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Trends of optimizing the usage of Parallel HPC Cluster in Various Domains

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Abstract— With the increasing demand of cluster computing many organizations are publishing innovative flavours in HPC cluster computing to boost up the application performance and scalability. High Performance Computing: which includes computers, networks, algorithms and environments to make such systems usable - range from small cluster of PCs to fastest supercomputer. As to build HPC Clusters is not always feasible or may be not cost-effective since the purchasing, operational and maintenance cost of the dedicated systems is too high but they are not fully utilized in most of the time. In this paper we have represented a survey of parallel architecture, performance issues, clustering components and software hardware configuration required for HPC cluster in various domains.

Keywords— Parallel processing; cluster computing; cluster architecture; shared memory; Distributed memory; Hybrid distributed-shared memory; HPC cluster.

I. INTRODUCTION

Clustering is a group of loosely coupled commodity computers working together to achieve the same goal, maintain a Single System Image, good computational performance and Reliability. Clustering have been used in many fields including machine learning, pattern recognition, image analysis, information retrieval, and bioinformatics. Cluster analysis as such is not an automatic task, but an iterative process of knowledge discovery or interactive multi-objective optimization. It will often be necessary to modify preprocessing parameters until the result achieves the desired properties.

a. *Parallel Memory Architecture*

In the Traditional sense, software has been written for ***serial*** computation: To be run on a single computer having a single Central Processing Unit. A problem is broken into a discrete series of instructions. At single instance of time only one instruction may execute. In the case of ***parallel computing,*** it is the simultaneous use of multiple computing resources to resolve a computational problems: which are to be run using multiple processors. A problem is broken into discrete sections that can be solved concurrently. Each section is further broken down to a series of instructions. Instructions from each section execute simultaneously on different processors [3].

Following are the classifications of different architectures.

1. *Shared Memory Architecture :*

   In Shared memory architecture every processor can operate independently but share the same memory resources. In this all processors are sharing memory as global address space. In this architecture care should be taken care for change in a memory location effected by one processor are visible to all other processors. Based upon memory access times Shared memory architecture is classified as UMA and NUMA [3].

   i. *Uniform Memory Access (UMA):* UMA is the collection of identical processors also known as Symmetric Multiprocessor (SMP) machines. Each of having equal access and access times to memory.
   ii. *Non-Uniform Memory Access (NUMA):* NUMA is often made by physically linking two or more SMPs. One SMP can directly access memory of another SMP. In this not all processors have the same access time to all memories.

2. *Distributed Memory Architecture :*

   Distributed memory systems vary widely but share a common characteristic. Distributed memory systems require a communication network to connect inter-processor memory. In Distributed architecture processors have their own local memory. Memory addresses in one processor do not map to another processor, so there is no concept of global address space across all processors. Changes it makes to its local memory have no effect on the memory of other processors. When a processor needs access to data in another processor, it is usually the task of the programmer to explicitly define how and when data is communicated. Here it is the job of programmer to provide synchronization between tasks [3].

3. *Hybrid Distributed-Shared Architecture :*
   Hybrid distributed shared architecture as name itself suggest which employs both shared and distributed memory architectures. The shared memory component can be a shared memory machine and/or graphics processing units (GPU). The distributed memory component is the networking of multiple shared memory/GPU machines, which know only about their own memory - not the memory on another machine. Current trends seem to indicate that this type of memory architecture will continue to prevail and increase at the high end of computing for the foreseeable future [3].

b. *Parallel Architecture*
   1. *Single Instruction Single Data (SISD) :*
      SISD is a term referring to a computer architecture in which a single processor, a uniprocessor, executes a single instruction stream, to operate on data stored in a single memory [12]. It is a serial (non-parallel) computer. **Single Instruction:** Only one instruction stream is being acted on by the CPU during any one clock cycle. **Single Data:** Only one data stream is being used as input during any one clock cycle Deterministic execution. Examples: older generation mainframes, minicomputers and workstations; most modern day PCs [4].
   2. *Single Instruction, Multiple Data (SIMD) :*
      SIMD is a type of parallel computer. It describes computers with multiple processing elements that perform the same operation on multiple data points simultaneously. Thus, such machines exploit data level parallelism [12]. **Single Instruction:** All processing units execute the same instruction at any given clock cycle. **Multiple Data:** Each processing unit can operate on a different data element. Best suited for specialized problems characterized by a high degree of regularity, such as graphics/image processing. Examples: Processor Arrays, Vector Pipelines [4].
   3. *Multiple Instruction, Single Data (MISD) :*
      MISD is a type of parallel computing architecture where many functional units perform different operations on the same data [12]. It is a type of parallel computer. **Multiple Instruction:** Each processing unit operates on the data independently via separate instruction streams. **Single Data:** A single data stream is fed into multiple processing units. Examples of this class of parallel computer have ever existed [4].
   4. *Multiple Instructions Multiple Data (MIMD) :*
      MIMD is a technique employed to achieve parallelism. Machines using MIMD have a number of processors that function asynchronously and independently. At any time, different processors may be executing different instructions on different pieces of data [12]. It is a type of parallel computer. **Multiple Instruction:** Every processor may be executing a different instruction stream. **Multiple Data:** Every processor may be working with a different data stream. Execution can be synchronous or asynchronous, deterministic or non-deterministic. Examples: most current supercomputers, networked parallel computer clusters and "grids", multi-processor SMP computers, multi-core PCs [4].

c. *Parallel Programming Model*
   1. *Single Program Multiple Data (SPMD) :*
      SPMD is actually a "high level" programming model that can be built upon any combination of the previously mentioned parallel programming models [4].
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II. CLUSTER COMPONENTS

Clustering is a process of grouping objects with similar properties. Any cluster should exhibit two main properties; low inter-class similarity and high intra-class similarity. Clustering is an unsupervised learning i.e. it learns by observation rather than examples. There are no predefined class label exists for the data points [14]. Clustering is a fundamental operation in data mining. A cluster is a group of data objects that are similar to one another within the same cluster and are dissimilar to the objects in other clusters. A good clustering algorithm is able to identity clusters irrespective of their shapes. Following figure shows the stages of clustering process [2].

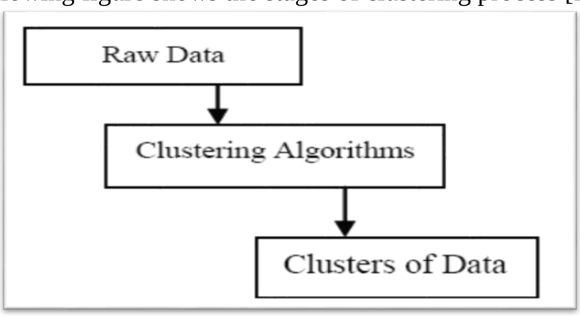

Fig. 1- Stages of clustering process Source: [2]

A. Cluster Components

Cluster components are listed as: Cluster Software, Cluster Hardware, Cluster Network, and Cluster Storage.

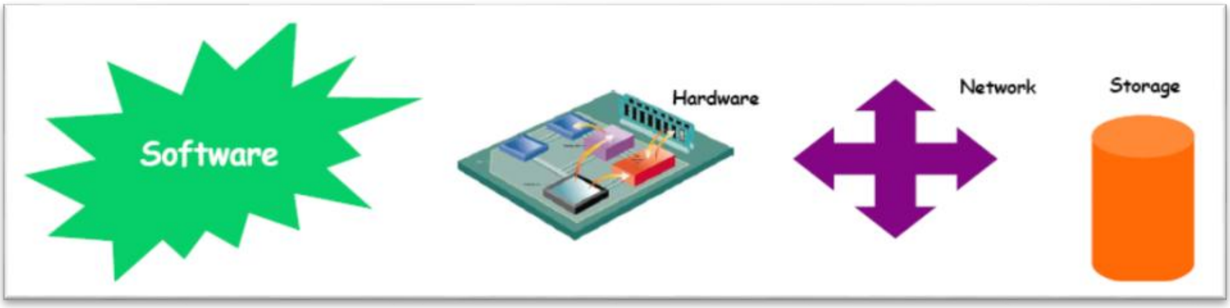

Figure 2- Cluster components Source: [5]

Cluster Software: Cluster compatible Operating system is require, Cluster software to generate and maintain cluster, Cluster aware application.

Hardware: Uses commodity components, Advanced Processors with large cache, High speed memory, Advance chipsets, Faster I/O subsystem.

Network: High speed, Low latency, Scalable, reliable, Accelerators.

Storage: Linear scaling, Extreme bandwidth & I/O, Hierarchical storage management, single storage pool, Reliable.

B. Benefits of Cluster Computing

As cluster has many standard benefits its popularity increasing day by day. The clusters are also utilized to host many new internet service sites [10, 11]. In the commercial arena, servers can be consolidated to create an enterprise server that can be optimized, tuned and managed for increased efficiency and responsiveness depending on the workload through load balancing [13-6]. A large number of machines can be clustered along with storage and application for efficient performance. These are various measures of performance of clusters. However, the most important three parameters that need to be analyzed for high performance computing are **High Availability**, **Load Balancing** and **Fault Tolerance** [7, 8].

III. HPC CLUSTER

[1] Min Li et al. Presented HPC cluster monitoring and its different functionalities such as Job monitoring, System monitoring etc. They have discussed, the user allows to build HPC cluster computing monitoring environment on their demand and can customize based on needs. High Performance Computing which includes computers, networks, algorithms and environments to make such system usable. High-performance computing (HPC) is a broad term that at its core represents compute intensive applications that need acceleration. Users of application acceleration systems range from medical imaging, financial trading, oil and gas expiration, to bioscience, data warehousing, data security, and many more. In the information age, the need for acceleration of data processing is growing exponentially and the markets deploying HPC for their applications are growing every day. The HPC expansion is being fueled by the coprocessor, which is fundamental to the future of HPC. HPC allows scientists and engineers to solve complex science, engineering and business problems using applications that require high bandwidth, low latency networking, and very high compute capabilities. Typically, scientists and engineers must wait in long queues to access shared clusters or acquire expensive hardware systems [9].

HPC Cluster Minimum Requirements

Table 1: HPC Cluster Requirement

Minimum requirements	**Master Node/ Slave Node**	**Network**
Head /Master node, Compute/Slave node, Cluster software, Cluster interconnect and Storage	1 Ethernet Port CDROM Drive 256MB RAM	Crossover network cable

IV. PRL HPC CLUSTER

Physical Research Laboratory (PRL) is a national Research institute for space and science, supported mainly by Department of Space, Government of India. PRL carries out fundamental research in select areas of Physics, Space & Atmospheric Sciences, Astronomy, Astrophysics & Solar Physics, and Planetary & Geosciences. PRL Uses HPC cluster for space and atmospheric science division. PRL HPC Cluster Architecture: It is a 21 node cluster with 20 compute nodes and 1 master node with a peak performance of 3.2TF and a sustained performance of 2.2TF (approx.). It supports 64-bit Hardware and 32/64 bit software. It has different types of nodes like Backup Node, I/O Node, a Storage Node and a management node. The cluster is having a 10TB of usable storage based on FC disk drives (minimum 10k rpm). It has

20TB of raw storage with LTO Gen 4 Tape Library for Data Backup. The primary Network is Infiniband and the Secondary Network is Gigabit. There is as additional Management Switch for Node Management using intelligent platform Management Interface (IPMI). PRL HPC cluster architecture is given in Figure 3.

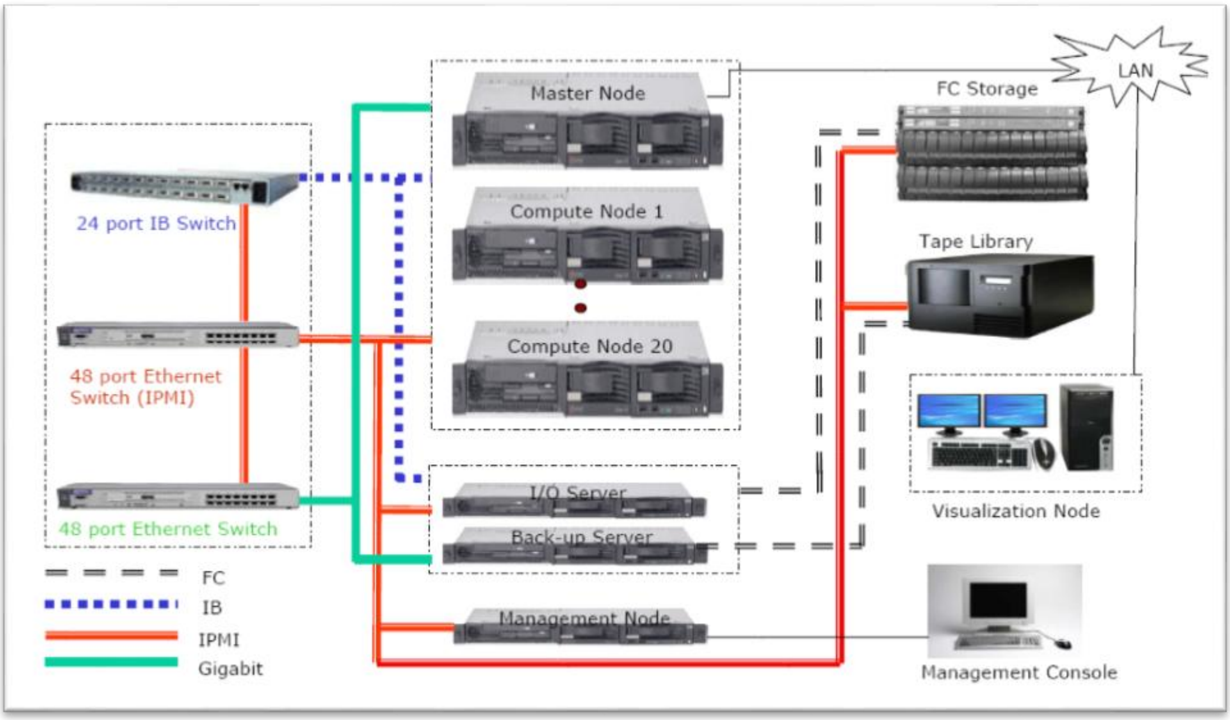

Figure 3- PRL HPC Cluster Architecture

The Master Node and all compute Nodes (20 Nos.), are of the make HP DL 585G5.
Master Node: It is having Quad core and Quad socket AMD Opteron 8360SE, 2.5GHz processor, 64 GB memory capacity and a capacity of 4*146GB SAS.
Computer Nodes: All the 20 compute nodes are having Quad core and Quad socket AMD Opteron 8360SE, 2.5GHz processor, 64 GB memory capacity and Hard disc capacity of 2*73GB SAS.

The Master node and all Compute nodes are installed with Red Hat Linux Enterprise Linux 5.1(2.6.18-53.e15) as operating System with Rock 5.1 as cluster management Tool.

Storage Node: It is having Quad core Dual Socket Socket Xeon E5420, 2.5 GHz processor, 8GB RAM, 4*72GB10K SAS.

Backup Node: It is having Quad core Dual Socket Xenon E5420, 2.5 GHz processor, 8GB RAM, 2*120GB SATA.

Disk Array: The EVA 4400 Disk Array is having 4 Disk Enclosures, 42*422GB 10K RPM FC Disks, total capacity of 16 TB (approx.) and a usable storage of 10TB.

IPMI Management Node: Quad Core Dual Socket AMD Opteron2360, 2.5GHz processor, 4GB RAM, 2*160GB SATA.

Software used on PRL HPC Cluster: Intel C,C++,Fortran, GNU C,C++,Fortran, Parallel Compiler Suites-INTEL MPI and OpenMP Compilers, Intel Profiler and Analyzer and Intel Debugger Suite, Torque Scheduler Suite.

Nodes and functions of each node is described as below:

Table 2: Cluster Nodes and Functionalities

Cluster Nodes	Functions
Master Node	The head node provides the interface of the cluster to the outside world.
Compute Node	Compute nodes are dedicated servers with very limited storage or no storage at all, which constitute the processing power of the cluster. Compute nodes are connected using dedicated interconnect fabric.
Interconnect Fabric	Multiple interconnects are user within a single cluster for faster data messages.

Management Node	It has the capability of providing critical control of other nodes of the cluster even if the building network is down. This includes the ability to get to the system console and ability to monitor the software & hardware of other nodes and also ability to power-cycle any node on need basis.
Storage Node	If the applications being run on the cluster requirement any significant amount of storage, a storage node is deployed. Usage storage area of 10TB.
Backup Node	It controls the functioning of Tap-drive and helps to take back up of user data. Its privacy is defined to take back up every day.
I/O Node	The I/O node is used to present the GFS file system on storage to master node and all compute node.

V. APPLICATIONS OF HPC CLUSTER

Computation has become a vital tool for scientific discovery. In many cases computational needs of researchers go far beyond individual workstation and require use of computing clusters. As big organizations have their own data center environment at their places for optimizing huge amount of data very efficiently. HPC allows scientists and engineers to solve complex science, engineering and business problems using applications that require high bandwidth, low latency networking, and very high compute capabilities. Typically, scientists and engineers must wait in long queues to access shared clusters or acquire expensive hardware systems. One of the major use of PRL HPC cluster is in measuring the weather research forecasting based on different parameters. Following Table 3 gives the measurement of different altitude data (in kilometers), temperature (in kelvin) and winds (in Meters per second), was generated by MOZART (**M**odel for **OZ**one **A**nd **R**elated chemical **T**races) atmospheric Model, run on the **PRL HPC cluster**.

Table 3: Altitude, temperature and winds generated by MOZART atmospheric model

Altitude(km)	Temperature(k)	Horizontal Winds(m/s)
43.0699	255.1007	26.19989
33.4855	228.4294	16.29984
29.1675	218.5481	2.780971
25.8731	212.3895	-1.913238
23.1667	207.1654	1.628327
20.7872	199.5837	4.486693
18.6162	193.6028	9.063416
16.6292	198.2838	17.25228
14.7799	207.5007	24.70785
13.0522	215.5014	26.9028
11.4363	222.0745	23.91656
9.93862	230.4629	20.3398
8.55197	241.03	17.34932
7.28579	250.813	13.81462
6.13750	258.9465	10.01796
5.11281	266.1564	6.384558
4.20982	272.9035	3.74246
3.42511	278.7509	1.927115
2.75244	281.8031	0.63262
2.18408	285.6081	0.493586
1.71026	289.6311	0.4411036
1.31852	293.3985	0.4560454
0.999240	296.4246	0.4855037
0.740056	298.9154	0.6478788
0.532072	300.2106	0.9241192
0.365196	301.1447	1.450481
0.233071	300.9193	2.005145
0.138268	300.6815	1.874966

VI. CONCLUSION

In this paper, a survey is given the details of parallel processing which is used in HPC cluster computing. As clustering is one of the data mining technique by which we can utilize the memory and processing power of systems. The information and architectures given in this survey will be helpful to the researchers for Physics, Space & Atmospheric Sciences, Astronomy, Astrophysics & Solar Physics, and Planetary & Geosciences. The survey mainly focuses the need of HPC clustering for improving the processing of the cluster based applications. This paper also focuses on the architecture of

HPC cluster used at PRL for weather predictions.

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