1. What is a Distributed System ??

A distributed system is A collection of independent computers that appears to its users as a single coherent system.

Distributed computing is a field of computer science that studies distributed systems. A **distributed system** consists of multiple autonomous computers that communicate through a computer network. The computers interact with each other in order to achieve a common goal. A computer program that runs in a distributed system is called a **distributed program**, and **distributed programming** is the process of writing such programs.

Distributed computing also refers to the use of distributed systems to solve computational problems. In distributed computing, a problem is divided into many tasks, each of which is solved by one or more computers.

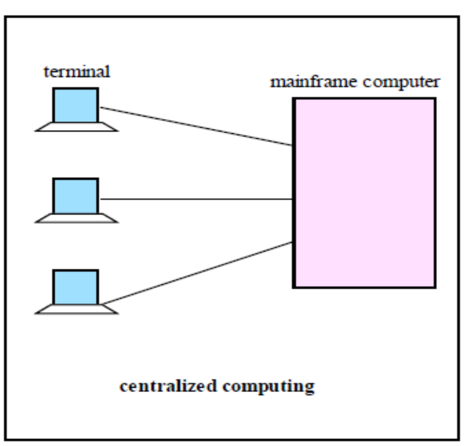
A *distributed system* is a collection of independent computers, interconnected via a network, capable of collaborating on a task.

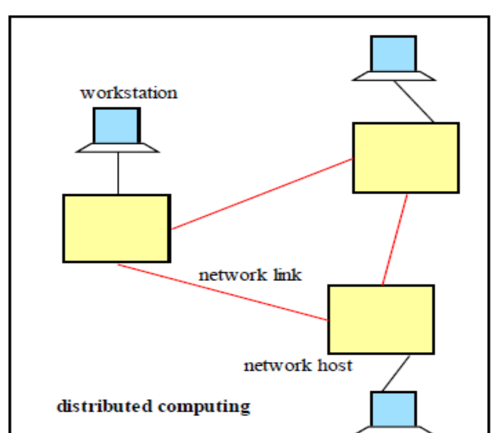
Distributed computing is computing performed in a distributed system. Distributed computing has become increasingly common due advances that have made both machines and networks cheaper and faster.

Some examples of distributed systems :

- ♦ Local Area Network and Intranet
- ♦ Database Management System
- ♦ Automatic Teller Machine Network
- ♦ Internet/World-Wide Web
- ♦ Mobile and Ubiquitous Computing

2. Centralized vs. Distributed Computing





Centralized System Characteristics

- One component with non-autonomous parts
- Component shared by users all the time
- All resources accessible
- Software runs in a single process
- Single point of control
- Single point of failure

Distributed System Characteristics

- Multiple autonomous components
- Components are not shared by all users
- Resources may not be accessible
- Software runs in concurrent processes on
- different processors
- Multiple points of control
- Multiple points of failure

3. Advantages of Distributed Systems over Centralized System

- **Economics**: a collection of microprocessors offer a better price/performance than mainframes. Low price/performance ratio: cost effective way to increase computing power.
- **Speed**: a distributed system may have more total computing power than a mainframe.
- Inherent distribution: Some applications are inherently distributed. Ex. a supermarket chain.
- **Reliability**: If one machine crashes, the system as a whole can still survive. Higher availability and improved reliability.
- **Incremental growth**: Computing power can be added in small increments. Modular expandability
- **Another deriving force**: the existence of large number of personal computers, the need for people to collaborate and share information.

4. Advantages of Distributed Systems over Independent PCs

- Data sharing: allow many users to access to a common data base
- Resource Sharing: expensive peripherals like color printers
- Communication: enhance human-to-human communication, e.g., email, chat
- Flexibility: spread the workload over the available machines

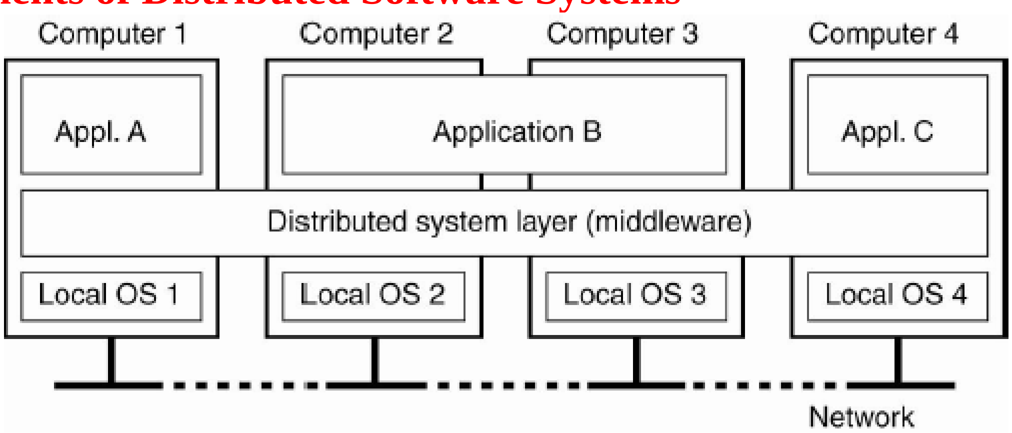
5. Design Issues of Distributed Systems

- Transparency
- Flexibility
- Reliability
- Performance
- Scalability

6. Basics of Distributed Systems:

- Networked computers (close or loosely coupled) that provide a degree of operation transparency.
- Distributed Computer System = independent processors + networking infrastructure
- Communication between processes (on the same or different computer) using message passing technologies is the basis of distributed computing.

7. Components of Distributed Software Systems



• Distributed systems
• Middleware
• Distributed applications

8. Goals of Distributed Systems:

8.1 Resource sharing: easy for users to access remote resources.
8.2 Transparency: to hide the fact that processes and resources are physically distributed across multiple computers.
8.3 Openness: to offer services according to standard rules.
8.4 Scalability: easy to expand and manage.
8.5 Heterogeneity : Variety and differences in
– Networks
– Computer hardware
– Operating systems
– Programming languages
– Implementations by different developers

8.6 Concurrency Components in distributed systems are executed in concurrent processes, Components access and update shared resources (e.g. variables, databases, device drivers).

8.7 Transparency : Distributed systems should be perceived by users and application programmers as a whole rather than as a collection of cooperating components.

8.1 Make Resources Accessible:

Access resources and share them in a controlled and efficient way. Printers, computers, storage facilities, data, files, Web pages, and networks, …

8.2 Distribution Transparency

Transparency	Description
Access	Hide differences in data representation and how a resource is accessed
Location	Hide where a resource is located
Migration	Hide that a resource may move to another location
Relocation	Hide that a resource may be moved to another location while in use
Replication	Hide that a resource is replicated
Concurrency	Hide that a resource may be shared by several competitive users
Failure	Hide the failure and recovery of a resource

8.3 Openness

Goal: Open distributed system -- able to interact with services from other open systems, irrespective of the underlying environment:

• Standard rules (protocols/interfaces) to describe services/components

• Flexibility – ability to integrate multiple components

• Achieving openness**:** At least make the distributed system independent from heterogeneity of the underlying environment:

– Hardware

– Platforms

– Languages

8.4 scalable

Distributed system operate effectively and efficiently at many different scales, ranging from a small intranet to the internet. A system is described as scalable if will remain effective when there is a significant increase in the number of resources and the number of users.

9. User Requirements :

• What services the system can provide?

• How easy to use and manage the system?

• What benefits the system can offer?

- What is the ratio of performance/cost?
- How reliable the system is?
- How secure the system can guarantee?

10. Types of Distributed Systems

10. 1 Distributed Computing Systems

Many distributed systems are configured for **High-Performance Computing Cluster Computing:** Essentially a group of high-end systems connected through a LAN:

10.2 Distributed Information Systems

The vast amount of distributed systems in use today are forms of traditional information systems, that now integrate legacy systems. **Example:** Transaction processing systems.

10.3 Distributed Pervasive Systems

There is a next-generation of distributed systems emerging in which the nodes are small, mobile, and often embedded as part of a larger system.

11. Criterion of Distributed Computer System (Metrics)

- **Latency** – network delay before any data is sent
- **Bandwidth** – maximum channel capacity (analogue communication Hz, digital communication bps)
- **Granularity** – relative size of units of processing required. Distributed systems operate best with coarse grain granularity because of the slow communication compared to processing speed in general
- **Processor speed**
- **Reliability** – ability to continue operating correctly for a given time
- **Fault tolerance** – resilience to partial system failure
- **Security** – policy to deal with threats to the communication or processing of data in a system
- **Administrative/management** domains – issues concerning the ownership and access to distributed systems components

12. Communication Hardware Characteristics: Circuit vs. Packet Switching

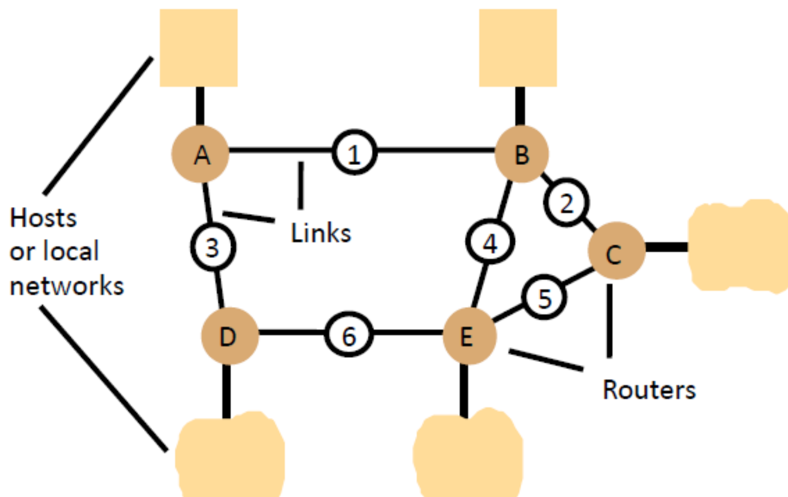
- **Circuit switching**
  - –Example: telephony
  - –Resources are reserved and dedicated during the connection
  - –Fixed path between peers for the duration of the connection
- **Packet switching**

–Example: internet

–Entering data (variable-length messages) are divided into (fixed-length) packets

–Packets in network share resources and may take different paths to the destination

Routing in a wide area network



Routing Table of the network

Routings from A		
To	*Link*	*Cost*
A	local	0
B	1	1
C	1	2
D	3	1
E	1	2

Routings from B		
To	*Link*	*Cost*
A	1	1
B	local	0
C	2	1
D	1	2
E	4	1

Routings from C		
To	*Link*	*Cost*
A	2	2
B	2	1
C	local	0
D	5	2
E	5	1

Routings from D		
To	*Link*	*Cost*
A	3	1
B	3	2
C	6	2
D	local	0
E	6	1

Routings from E		
To	*Link*	*Cost*
A	4	2
B	4	1
C	5	1
D	6	1
E	local	0

13. System Architectures

The architecture include:

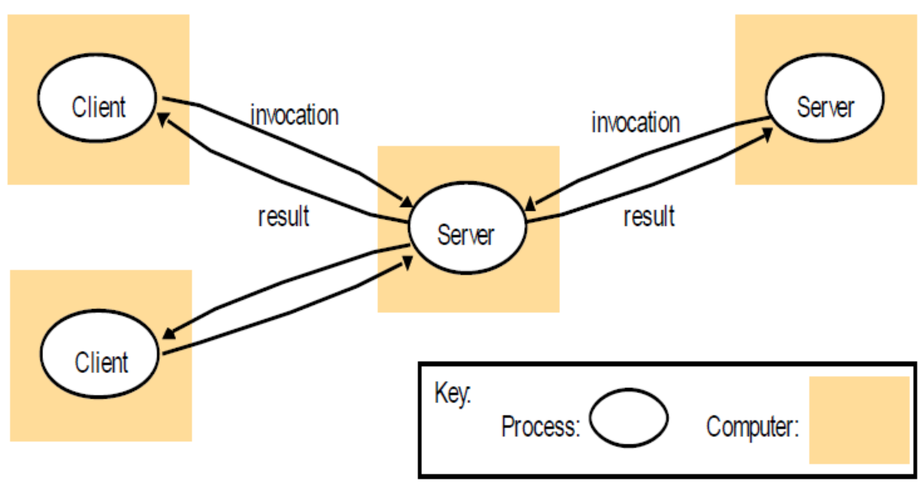
–The division of responsibilities between system components.

–The placement of the components on computers in the network.

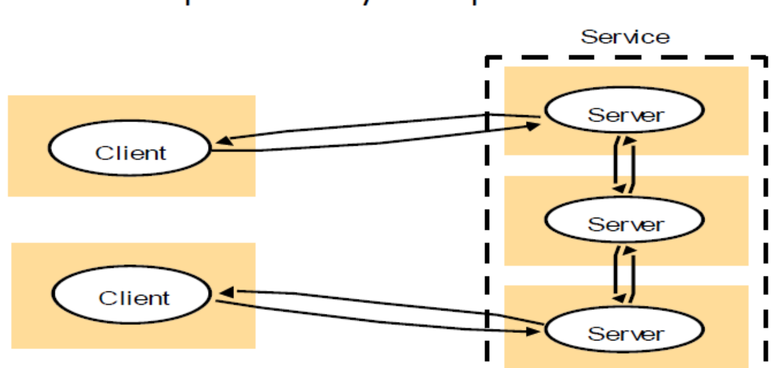
- **Client-server model:**

  - Most important and most widely distributed system architecture.
  - Client and server roles are assigned and changeable.
  - Servers may in turn be clients of other servers.
  - Services may be implemented as several interacting processes in different host computers to provide a service to client processes:
  - Servers partition the set of objects on which the service is based and distribute them among themselves (e.g. Web data and web servers)

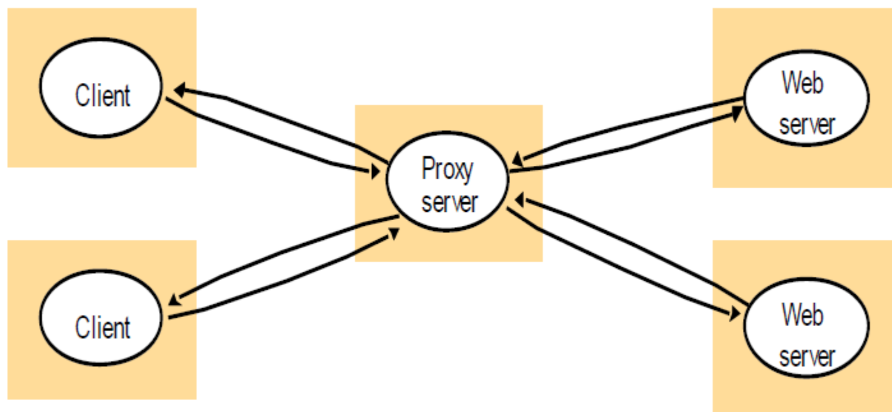
- Clients invoke individual servers



- A service provided by multiple servers



- **Web proxy server**
  - Provides a shared cache of web resources for client machines at a site or across several sites.
  - Increase availability and performance of a service by reducing load on the WAN and web servers.



- **Peer processes Model**
  - All processes play similar roles without destination as a client or a server.
  - Interacting cooperatively to perform a distributed activity.
  - Communications pattern will depend on application requirements.

A distributed application based on peer processes