3. System Model

The theoretical background of LBA, like goals, taxonomy, components, and basic types of LBAs, the related work done by other researchers, and the research gaps are discussed in the previous chapter. In this chapter, we have stated the scope of our research work and the notations used in the thesis. Further, A hybrid architecture of DS is proposed in the chapter. The detail explanation of the evaluation parameters is given at the end of the chapter, which are going to used in the chapters 5, 6, 7, 8, 9, and 10 for the performance evaluation of the proposed DLBAs.

3.1 Scope of Research Work

The scope of the research work presented in this thesis is limited to the following properties of the DS.

- Users generate job with different resource requirement and submit to a system for execution.

- The study is limited to non-preemptive scheduling as there is no process migration.

- The high capacity of queue size is selected to eliminate the possibility of neglecting the job due to unavailability of free space in the queue.

- The study is limited for the DC in which nodes are grouped into the different clusters.

- The clusters are heterogeneous concerning machines, cost of processing, processing speed, operating system, memory capacity, and I/O capacity.

- The study is limited to a centralized dynamic load balancing approach.

- The study is limited to balancing the computational load (CPU load) among the clusters of DS.
3. System Model

3.2 Notations used in Thesis

The notations used in the thesis are tabulated in Table 3.1. The notations are used in the formulas of the evaluation parameters and the pseudocode of proposed algorithms presented in the chapters 5, 6, 7, and 8.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N$</td>
<td>Total number of nodes in the DS</td>
</tr>
<tr>
<td>$M$</td>
<td>Total number of clusters in the DS</td>
</tr>
<tr>
<td>$J$</td>
<td>Total number of jobs</td>
</tr>
<tr>
<td>$N_i$ where $1 \leq i \leq N$</td>
<td>$i^{th}$ node in the DS</td>
</tr>
<tr>
<td>$L_i$</td>
<td>CPU load of $N_i$ node</td>
</tr>
<tr>
<td>$C_j$ where $1 \leq j \leq M$</td>
<td>$j^{th}$ cluster in the DS</td>
</tr>
<tr>
<td>$k_j$</td>
<td>Size of the cluster $C_j$</td>
</tr>
<tr>
<td>$\bar{C}T_j$</td>
<td>Cluster Threshold value $j^{th}$ cluster</td>
</tr>
<tr>
<td>$ST$</td>
<td>System Threshold value</td>
</tr>
<tr>
<td>$Overloaded_j$</td>
<td>Overloaded status counter of $j^{th}$ cluster</td>
</tr>
<tr>
<td>$Underloaded_j$</td>
<td>Underloaded status counter of $j^{th}$ cluster</td>
</tr>
<tr>
<td>$DayStatus_j$</td>
<td>Per day load status of $j^{th}$ cluster</td>
</tr>
<tr>
<td>$OL$</td>
<td>List of overloaded clusters</td>
</tr>
<tr>
<td>$UL$</td>
<td>List of underloaded clusters</td>
</tr>
<tr>
<td>$ML$</td>
<td>List of midumloaded clusters</td>
</tr>
<tr>
<td>$CU_j$</td>
<td>Cluster Utilization of $j^{th}$ cluster</td>
</tr>
<tr>
<td>$ACU$</td>
<td>Average Cluster Utilization of the DS</td>
</tr>
<tr>
<td>$\lambda_j$</td>
<td>Percent Load Imbalance Metric of $j^{th}$ cluster</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Standard Deviation of the DS</td>
</tr>
<tr>
<td>$L_{j\max}$</td>
<td>Maximum load of $j^{th}$ cluster</td>
</tr>
<tr>
<td>$\bar{L}$</td>
<td>Mean load of all the clusters</td>
</tr>
</tbody>
</table>

3.3 Proposed Architecture of Distributed System

As listed in section 1.4, the first objective of our research work is the proposed hybrid architecture. The primary goal is to overcome the limitations of the centralized and decentralized approaches as mentioned in section 2.3.2. A hybrid DLBA for heterogeneous environments in DS is proposed in the [37, 40], which overcomes the several limitations of centralized and decentralized approaches.

We have considered a heterogeneous system for proposed architecture in which a large number of the geographically dispersed set of nodes are connected as shown in figure 3.1. Each node in the proposed architecture is having a mixture of various
resources containing a processor, memory, and IO devices. Every node is differing concerning processor, memory and IO devices. The total number of nodes in a DS is divided into virtual groups known as a cluster. One node with higher numbers of resources and backup support or group of nodes are selected as system coordinator (SC) in this proposed architecture. The main components of the architecture are users, SC, clusters, cluster coordinator (CC), and nodes.

The SC works as an intermediate between users and clusters. It performs different tasks like observation, selection, scheduling, prediction, and load balancing. The users create jobs and submit to SC for the execution. The SC selects best suitable cluster by location strategy and schedule jobs to the selected cluster. The SC communicates with all CC for job allocation, and cluster load information. The SC observed the load on the different cluster and predicted the future load of the clusters. The prediction helps the SC in the load balancing activity.

In every cluster, one node works as a CC. The CC communicates with all nodes in
the cluster for job allocation and the node’s load information. It periodically collects
the load information of the other nodes in the cluster and computes the average load
of the cluster. This average load data is used to set the status of the cluster for the
particular period. The load status of clusters is categorized as underloaded, medium
loaded, and overloaded. The CC periodically passes the information of the cluster’s
load status to the SC.

The nodes are responsible for executes the job allocated by the CC. The nodes
periodically send the load value to the CC, which required to calculate the cluster load.

3.4 Evaluation Parameters

The evaluation parameters are playing an essential role in the performance measure-
ment and evaluation of proposed DLBAs. The comparative result analysis can be done
by different evaluation parameters. We have selected the evaluation parameters for
DLBAs from the research papers [40, 18].

3.4.1 Cluster Threshold and System Threshold

The primary requirement for balancing the load among the clusters is to identify the
current load on the clusters. The current load on the cluster is calculated by averaging
the current load on every individual node of the cluster. The cluster threshold (CT)
is defined in [40] as an average load of each node of the particular cluster. The CT is
calculated using the following formula.

For cluster $C_j$,

$$CT_j = \frac{\sum_{i=1}^{k_j} L_i}{k_j} \quad \text{Where} \ 1 \leq j \leq M$$

(3.1)

We have define the system threshold (ST) as the average of CT values of all the
clusters in the DS. The ST is calculated using the following formula.

$$ST = \frac{\sum_{i=1}^{M} CT_i}{M}$$

(3.2)
The CT value of each cluster is compared with the ST value once the ST is calculated. The cluster status is defined as overloaded if the CT value of the cluster is more than the ST value otherwise the cluster status is defined as underloaded. The ST and CT values are calculated on an hourly basis for each cluster. The day wise cluster status is defined by the numbers of hours the cluster remains overloaded or underloaded in a day. The details discussion is given in 5.1.1.

We have not used the CT and ST as evaluation perimeters, but

### 3.4.2 Average Cluster Utilization

One of the most important parameters to evaluate the LBA is the average cluster utilization (ACU) of the DS. The proper load balancing mechanism always improves the ACU of the DS. The prerequisite for calculating ACU is to calculate the individual cluster utilization in the DS. The individual cluster utilization and ACU are calculated using the following equations.

For cluster $C_j$,

$$CU_j = \frac{\text{Total Processors in } C_j \times \text{MIPS Rating} \times \text{Job Running Time on } C_j}{\text{Total Processors} \times \text{MIPS Rating} \times \text{Total Execution Time}} \tag{3.3}$$

$$\text{Average Cluster Utilization} = \frac{\sum_{i=1}^{M} CU_i}{M} \tag{3.4}$$

The higher utilization of individual cluster will improve the ACU of the system. The ACU depends upon the computation capabilities of clusters, the numbers of incoming jobs, and most important the proper balancing of load among the clusters. The impact of ACU is positive. The higher value of ACU indicates proper load balancing among the clusters and higher utilization of the clusters. The goal of this research work is to improve the ACU.
3. System Model

3.4.3 Load Imbalance Metric

Load imbalance metrics (LIM) characterize how unevenly work is distributed among the clusters. The LIM ($\lambda$) is the most commonly used parameter to check the level of load imbalance in the DS\[19, 18\]. This metric measures the performance lost due to imbalanced load, the performance that could be reclaimed by balancing the load. LIP measures the harshness of load imbalance in any LBAs. The equation of LIM ($\lambda$) is defined in [18]. The equation of $\lambda$ is as follow.

For cluster $C_j$,

$$\lambda_j = \left( \frac{L_{j_{\text{max}}}}{\bar{L}} - 1 \right) \times 100$$  \hspace{1cm} (3.5)

Where, $L_{j_{\text{max}}}$ is the maximum load on $j^{th}$ cluster and $\bar{L}$ is the mean load of all clusters.

The impact of LIM is positive as well as negative. The higher value of $\lambda$ indicates a higher level of imbalance load among the clusters and vice-versa. The value of $\lambda$ can be positive or negative. The positive value indicates the overutilization of the cluster while the negative value indicates underutilization of the cluster. The zero value of $\lambda$ for all the cluster indicates the ideal situation of any DS regarding load balancing.

The excellent LBA always reduces the range of $\lambda$ values for all the clusters. Hence, the goal of our research work is to minimize the range of $\lambda$ values for the clusters in the system. The focus is given to design DLBA which scales the values of $\lambda$ towards zero for all the clusters.

3.4.4 Standard Deviation

The standard deviation (SD), is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low value of SD indicates that the data points tend to be close to the mean of the set, while a high value of SD indicates that the data points are spread out over a broader range of values.

Here, the low value of SD indicates that the individual cluster’s utilization is near to the ACU, while a high value of SD indicates that the individual cluster’s utilization
is far from the ACU of the system. The equation of standard deviation ($\sigma$) for the DS regarding the load is defined in [18] as,

$$\sigma = \sqrt{\frac{1}{M-1} \sum_{i=1}^{M} (L_i - \bar{L})^2}$$  \hspace{1cm} (3.6)$$

Where, $M$ is the total number of clusters, $L_i$ is the load on the $i^{th}$ cluster, and $\bar{L}$ is the mean load of all the clusters.

The impact of SD is negative. The higher value of $\sigma$ indicates the difference of load among the cluster is high and vice-versa. The zero value of $\sigma$ indicates the ideal situation of any DS regarding load balancing. It means a load of every cluster is the same, which is next to impossible in a heterogeneous environment.

A good LBA always reduces $\sigma$ values for the DS. Hence, the goal of our research work is to minimize the $\sigma$ value of the DS. The focus is given to design DLBA which scales the value of $\sigma$ as much as closer to zero.

### 3.5 Conclusion

In this chapter, we have listed the scope of our research work and discussed the proposed architecture of a DS. Further, the definition, equation, and detail discussion of selected evaluation parameters presented at the end of the chapter. The impact of the parameters and the goal of our research work concerning selected evaluation parameters is also discussed. The goals are to achieve 100% average cluster utilization, zero value for the load imbalance metric for all the clusters, and SD value closer to zero.