

# A Study of Solution Approach for the Development of Computing Clusters

<sup>1</sup>Shaik Hameeda & <sup>2</sup>Dr. R. P. Singh

<sup>1</sup>Research Scholar, Sri Satya Sai University, Bhopal (India)

<sup>2</sup>Vice Chancellor, SSSUTMS, Bhopal (India)

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## ABSTRACT

The High Performance Computing (HPC) allows scientists and engineers to deal with very complex problems using fast computer hardware and specialized software. Since often these problems require hundreds or even thousands of processor hours to complete, an approach, based on the use of supercomputers, has been traditionally adopted. Recent tremendous increase in a speed of PC-type computers opens relatively cheap and scalable solution for HPC using cluster technologies.

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## 1. Introduction

Development of new materials and production processes, based on high-technologies, requires a solution of increasingly complex computational problems. However, even as computer power, data storage, and communication speed continue to improve exponentially, available computational resources are often failing to keep up with what users demand of them. Therefore high-performance computing (HPC) infrastructure becomes a critical resource for research and development as well as for many business applications. Traditionally the HPC applications were oriented on the use of high-end computer systems - so-called "supercomputers". Before considering the amazing progress in this field, some attention should be paid to the classification of existing computer architectures. SISD (Single Instruction stream, Single Data stream) type computers. These are the conventional systems that contain one central processing unit (CPU) and hence can accommodate one instruction stream that is executed serially. Nowadays many large mainframes may have more than one CPU but each of these execute instruction streams that are unrelated. Therefore, such systems still should be regarded as a set of SISD machines acting on different data spaces. Examples of SISD machines are for instance most workstations like those of DEC, IBM, Hewlett-Packard, and Sun Microsystems as well as most personal computers. SIMD (Single Instruction stream, Multiple Data stream) type computers. Such systems often have a large number of processing units that all may execute the same instruction on different data in lock-step. Thus, a single instruction manipulates many data in parallel. Examples of SIMD machines are the CPP DAP Gamma II and the Alenia Quadrics. Vector processors, a subclass of the SIMD systems. Vector processors act on arrays of similar data rather than on single data items using specially structured CPUs. When data can be manipulated by these vector units, results can be delivered with a rate of one, two and, in special cases, of three per clock cycle (a clock cycle being defined as the basic internal unit of time for the system). So, vector processors execute on their data in an almost parallel way but only when executing in vector mode. In this case they are several times faster than when executing in conventional scalar mode. For practical purposes vector processors are therefore mostly

regarded as SIMD machines. Examples of such systems are Cray 1 and Hitachi S3600. MIMD (Multiple Instruction stream, Multiple Data stream) type computers. These machines execute several instruction streams in parallel on different data. The difference with the multi-processor SISD machines mentioned above lies in the fact that the instructions and data are related because they represent different parts of the same task to be executed. So, MIMD systems may run many sub-tasks in parallel in order to shorten the time-to-solution for the main task to be executed. There is a large variety of MIMD systems like a four-processor NEC SX-5 and a thousand processor SGI/Cray T3E supercomputers. Cloud computing is shared pools of configurable computer system resources and higher-level services that can be rapidly provisioned with minimal management effort, often over the Internet. Cloud computing relies on sharing of resources to achieve coherence and economies of scale, similar to a public utility.

Third-party clouds enable organizations to focus on their core businesses instead of expending resources on computer infrastructure and maintenance. Advocates note that cloud computing allows companies to avoid or minimize up-front IT infrastructure costs. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and that it enables IT teams to more rapidly adjust resources to meet fluctuating and unpredictable demand. Cloud providers typically use a "pay-as-you-go" model, which can lead to unexpected operating expenses if administrators are not familiarized with cloud-pricing models.

The availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of hardware virtualization, service-oriented architecture, and autonomic and utility computing has led to growth in cloud computing.

The idea of using the cloud for development is gaining popularity. In a 2013 assessment of "The Cloud Economy and Developing Countries" United Nations Secretary-General BAN Ki-moon lauded the cloud's potential for fostering economic

and social development and furthering Millennium Development Goals.

A 2016 World Economic Forum report said with help from cloud provided services, "... the financial barriers to new business entry have fallen significantly," providing both startups and small to medium enterprises the ability to scale and remain resilient.

## 2. Cluster Computing

Cluster computing refer to technologies that allow multiple computers, called cluster nodes, to work together with the aim to solve common computing problems. A generic cluster architecture is shown in Figure. Each node can be a single or multiprocessor computer, such as a PC, workstation or SMP server, equipped with its own memory, I/O devices and operating system. The cluster, having similar nodes, is called homogeneous, otherwise - heterogeneous. The nodes are usually interconnected by local area network (LAN) based on one of the following technologies: Ethernet, Fast Ethernet, Gigabit Ethernet, , Quadrics Network (QsNet) , Infini Band

communication fabric [9], Scalable Coherent Interface (SCI), Virtual Interface Architecture (VIA) or Memory Channel . The speed of network technology is characterised by a bandwidth and a latency. Bandwidth means how much information can be sent through a particular network connection, and latency is defined as the time it takes for a networking device to process a data frame. A comparison of these two parameters for above mentioned network technologies is given in Table. Note that a higher network speed is usually associated with a higher price of related equipment. To improve further cluster performance, different network topologies can be implemented in each particular case. Moreover, channel bonding technology can be used in the case of the Ethernet-type networking to double the network bandwidth. To realise this technology, two network interface cards (NICs) should be installed in each node, and two network switches should be used, one for each channel, to form two separate virtual networks. The optimal choice of the network type is dictated by demands on speed and volume of data exchange between several parts of the application software, running on different nodes.

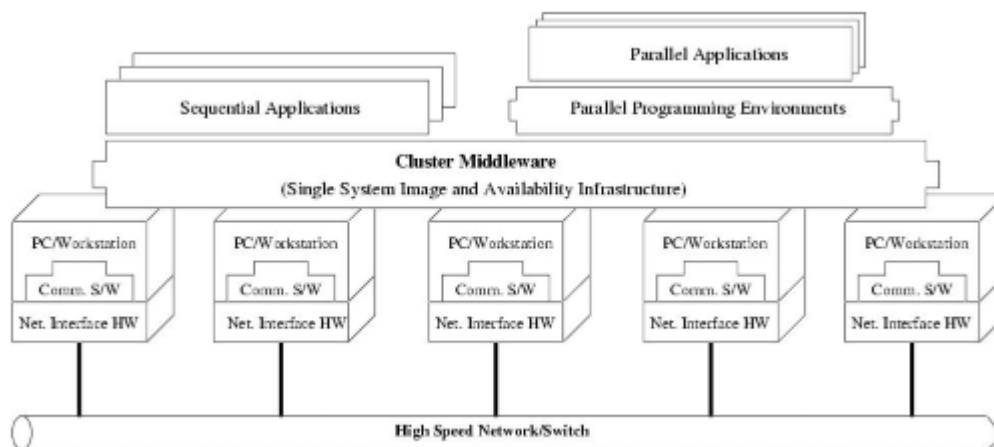


Figure. Typical cluster architecture

TABLE. Comparison of network technologies used in cluster systems

Network Technology	Bandwidth (MByte/sec)	Latency (µsec/packet)
Ethernet	1.25	-
Fast Ethernet	12.5	158
Gigabit Ethernet	125	33
Myrinet	245	6
QsNet	340	2
InfiniBand	320, 1280 and 3840	<10
SCI	400	1.5
VIA	150	8
Memory Channel	100	3

Various operating systems, including Linux, Solaris and Windows, can be used to manage the nodes. However, in order for the clusters to be able to pool their computing resources, special cluster-enabled applications must be written using clustering libraries or a system level middleware should be used. The most popular clustering libraries are PVM (Parallel Virtual Machine) and MPI (Message Passing Interface) both are very mature and work well. By using PVM or MPI, programmers can design applications that can span across an entire cluster's computing resources rather than

being confined to the resources of a single machine. For many applications, PVM and MPI allow computing problems to be solved at a rate that scales almost linearly in relation to the number of processors in the cluster.

## 3. Conclusion

the motivation for using clusters as well as the technologies available for building cluster-based systems. There is much emphasis placed on using the commodity-

based hardware and software components to achieve high performance and scalability and at the same time keep the ratio of price versus performance low. A number of emerging basic building blocks, such as network technologies, operating systems, and middleware have been discussed. A number of software solutions for providing a single system image for clusters are emerging, yet there are still many opportunities for integrating various cluster tools and techniques and making them work together and so help create more usable and better unified clusters. Clusters are being used to solve many

scientific, engineering, and commercial applications. We have discussed a sample of these application areas and how they benefit from the use of clusters. The applications studied include, a Web server, an audio processing system (voicebased email), data mining, network simulations, and image processing. Many large international Web portals and e-commerce sites use clusters to process customer requests quickly and maintain high availability for 24 hours a day and throughout the year.

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