the applied approximations, the model was simulated. The items which were examined carefully are as follows:

- Network parameters: C=8, m=8, n=2
- Message length: M=32 and M=64 flits
- Flit length: L_m=256 and 512 bytes
- Network technology bandwidth: 500
- Network latency: 0.02
- Switch latency: 0.01

The results of simulation and analysis for a system with above mentioned parameters are depicted in Fig. 3 and Fig. 4.

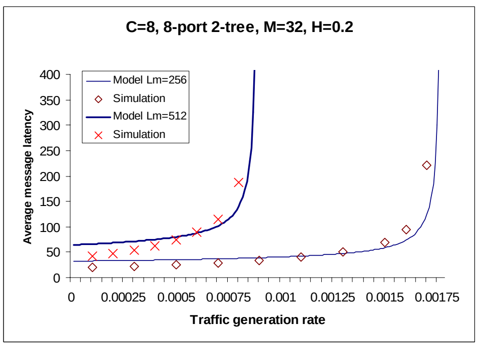

Fig. 3. Average message latency in a heterogeneous cluster of clusters with degree of heterogeneity =0.2

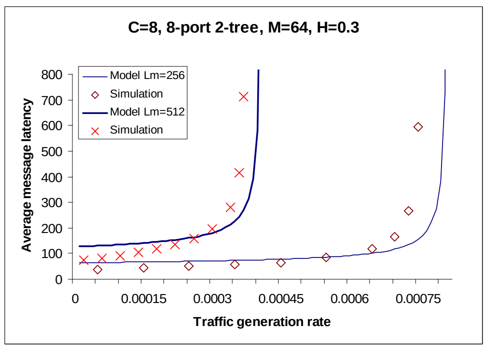

Fig. 4. Average message latency in a heterogeneous cluster of clusters with degree of heterogeneity =0.3