Cluster Performance Oriented Characteristics of Network Simulations

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***Abstract*—As the price of parallel computer is decreasing and the network simulation is being more complex, people turn to study the high performance network simulation based on the parallel computer platform. This makes the platform performance oriented characteristics of network simulation become a new important research focus. Taking the cluster, which is a representative parallel computer, as the platform, this paper does research on issues in the cluster performance oriented characteristics of network simulation from two aspects, including the performance capabilities of cluster, and the characteristics of network simulation and their performance demands of cluster. The research results in this paper can guide the selection of the appropriate cluster platform exactly and efficiently, and guide the development of performance oriented parallel optimization techniques.**

Keywords-cluster; network simulation; high performance; characteristic; performance capability

I. INTRODUCTION

With the rapid developing of network simulation, the real-time, large-scale, high-fidelity performance requirements for the network simulation become more and more urgent[1][2]. The network presents a huge demand for the high performance computing. Thus how to use the high performance architecture to accelerate network simulation applications is worth studying further[3].

The cluster is a typical high performance architecture that uses abundant arithmetic units, an effective multi-level memory hierarchy, and multiple parallel techniques synthetically. It has shown tremendous performance advantages in the domains of analytic simulation[4][5][6]. The network simulation applications require very high arithmetic rates, and they often exhibit multifold characteristics that are related to diverse performance potentials of the cluster respectively. In order to make the network simulation application exert performance advantages of the cluster architecture, this paper researches on the cluster performance oriented characteristics of network simulation. Especially, two important aspects are researched as follows:

- The performance capabilities of cluster are summarized completely.
- The characteristics of network simulation are analyzed deeply, so as to meet diverse performance demands of cluster.

The characteristic research is the foundation to implement the high performance simulation[7]. The results in this paper can guide the selection of the appropriate cluster platform exactly and efficiently, and also guide the development of performance oriented parallel optimization techniques according to the characteristics of network simulation.

II. THE PERFORMANCE CAPABILITIES OF CLUSTER

The network simulation aims at constructing the network environment through using the simulation technique. The corresponding application has mass data and computations, which is able to discover the performance advantages of cluster architecture. Thus, the network simulation demands that the cluster platform possesses some performance capabilities, mainly including the capabilities of scaling, computing, communicating, memory accessing, paralleling, parallel I/O[8]. The detailed descriptions of the six aspects are described in the following sections.

A. The scaling capability

The scaling capability of cluster refers to the number of nodes and the number of arithmetic units of cluster. The typical cluster architecture as shown in Fig. 1[7], wherein N represents node, and M represents memory. The scaling capability of cluster in Fig. 1 is shown with dashed box. It can be measured by the extent of speedup increase when the nodes of cluster scale up.

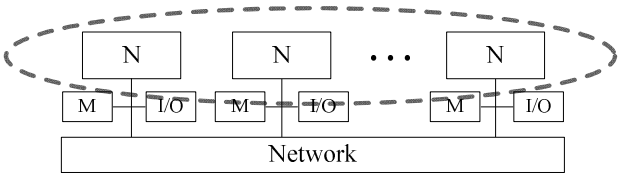

Figure 1. The scaling capability of cluster

B. The computing capability

The computing capability of cluster comes from the comprehensive computing capability generated by the multiple arithmetic units. And it can be measured by the intensive extent and the saturated utilization of on-chip arithmetic units. Fig. 2 gives a diagram of cluster with multi-core processor, where P represents the processor.

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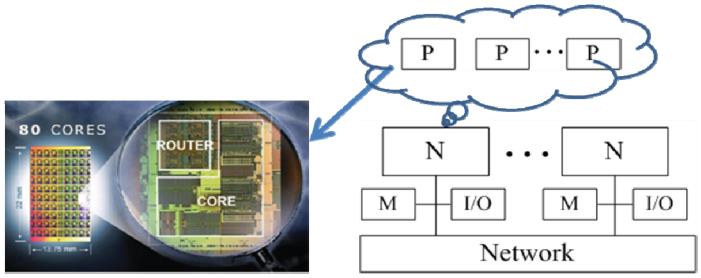

Figure 2. The computing capability of cluster

C. *The communicating capability*

The communicating capability of cluster refers to the capability of information exchanging between nodes of cluster. It can be estimated by the communication overhead, which should be measured by the network topological structure between the two nodes that are connected by communication relationship. Fig. 3 gives the diagram of communication between cluster nodes.

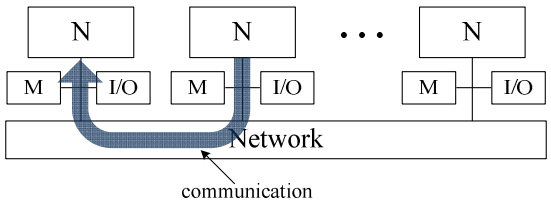

Figure 3. The communicating capability of cluster

D. *The memory accessing capability*

The memory accessing capability of cluster includes memory capacity and memory access overhead. Wherein, the memory access overhead refers to the reading and writing delay of processing data from arithmetic units. It can be measured by the hierarchical distance between the accessing data in the memory and the arithmetic unit. For the cluster, multiple arithmetic units in a node share a single memory space, so that the remote memory access latency between different nodes is much larger than the memory access latency in a single node, as shown in Fig. 4. The gap can usually reach 1 to 2 orders of magnitude[9].

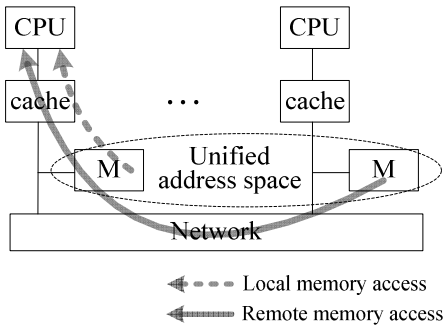

Figure 4. The memory accessing capability of cluster[9]

E. *The paralleling capability*

The paralleling capability of cluster comes from the paralleling work of arthritic units or nodes. It can be measured by what levels of parallelism provided by computing platform, including task-level parallelism, data-level parallelism, thread-level parallelism and instruction-level parallelism. Wherein, the task-level parallelism and data-level parallelism are coarse-grain parallelism, and the thread-level parallelism and instruction-level belong to fine-grain parallelism, as shown in Fig. 5.

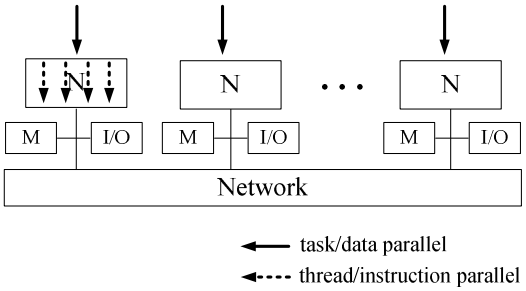

Figure 5. The paralleling capability of cluster

F. *The parallel I/O capability*

The parallel I/O capability of cluster depends on the I/O interconnect technique, I/O architecture and I/O file system. It is implemented through the use of a set of storage devices to store massive data, and provide the corresponding interface to access these devices, as shown in Fig. 6. The parallel I/O capability can be measured by the parallel writing and reading ability from the computing nodes to the off-chip storage, such as disk.

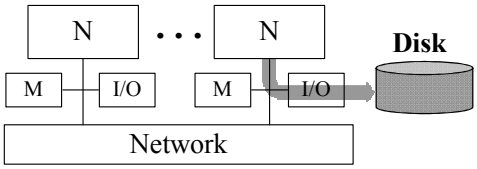

Figure 6. The parallel I/O capability of cluster

The multicore cluster is typical cluster architecture. The system consists of a plurality of nodes that are connected by network. Each node has several multi-core CPUs and the only local memory, that is, each node is an independent

shared memory computer, and the memory on different nodes is physically separate. These nodes constitute distributed memory architecture. The multicore cluster is a kind of hierarchical structure, the diagram as shown in Fig. 7, where NIC represents a network interface. The architecture has the advantages of easy constructing, high cost performance and good scalability.

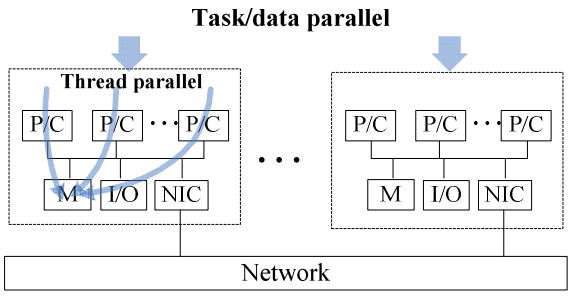

Figure 7. the architecture of multicore cluster

The multicore cluster is the base platform for realizing high performance computing. It combines the parallel computer system and parallel programming model, and provides parallel execution pattern for multiple tasks in a program. When we are developing a parallel simulation program, we need to select suitable parallel optimization algorithm through combining the platform performances and the program characteristics, so as to write correct and efficient parallel programs. The multicore cluster has powerful performance advantages, and exhibits the potential to improve the performance of network simulation. These potentials are mainly reflected in the following five aspects.

The multicore cluster has good scalability. It takes advanced microprocessor as the processing unit based on the distributed memory technique, and connects a plurality of nodes to each other through the high speed network. Compared with the shared memory computing platform with finite scale, the distributed memory computing platform can effectively extend the number of computing nodes to achieve large scale, and thus it has good scalability. Thereby, the multicore cluster can be applied to simulate the large-scale network environment effectively, so as to adapt to the sustainable development of network scale. Thus, the multicore cluster maybe a good candidate to be the development platform of network simulation application.

III. THE CLUSTER PERFORMANCE ORIENTED CHARACTERISTICS OF NETWORK SIMULATION

The network simulation possesses multifold characteristics, which reflect diverse performance advantages of cluster respectively. The specific characteristics are explained in detail below.

A. The openness characteristic

The network simulation possesses the openness characteristic. The network simulation requires a large amount of simulation nodes[10]. When the number of nodes is limited, the real hardware equipments can be directly used to construct the network. However, when the number of nodes is increased to a certain size, the network can only be constructed through the computer simulation. Especially, when the simulation nodes are increased to a huge extent, for example hundreds of thousands of nodes, the traditional PC based distributed simulation technique is incapable of action, and it is difficult to efficiently provide complex, large-scale network test environment. Thus we must research and implement parallel network simulation based on the cluster platform, so as to achieve the dynamic and sustainable growth of simulated network. For a single node of cluster, the number of simulation nodes is limited by the restricted capacity of memory and computation. Therefore, the openness characteristic of network simulation puts forward the demand of scaling capability of cluster.

B. The complexity characteristic

The network simulation possesses the complexity characteristic. The complexity of network simulation comes from the diversity and difference of the network structure. In order to achieve high-fidelity, large-scale and full system simulation, the network simulation application will reflect the complexity characteristic because of the complicated simulation model, a large amount of data and complex computation, which presents a huge demand for high performance computing. According to the statistics, the large-scale military network simulation often requires the computing capability that is trillions and tens of trillions floating-point operations per second to meet the user's expectation of super real-time simulation. This computing capability can generate doubling combat effectiveness and speed, to ensure initiative and counterbalance in counterwork. In order to realize the real-time and high-speed of network simulation, it needs to adopt parallel computing technique based on the cluster platform with multiple arithmetic units, to accelerate complex network simulation model. Therefore, the complexity characteristic of network simulation puts forward the demand of computing capability of cluster.

C. The interaction characteristic

The network simulation possesses the interaction characteristic. The network reflects multiple characteristics regarding interaction in the information domain, including numerous interactive nodes, diversiform interaction mechanism, high interactive frequency, real-time interactive speed, and a large amount of interactive data, et al. In order to simulating network environment realistically, we should not be confined to implement the static network simulation, and should pay attention to the flow of information caused by different user behavior on network business layer. Thus, the network simulation needs to simulate the interaction capability with the features of real-time, flexible, safe and reliable between large-scale simulation nodes[11][12], so as to implement realistic and dynamic network simulation. To improve the simulating speed effectively, the computing platform for network simulation should provide efficient, high bandwidth and low latency communication network. Therefore, the interaction characteristic of network

simulation puts forward the demand of communicating capability of cluster.

D. The coupling characteristic

The network simulation possesses the coupling characteristic. According to the requirement of application change, the network simulation environment needs to be reconfigured flexibly and dynamically. This change requirement will lead to frequent interactive operations between simulation nodes, so that it causes a portion of node sets have strong data coupling. When the network environment is constructed, since the local memory access latency is far less than the remote memory access latency, the simulation nodes in a strong coupling node set should be arranged in the same cluster node as much as possible, so as to improve the flexibility of network environment change and reduce the cost of frequent interactions. From the angle of parallelism, the more simulation nodes are assigned to a single cluster node, the more parallelism can be explored in network simulation. However, the memory capacity in a node is limited by the hardware and operating system. The increase in the number of simulation nodes will likely cause that the summation of address space required by all processes in a single node beyond memory capacity. It will introduce the disk space to a virtual storage space, which will lead to a very slow access overhead that is larger than the memory access overhead by tens of thousands of times. Due to the contradiction between parallel degree and storage capacity, the number of internal simulation nodes on a single cluster node can't be increased discretionarily, and its maximum should be determined by the ratio of memory space required by process to inherent memory capacity. Therefore, the coupling characteristic of network simulation puts forward the demand of memory accessing capability of cluster.

E. The pluralism characteristic

The network simulation possesses the pluralism characteristic. The real network is mainly comprised by the communication terminal, communication relay station, network control and management center, computer and other facilities. It presents the pluralism characteristic for the reason of wide coverage, diverse structure, complicated relationship and multifarious elements. So the corresponding simulated network needs to span from the physical layer to application layer, namely the OSI seven layers model, and includes a large number of different types of virtual and simulated resources. According to the network simulation's manifestation regarding wide span, multiple levels and diverse elements, the simulated object of network presents the pluralism characteristic that concretely includes the following aspects: microscopic to macroscopic, physics to cognition, signal to information, and function to performance. The accurate analysis and simulation of the pluralism characteristic directly determines the accuracy, completeness and validity of the simulated network. In order to simulate the pluralism characteristic better, we need to integrate multiple simulation techniques including the mechanisms of multi-granularity resource generation and hierarchical integration, so as to realize the on-demand construction and rapid deployment of simulated network. This technique for hybrid, multi-granularity, hierarchical network simulation is applied to mining the multi-level parallelism of cluster. Therefore, the pluralism characteristic of network simulation puts forward the demand of paralleling capability of cluster.

F. The reproducibility characteristic

The network simulation possesses the reproducibility characteristic. In order to reproduce the factual features of real network, the simulated network is required to detect a large number of parameters and data of the real network, and takes these parameters and data as the input of network simulation process. Especially for the simulation of network background environment, a method of flow playback is usually applied. This method not only needs a large amount of data, but also sometimes has plentiful simulation entities that are visited at the same time and asked to maintain the global data consistent. Based on this requirement, the network simulation needs the support of global parallel file system with high performance, high capacity, high scalability ability, so as to reduce the reading and writing overhead of disk data. Therefore, the reproducibility characteristic of network simulation puts forward the demand of parallel I/O capability of cluster.

Table I summarizes the corresponding relationship between the characteristics of network simulation and the performance demands of cluster.

TABLE I. THE RELATIONSHIP BETWEEN NETWORK SIMULATION CHARACTERISTICS AND CLUSTER PERFORMANCE

Characteristics of Network Simulation	Performance Demands of Cluster
openness	scaling capability
complexity	computing capability
interaction	communicating capability
coupling	memory accessing capability
pluralism	paralleling capability
reproducibility	parallel I/O capability

IV. CONCLUSION

It is significant to study the characteristics of network simulation and their corresponding performance demands of cluster platform. Thus, this paper researched on the cluster performance oriented characteristics of network simulation, so as to make the network simulation exploit the performance advantages of cluster sufficiently. Especially, two important aspects are researched in detail, including the performance capabilities of cluster, and the characteristics of network simulation and their corresponding performance demands of cluster platform. The research result in this paper indicates definitely that the network simulation is appropriate for mapping to cluster to achieve high performance, and can

guide the designation of parallel optimization techniques for network simulation.

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