1.3.3 Clustered Systems

Another type of multiprocessor system is a clustered system, which gathers multiple CPUs. Clustered systems differ from the multiprocessor systems described in Section 1.3.2 in that they are composed of two or more individual systems—or nodes—joined together; each node is typically a multicore system. Such systems are considered loosely coupled. We should note that the definition of clustered is not concrete; many commercial and opensource packages wrestle to define what a clustered system is and why one form is better than another. The generally accepted definition is that clustered computers share storage and are closely linked via a local-area network LAN (as described in Chapter 19) or a faster interconnect, such as InfiniBand.

1.3.3 Clustered Systems

🔹 **What is a Clustered System?**

A clustered system is a type of multiprocessor system made by joining multiple independent computers (nodes) together.

📌 Each **node**:

- Is a **separate computer**
- Has its **own CPU, memory, OS**
- Is usually **multi-core**

🔹 **Clustered vs Multiprocessor Systems (Key Difference)**

🔸 **Multiprocessor System (1.3.2)**

- One machine
- Multiple CPUs
- Shared memory
- **Tightly coupled**

🔸 **Clustered System (1.3.3)**

- Multiple machines (nodes)
- Each has its own memory
- Connected by network

- **Loosely coupled**

“Such systems are considered loosely coupled.”

🔹 **What Does “Loosely Coupled” Mean?**

- Nodes communicate via **network**
- No shared RAM
- Slower communication than shared memory
- More scalable

🔹 **Shared Storage (Critical Concept)**

“Clustered computers share storage”

Examples:

- SAN (Storage Area Network)
- NAS
- Distributed file systems

📌 Why shared storage?

- All nodes access same data
- Easy failover
- Consistent state

🔹 **Network Interconnect**

“Closely linked via a LAN or faster interconnect such as InfiniBand”

Common Interconnects:

- Ethernet (LAN)
- InfiniBand (very fast, low latency)

📌 Faster network = better cluster performance.

◆ **Why Definition of Cluster is "Not Concrete"**

"The definition of clustered is not concrete"

Because clusters can be built in many ways:

- High-availability clusters
- Load-balancing clusters
- Compute clusters
- Storage clusters

Different goals, different designs.

◆ **Types of Clustered Systems**

High Availability (HA) Clusters

- If one node fails → another takes over
- Used in banks, hospitals

Load-Balancing Clusters

- Distribute workload
- Web servers, cloud services

Compute Clusters

- High-performance computing
- Scientific simulations, ML

◆ **Advantages of Clustered Systems**

High availability
Scalability
Fault tolerance
Cost-effective (commodity hardware)

◆ **Disadvantages**

Network latency
Complex management
Synchronization challenges

◆ Real-World Examples

- Google data centers
- AWS / Azure backend
- Kubernetes clusters
- Hadoop / Spark clusters

◆ FAANG Interview One-Liner

A clustered system consists of multiple independent nodes connected via a high-speed network and shared storage, forming a loosely coupled system designed for scalability, fault tolerance, and high availability.

◆ Exam-Ready Short Answer

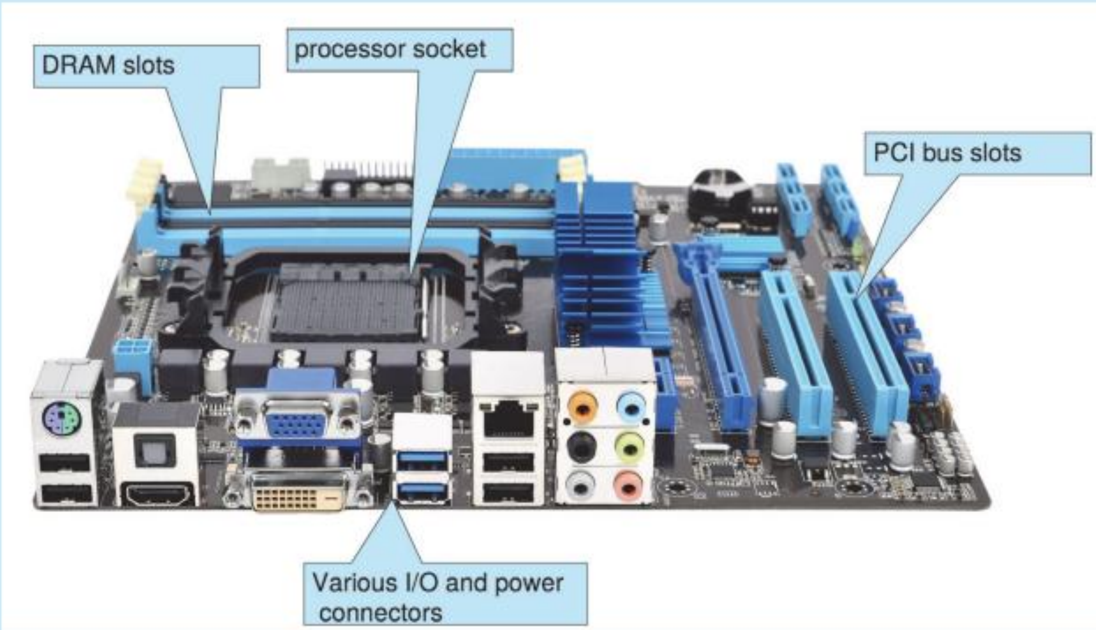
Clustered systems are composed of two or more independent systems connected by a LAN or fast interconnect, sharing storage and working together as a single system while remaining loosely coupled.

Clustering is usually used to provide high-availability service— that is, service that will continue even if one or more systems in the cluster fail. Generally, we obtain high availability by adding a level of redundancy in the system. A layer of cluster software runs on the cluster nodes. Each node can monitor one or more of the others (over the network). If the monitored machine fails, the monitoring machine can take ownership of its storage and restart the applications that were running on the failed machine. The users and clients of the applications see only a brief interruption of service.

Chapter 1 Introduction

PC MOTHERBOARD

Consider the desktop PC motherboard with a processor socket shown below:



This board is a fully functioning computer, once its slots are populated. It consists of a processor socket containing a CPU, DRAM sockets, PCIe bus slots, and I/O connectors of various types. Even the lowest-cost general-purpose CPU contains multiple cores. Some motherboards contain multiple processor sockets. More advanced computers allow more than one system board, creating NUMA systems.

In symmetric clustering, two or more hosts are running applications and are monitoring each other. This structure is obviously more efficient, as it uses all of the available hardware. However, it does require that more than one application be available to run.

The application must have been written specifically to take advantage of the cluster, however. This involves a technique known as parallelization, which divides a program into separate components that run in parallel on individual cores in a computer or computers in a cluster. Typically, these applications are designed so that once each computing node in the cluster has solved its portion of the problem, the results from all the nodes are combined into a final solution.

Other forms of clusters include parallel clusters and clustering over a wide-area network (WAN) (as described in Chapter 19). Parallel clusters allow multiple hosts to access the same data on shared storage. Because most operating systems lack support for simultaneous data access by multiple hosts, parallel clusters usually require the use of special versions of software and special releases of applications. For example, Oracle Real Application Cluster is a version of Oracle's database that has been designed to run on a parallel cluster. Each machine runs Oracle, and a layer of software tracks access to the shared disk. Each machine has full access to all data in the database. To provide this shared access, the system must also supply access control and locking to ensure that no conflicting operations occur. This function, commonly known as a distributed lock manager (DLM), is included in some cluster technology.

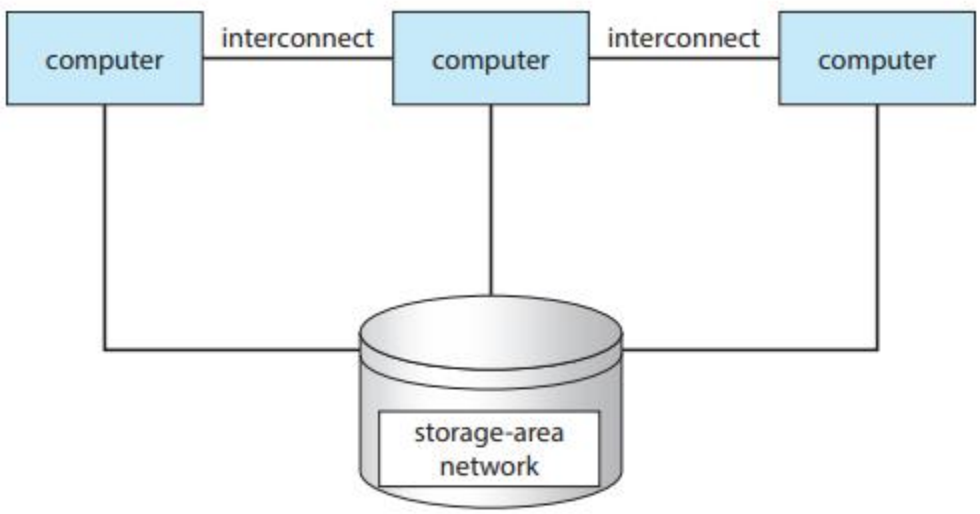


Figure 1.11 General structure of a clustered system.

Some cluster products support thousands of systems in a cluster, as well as clustered nodes that are separated by miles. Many of these improvements are made possible by storage-area networks (SANs), as described in Section 11.7.4, which allow many systems to attach to a pool of storage. If the applications and their data are stored on the SAN, then the cluster software can assign the application to run on any host that is attached to the SAN. If the host fails, then any other host can take over. In a database cluster, dozens of hosts can share the same database, greatly increasing performance and reliability. Figure 1.11 depicts the general structure of a clustered system