**Computing Clusters**

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## 1.Introduction

Using multiple PCs as a single unit computing core was introduced in the 1960s by IBM. In order to take advantage of all the resources for doing advanced computing's and provide a more cost efficient approach through parallel computing. Soon after the emergence of high-performance microprocessors, high-speed network, and tools for high-performance distributed computing the chance for using this architecture got higher. In this report, the computing clusters, as well as its architecture, is studied. In addition, different level of the architecture is covered in details at the end we examined some examples in this area.

## 2.What is computing clusters ?

A cluster is a type of parallel or distributed computer system, which consists of a collection of interconnected stand-alone computers working together as a single integrated computing resource. Figure 1 demonstrates the architecture of a cluster computer with the key components of a cluster. The architecture comprises multiple nodes (PCs, Workstations,etc) , operating systems, a decent high performance interconnects, communication software, middleware, and applications.
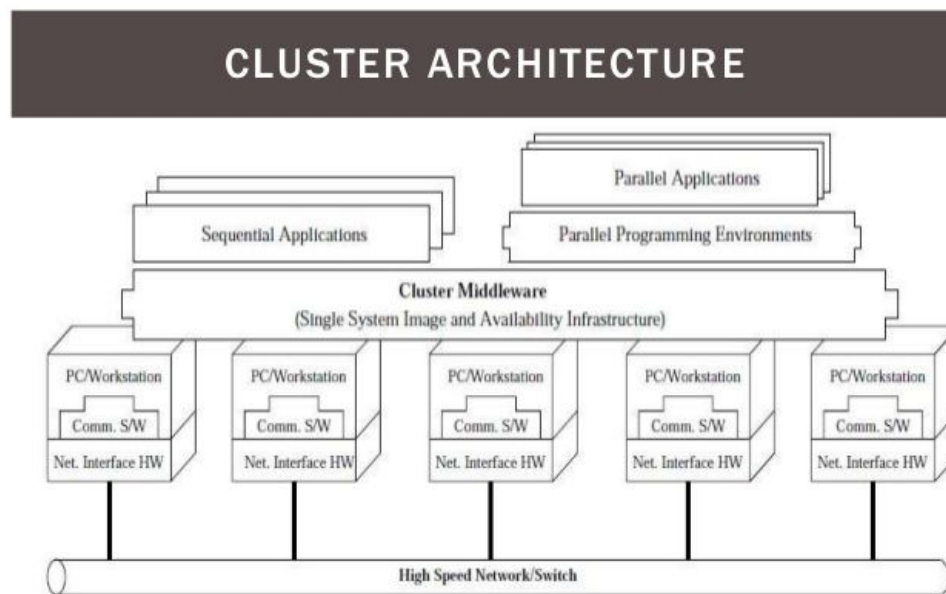
**Figure 1**

## 2.1 Interconnection Technologies

In order to have a reliable connection between workstations and a proper communication between processes need to provide a decent interconnection platform. High bandwidth and low latency for inter-process communications have always been a challenge for cluster computing. However, improvements in computer networking facilitate the path toward more efficient clusters.

### 2.1.1 Protocols for cluster communication

The standard Transmission Control Protocol/Internet Protocol (TCP/IP) is suitable for many cluster applications and it is the easiest approach to use when the cluster consists of inexpensive Fast Ethernet products. However, TCP/IP is designed for a wide-area network environment where errors are common. TCP/IP uses mechanisms to measure the round-trip time and tries to optimize the overall throughput. However, these optimizations will reduce resending a message due to an error. Therefore, it will increase the overall latency in cluster applications where errors are  not common and the physical distance is small. In order to achieve a good performance, clusters usually use interconnection technologies that are specifically designed for cluster computing. These technologies use specific software and extra hardware for reducing the latency in messages and in general reduce the number of errors in bits.

## 2.2 Operating Systems

The fundamental system supports and services are provided by operating systems. Protecting boundaries, process coordination, inter-process communication, and device handling are among the services that operating system supports. On the other hand, the  as well as provided services, operating system should have the following features.

| Features | Explanation |
|---|---|
| Manageability | To manage local and remote resources |
| Stability | Provides robustness with system recovery |
| Performance | Operations must be efficient and optimized |
| Extensibility | Easy cluster-specific extension |
| Scalability | Scalable while maintains the same performance |
| Support | Supports user and system administrator |

| Heterogeneity | This can be achieved via middleware |
|---|---|

## 2.3 Middleware

Middleware acts as a resource management system that enables users to execute jobs without noticing the complexity of the underlying cluster architecture. The middleware performs 4 main tasks for the system: resource management, job queueing, job management, and job scheduling. Figure 2 demonstrate a general view of the middleware architecture. The middleware manages the resources such as disk storage or processors and assigns jobs to the available machines. If the resources are not occupied, the jobs stay in the queue until resources become available. The jobs then are invoked to be executed by available resources and the end result is sent to the end-user.
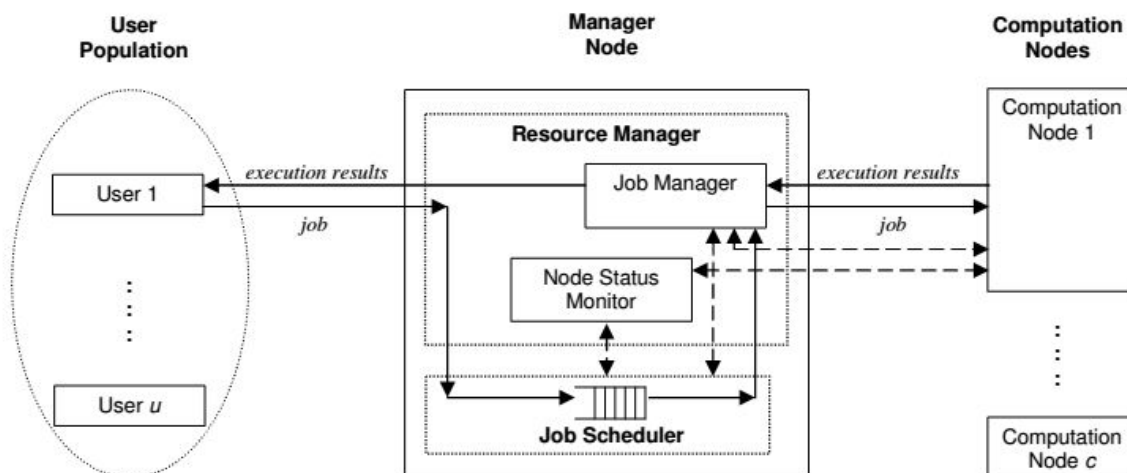
**Figure 2**

## 3. Single System Image (SSI)

Based on the definition of a computing cluster the whole system is required to be seen as a single unified computing resource. Single System Image (SSI) will help the users to utilize the system without noticing the complexities and the distributed and heterogeneous underlying of a cluster. SSI can be defined at different levels of abstraction in a cluster architecture; hardware, operating system, middleware, and applications.

The main goals for an SSI cluster system are to achieve transparency of resource management, scalable performance, and system availability for supporting applications.

The table explains the different levels of abstraction where SSI is applied.

| Level of abstraction | Description | Example |
|---|---|---|
| Hardware | Provides cluster as a | Memory Channel - Distributed |

|  | shared-memory system | Shared Memory (DSM) |
|---|---|---|
| Operating system | <ul><li>By modifying the kernel of the current operating system to support SSI</li><li>A new operating system layer that communicate with different operating systems on each node</li></ul> | <ul><li>MOSIX - Solaris MC - UnixWare</li><li>GLUnix</li></ul> |
| Middleware | A resource management system | Parallel Virtual Machine (PVM) Condor Loadleveler Load Share Facility (LSF) Open Portable Batch System (OpenPBS) Sun Grid Engine (SGE) Libra |
| Application | In the highest level of abstraction it provides a specific user interface | PARMON Linux Virtual Server Problem Solving Environments |

## 4. Types of computing clusters

There are several application areas to use computing clusters. Storage, High-availability, High-performance and Load balancing are the most important ones.

### 4.1 Storage

A clustered storage is the combination of two or more storage servers to improve the performance,reliability and capacity of the system. In this approach, the workload is distributed among servers and provide access from different physical location. The two basic architecture for storage cluster are loosely coupled and tightly coupled.

### 4.2 High availability

HA clusters are a group of computers which let server applications be utilized with a minimum of downtime. The redundant servers are used when the application fails or faces crashes and the other server will be replaced during the recovery time. HA clusters can be used for databases, file sharing on a network and business applications.

### 4.3 High performance

High-Performance Computing Clusters (HPCC) is a data-intensive computing system platform developed for intense calculations. The HPCC provides high-performance, data parallel processing for the  application using big data.

## 4.4 Load balancing

In load balancing clusters, the workload is distributed among multiple computing resources in order to optimize the use of resources.  This approach supports reliability and availability by making redundant servers.

# 5. Examples

Recently the need for solving problems with high computing demands in different areas is increasing. On the other hand, as High-Performance Computing (HPC) techniques  have the ability to perform intense computing tasks they are suitable solutions to answer the requirements. Following example demonstrate how computing cluster techniques  are used to manage the high number of inquiries the Google search engine receives.

## Google Search Engine

Google uses cluster computing to address the high demand for system resources as the performance of clusters is more cost efficient and also it uses less energy compared to high performing computing platforms. Reliability and request throughput are the main goals of the google search engine. Google achieves the request throughput by executing the queries in a parallel way.  Figure 3 demonstrate different phases of executing requests.
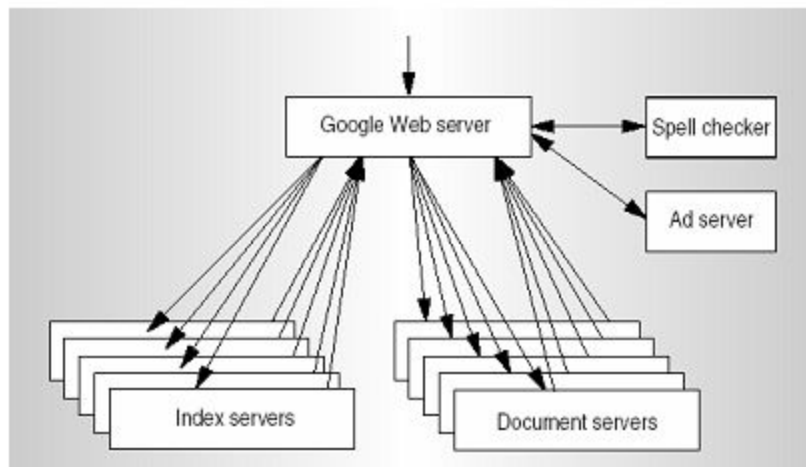


**Figure 3**

In the first step is to search through the inverted index in order to find the query keyword among the matching list of documents. The results are also scored and ordered according to the

relevance. The second phase is to fetch each document from disk to find the title and the query keyword. At the same time, the spell checker and ad server are also activated. The ad server shows advertisement related to the query as it might be useful for the user. Google uses clusters of 15,000 commodity PCs  distributed worldwide to perform these tasks.

## 6. Conclusion

In this report, we discussed the definition of a computing cluster and also the architecture was covered. The meaning of single system image was also examined at different abstraction levels, In addition, the use of computing clusters with example was covered and in general computing clusters bring reliability and improve the performance of the system. However, due to network and communication constraints, this is still an open problem.

## 7. References

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