Communication: Distributed System

Building A Distributed System

- Two questions:

1. Where to place the hardware?
2. Where to place the software?

Architecture

- The software architecture of distributed systems deals with how software components are organized and how they work together, i.e., communicate with each other.
- Typical software architectures include the layered, object-oriented, data-centred, and event-based architectures.

Logical organization of software components:

- Layered
- Object-oriented
- Data-centered
- Event-based

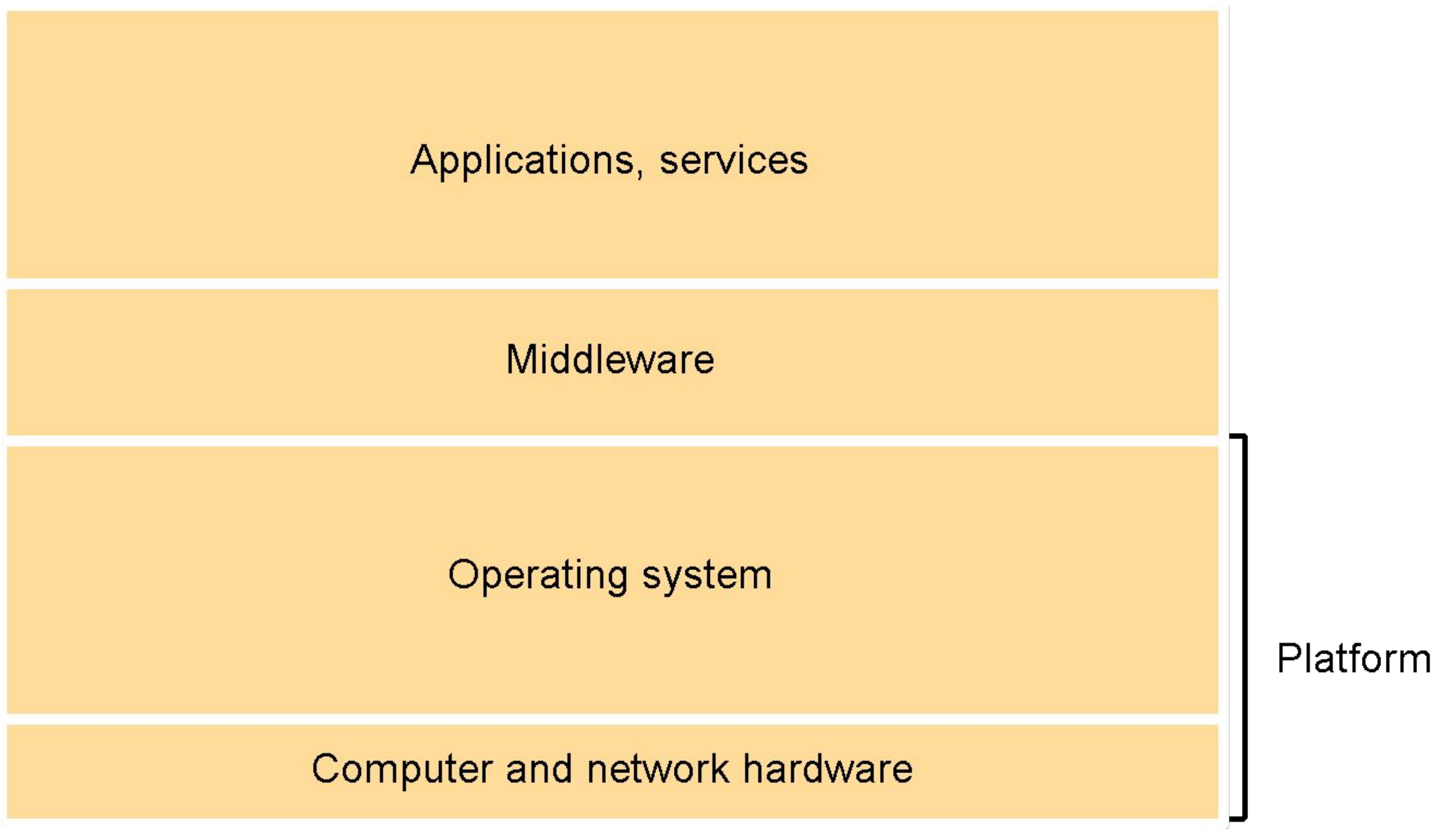
System Architecture:

- placement of machines
- placement of software on machines

There is no single best architecture:

- The best architecture for a particular system depends on the application requirements and the environment.

Layers in Distributed Systems



- The key difference between a distributed system and a uniprocessor system is the interprocess communication.
- In a uniprocessor system, interprocess communication assumes the existence of shared memory.
- A typical example is the producer-consumer problem.

- One process writes to -□ buffer -□reads from another process
- The most basic form of synchronization, the semaphore requires one word (the semaphore variable) to be shared.

- In a distributed system, there’s no shared memory, so the entire nature of interprocess communication must be completely rethought from scratch.
- All communication in distributed system is based on message passing.

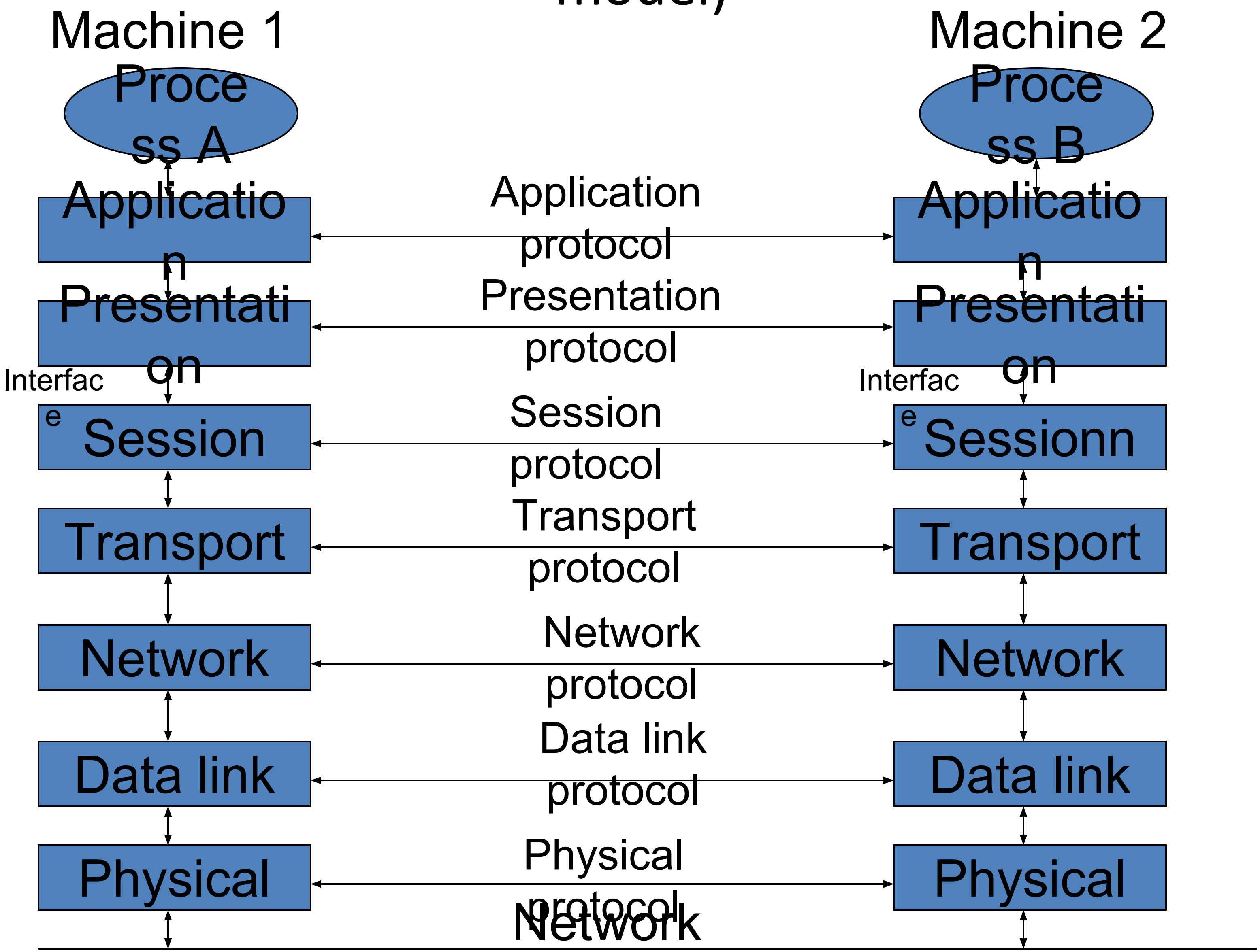
For ex. Process 1 wants to communicate with process 2

1. It first builds a message in its own address space
2. It executes a system call
3. The OS fetches the message and sends it through network to 2.

- 1 and 2 have to agree on the meaning of the bits being sent. For example,

- How many volts should be used to signal a 0-bit? 1-bit?
- How does the receiver know which is the last bit of the message?
- How can it detect if a message has been damaged or lost?
- What should it do if it finds out?
- How long are numbers, strings, and other data items? And how are they represented?

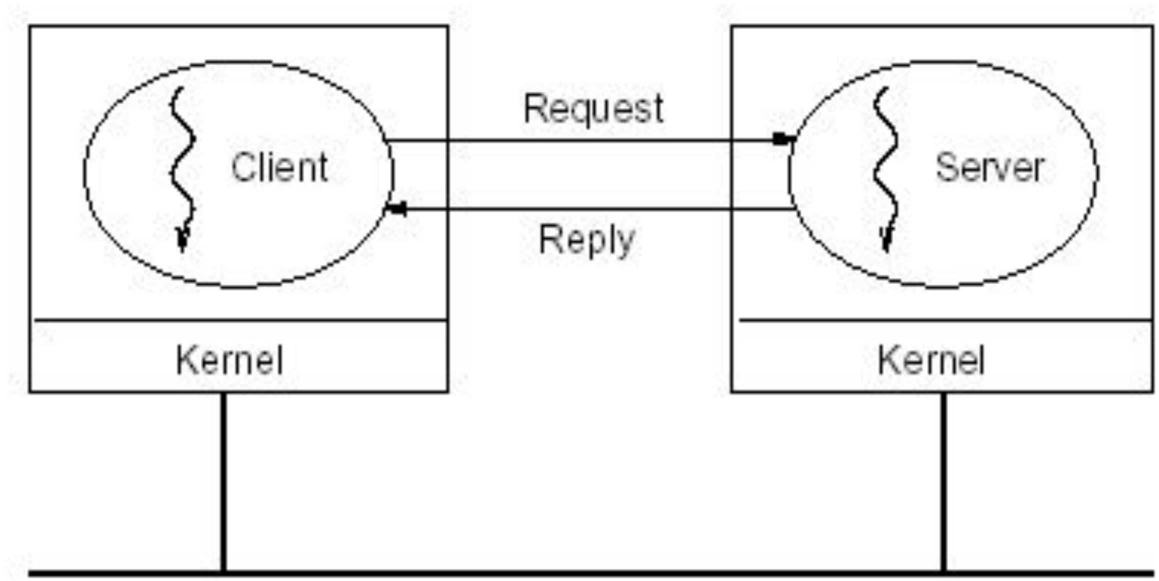
OSI (Open System Interconnection Reference model)



Client-Server Model Layer

7	
6	
5	Request/Reply
4	
3	
2	Data link
1	Physical

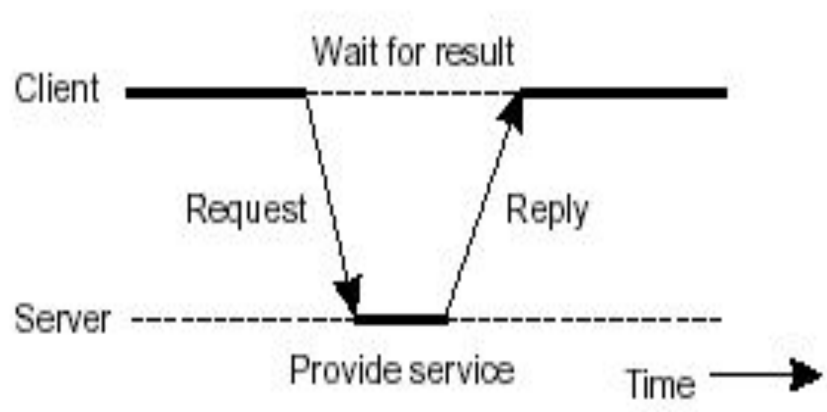
Client-Server



Client-Server from another perspective

A typical client-server application can be decomposed into three logical parts: the interface part, the application logic part, and the data part.

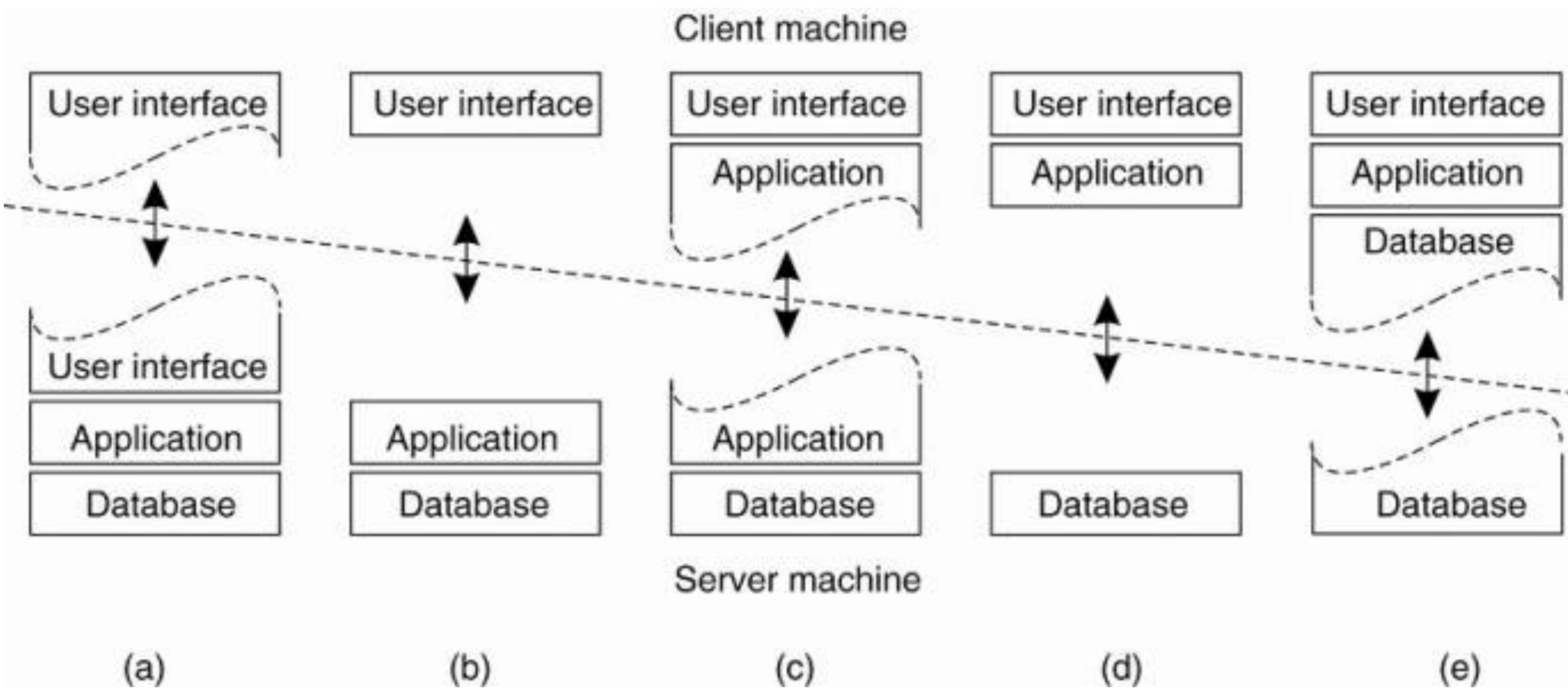
Implementation of the client-server architecture vary with regards to how the parts are separated over the client and server roles.



Advantages

- Simplicity: The client sends a request and gets an answer. No connection has to be established.
- Efficiency: just 3 layers. Getting packets from client to server and back is handled by 1 and 2 by hardware: an Ethernet or Token ring. No routing is needed and no connections are established, so layers 3 and 4 are not needed. Layer 5 defines the set of legal requests and replies to these requests.
- two system calls: send (dest, &mptr), receive (addr, &mptr)

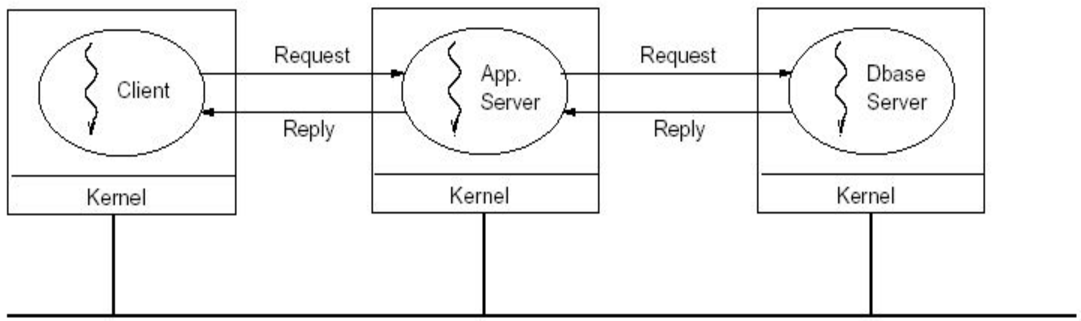
Alternative Client-Server Architectures



Vertical Distribution (Multi-Tier)

• Splitting up a server's functionality over multiple computers

•An extension of the client-server architecture, the vertical distribution, or multi-tier, architecture distributes the traditional server functionality over multiple servers. A client request is sent to the first server.



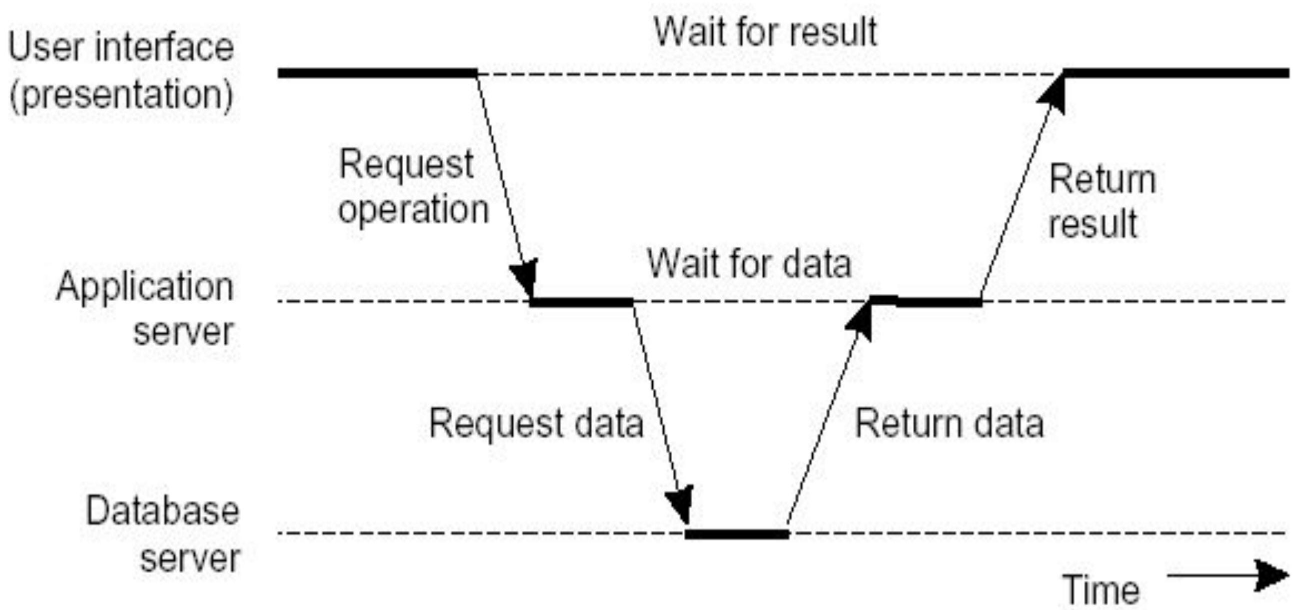
<u>Three layers' of functionality:</u>

- User interface
- Processing/Application logic
- Data

- Splitting up the server functionality in this way is beneficial to a system's scalability as well as its flexibility.
- Scalability is improved because the processing load on each individual server is reduced, and the whole system can therefore accommodate more users.

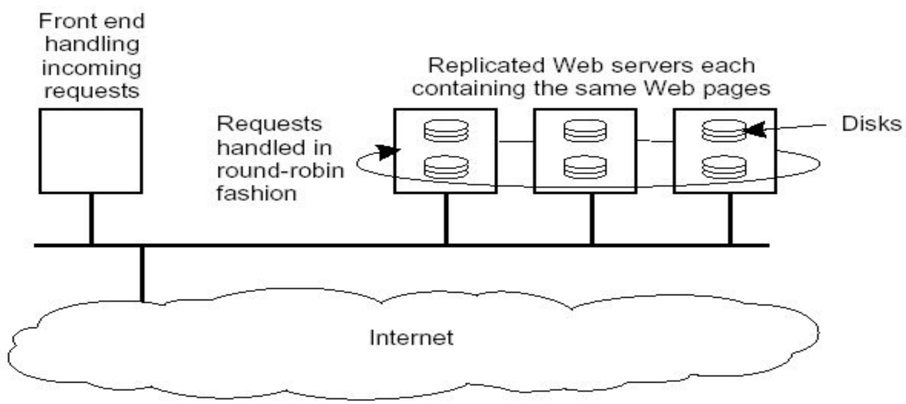
Logically different components on different machines

Vertical Distribution from another perspective

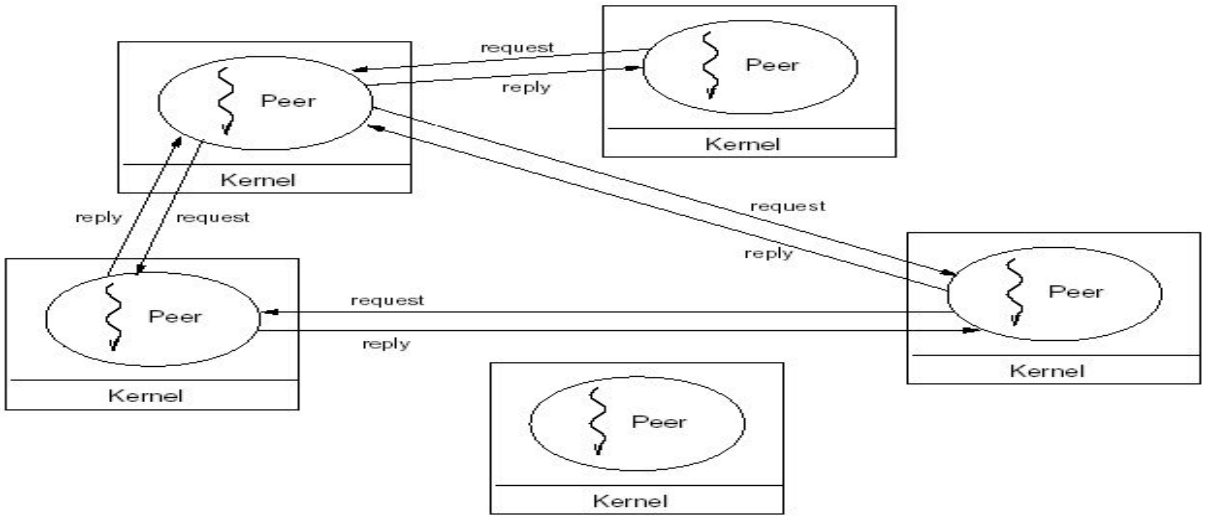


Horizontal Distribution

- Replicating a server's functionality over multiple computers
- In this case each server machine contains a complete copy of all hosted Web pages and client requests are passed on to the servers in a round robin fashion.
- The horizontal distribution architecture is generally used to improve scalability (by reducing the load on individual servers) and reliability (by providing redundancy).
- Logically equivalent components replicated on different machines.



Peer To Peer Communication Architecture

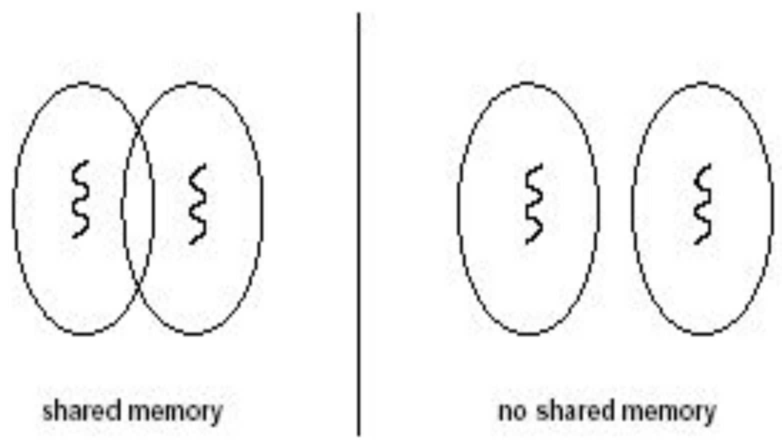


- All p
- With ... eer to peer ... keep track ... ffer.

Processes and Threads

- **Process:** Single thread of control per address space
- **Thread:** Multiple threads of control per address space

<u>Memory access:</u>



Stateful Vs Stateless Servers

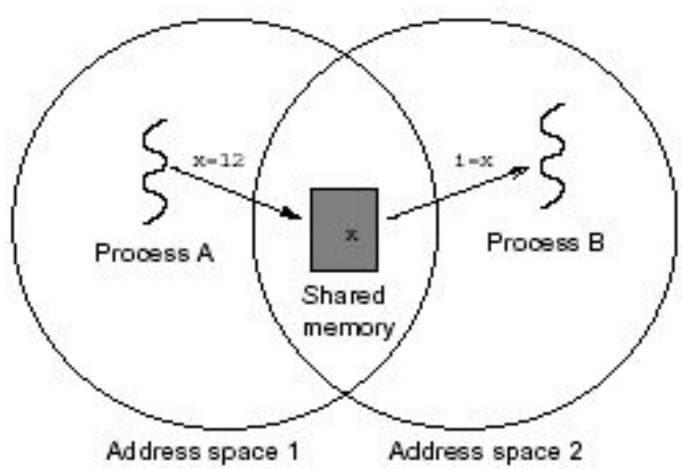
- Stateful:
  - Keeps persistent information about clients
  - Improved performance
  - Expensive recovery
  - Must track clients
- Stateless:
  - Does not keep state of clients
  - soft state design: limited client state
  - Can change own state without informing clients
  - Increased communication

Communication: Non distributed system

- Cooperating processes need to communicate:
  - For synchronization and control (Processes synchronize in order to coordinate their activities)
  - To share data (Processes share data about tasks that they are cooperatively working on)

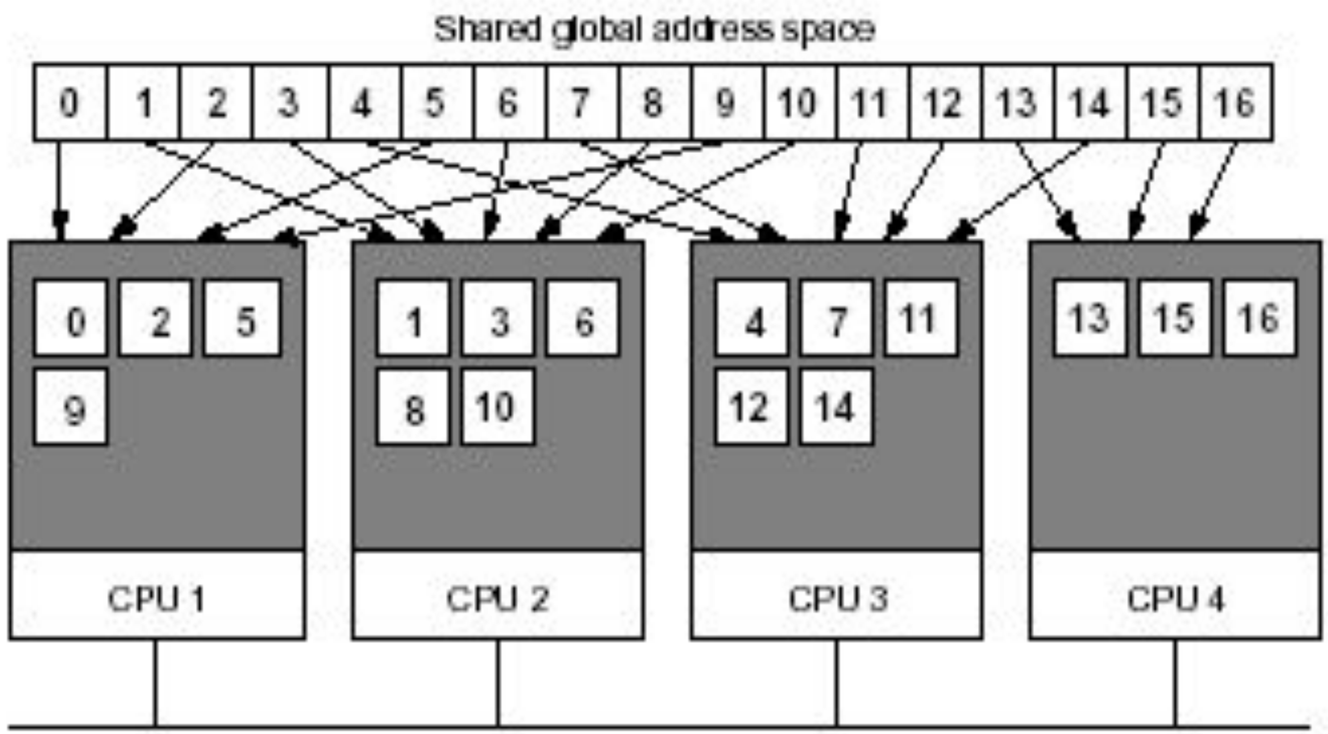
- Two approaches to communication:
  - **Shared memory-**processes must have access to some form of shared memory (i.e. they must be threads, they must be processes that can share memory, or they must have access to a shared resource, such as a file)
  - **Message passing-** OS’s IPC mechanisms

Communication: Distributed System

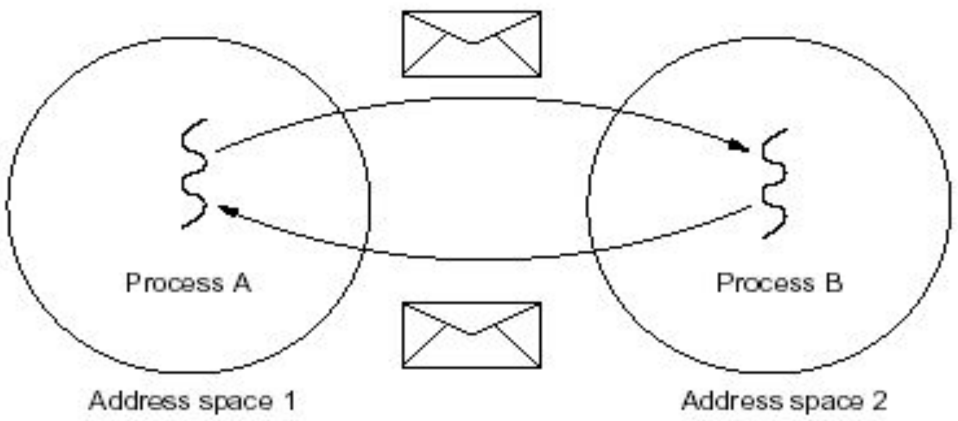


- Shared Me
  - There is no wa
  - Distributed Shared Memory

Distributed Shared Memory (DSM)



Message Passing



- **Message Pa**
- Over the netw
- Introduces lat
- Introduces higher chances of failure
- Heterogeneity introduces possible incompatibilities

Coupling

- Dependency between sender and receiver

- Temporal: do sender and receiver have to be active at the same time?
- Spatial: do sender and receiver have to know about each other? Explicitly address each other?
- Semantic: do sender and receiver have to share knowledge of content syntax and semantics?
- Platform: do sender and receiver have to use the same platform?

- Tight Vs loose coupling: yes Vs no

Message Passing

- **Basics**
- Send()
- Receive()
- **Variations:**
- Connection oriented Vs Connectionless
- Point-to-point Vs Group
- Synchronous Vs Asynchronous
- Buffered Vs Unbuffered
- Reliable Vs Unreliable
- Message ordering guarantees
- **Data Representation:**
- Marshalling
- Endianness

Desirable features of a good message-passing system

- Simplicity
- Uniform semantics
- Efficiency
- Reliability
- Correctness
- Flexibility
- Security
- portability

Communication Modes

- Synchronous Vs asynchronous communication
- Data oriented Vs control oriented communication
- Transient Vs persistent communication
- Provider-Initiated Vs Consumer-Initiated Communication
- Direct-Addressing Vs Indirect-Addressing Communication

Synchronous Communication

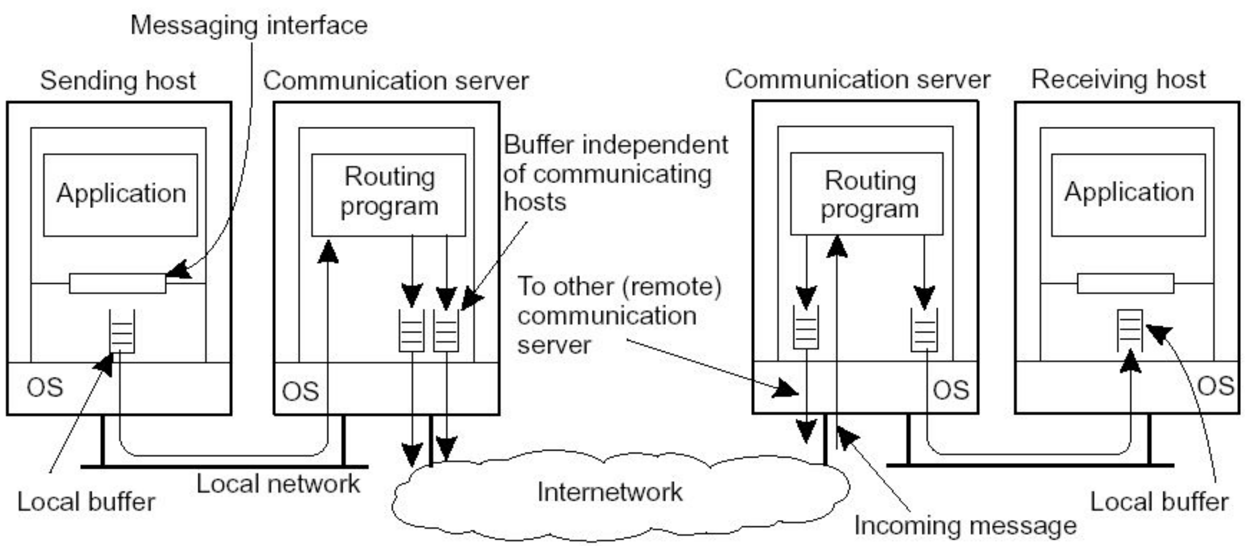
- Client/Server computing is generally based on a model of **synchronous communication**
- Client and server have to be active at the time of communication
- Client issues request and blocks until it receives reply
- Server essentially waits only for incoming requests, and subsequently processes them

Drawbacks of synchronous communication:

- Client cannot do any other work while waiting for reply
- Failures have to be dealt with immediately (the client is waiting)
- In many cases the model is simply not appropriate (mail, news)

Asynchronous Communication

- Sender continues execution after sending message (does not block waiting for reply)
- Message may be queued if receiver not active
- Message may be processed later at receiver's convenience



Data-Oriented Vs Control-Oriented Communication

- **Data-oriented communication**
  - Facilitates data exchange between threads
  - Shared address space, shared memory & message passing
- **Control-oriented communication**
  - Associates a transfer of control with every data transfer
  - remote procedure call (RPC) & remote method invocation (RMI)

- Hardware and OSes often provide data-oriented communication
- Higher-level infrastructure often provides control-oriented communication -- middleware

Transient vs Persistent Communication

 Transient:

- Message discarded if cannot be delivered to receiver immediately
- Example: HTTP request

 Persistent

- Message stored (somewhere) until receiver can accept it
- Example: email

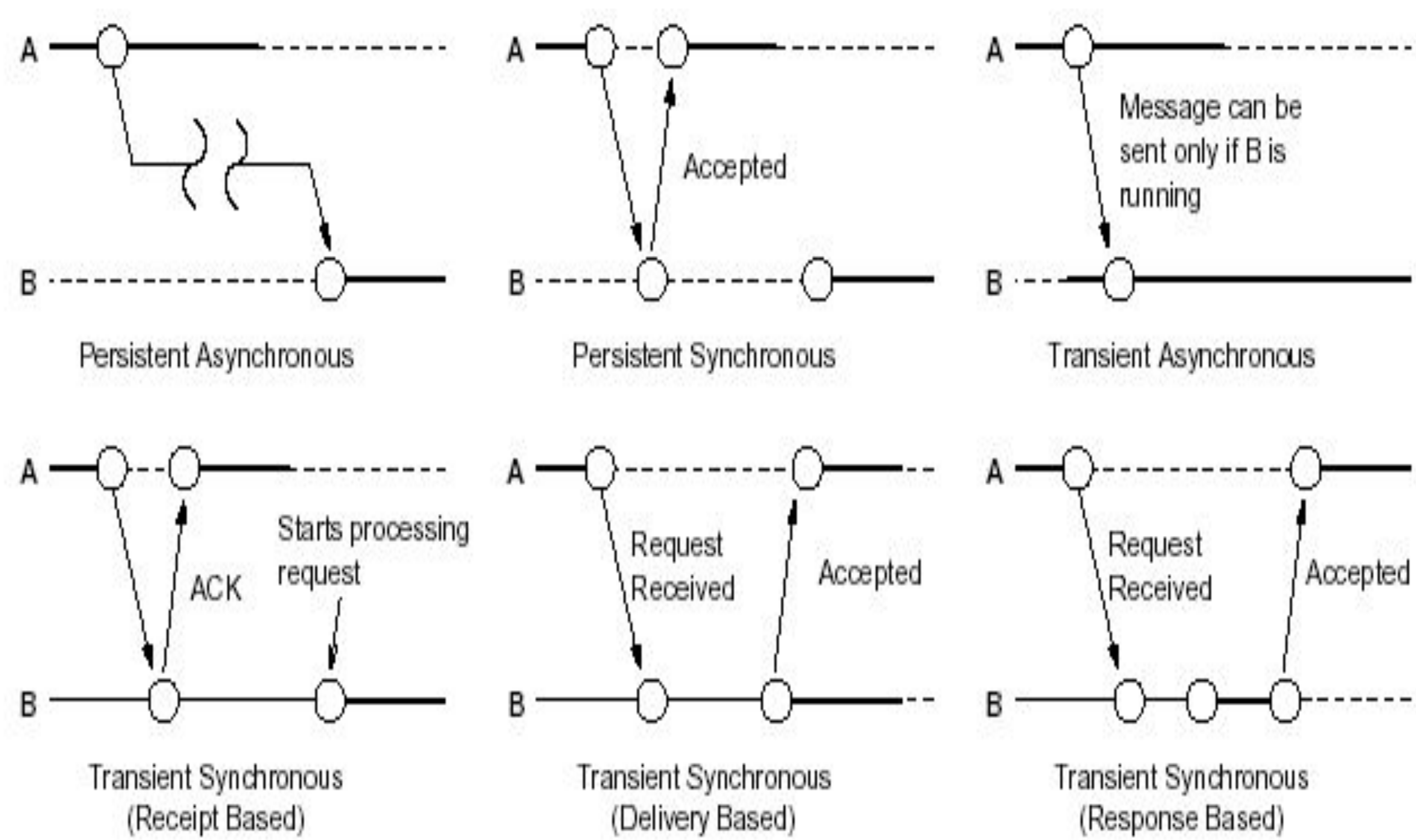
Provider-Initiated Vs Consumer-Initiated Communication

- Provider-Initiated
- Message sent when data is available
- Example: notifications
- Consumer-Initiated
- Request sent for data
- Example: HTTP request

Direct-Addressing Vs Indirect-Addressing Communication

- Direct-Addressing
- Message sent directly to receiver
- Example: HTTP request
- Indirect-Addressing
- Message not sent to a particular receiver
- Example: broadcast, publish/subscribe

Messaging Combinations



Communication Abstractions

- Number of communication abstractions that make writing distributed applications easier.

Provided by higher level APIs:

- Remote Procedure Call (RPC)
- Remote Method Invocation (RMI)
- Message-Oriented Communication
- Group Communication
- Streams

Remote Procedure Call (RPC)

- Replace message passing model by execution of a procedure call on a remote node.

- Synchronous - based on blocking messages
- Asynchronous - when no result to return - adding money, records in db, start remote service, etc.
- Message-passing details hidden from application
- Procedure call parameters used to transmit data
- Client calls local “stub” which does messaging and marshaling

Remote Method Invocation (RMI)

- The transition from Remote Procedure Call (RPC) to Remote Method Invocation (RMI) is a transition from the server metaphor to the object metaphor.

Why is this important?

- Using RPC: programmers must explicitly specify the server on which they want to perform the call.
- Using RMI: programmers invoke methods on remote objects.
- More natural resource management and error handling

Message-oriented Communication

Message-oriented Middleware (MOM)

- Message-oriented communication is provided by message-oriented middleware (MOM).

Middleware support for message passing:-

- Asynchronous or Synchronous communication
- Persistent or Transient messages
- Various combinations of the above

What more does it provide than send()/receive()?

- Persistent communication (Message queues)
- Hides implementation details
- Marshaling (packing of function parameters into a message packet)

Group Communication

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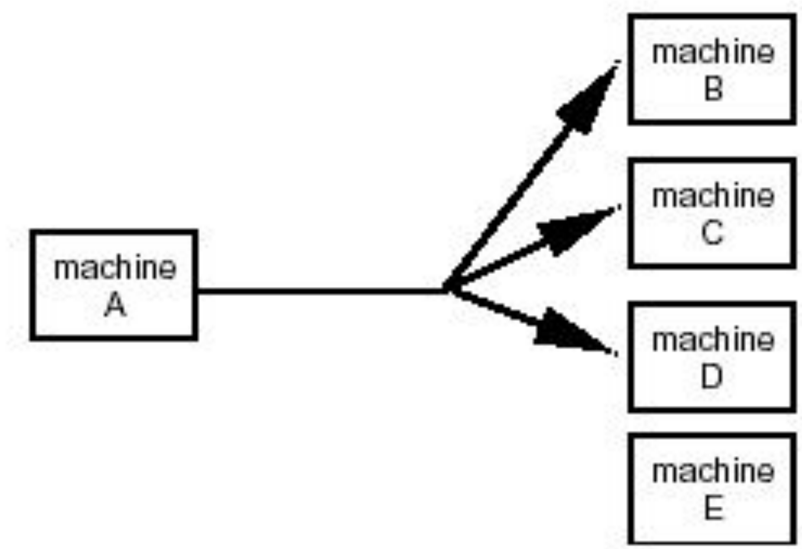


Group Communication

- <u>Two kinds of group communication</u>
  - Broadcast(msg sent to everyone)
  - Multicast(msg sent to specific group)
- <u>Used for</u>
  - Replication of services
  - Replication of data
  - Service discovery
  - Event notification
- <u>Issues</u>
  - Reliability
  - Ordering
- <u>Example</u>: IP multicast

Stream-Oriented Communication

- Support for continuous media
- Streams in distributed systems
- Stream management

Continuous Media

- All communication facilities discussed so far are essentially based on a <u>discrete</u>, that is <u>time independent</u> exchange of information

Continuous media: Characterized by the fact that values are time dependent:

- Audio
- Video
- Animations
- Sensor data (temperature, pressure, etc.)

Transmission modes: Different timing guarantees with respect to data transfer:

- **Asynchronous:** no restrictions with respect to *when* data is to be delivered
- **Synchronous:** define a maximum end-to-end delay for individual data packets
- **Isochronous:** define a maximum and minimum end-to-end delay (**jitter** is bounded)

Stream

- A (continuous) data stream is a connection-oriented communication facility that supports isochronous data transmission

Some common stream characteristics:

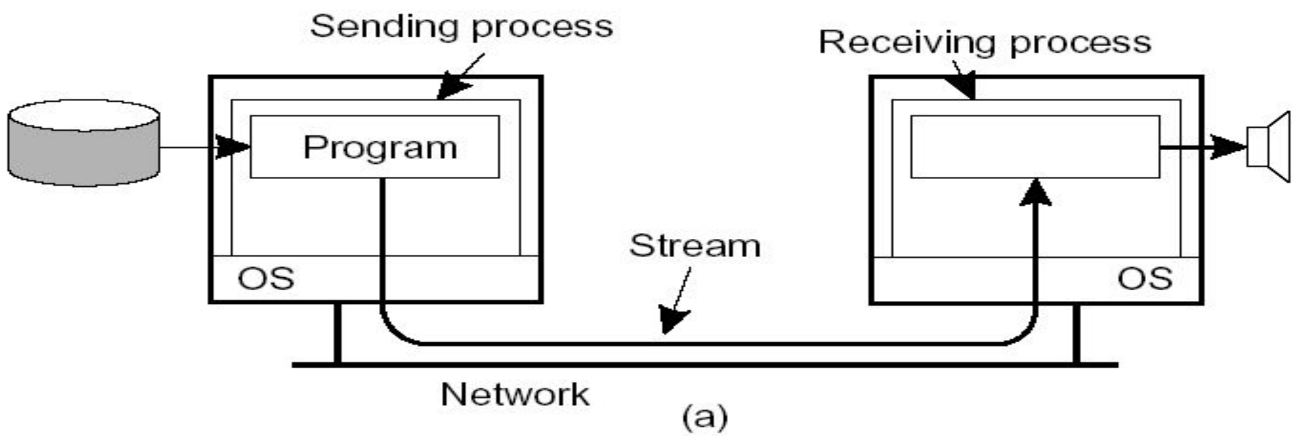
- Streams are unidirectional. There is generally a single **source**, and one or more **sinks**
- Often, either the sink and/or source is a wrapper around hardware (e.g., camera, CD device, TV monitor, dedicated storage)

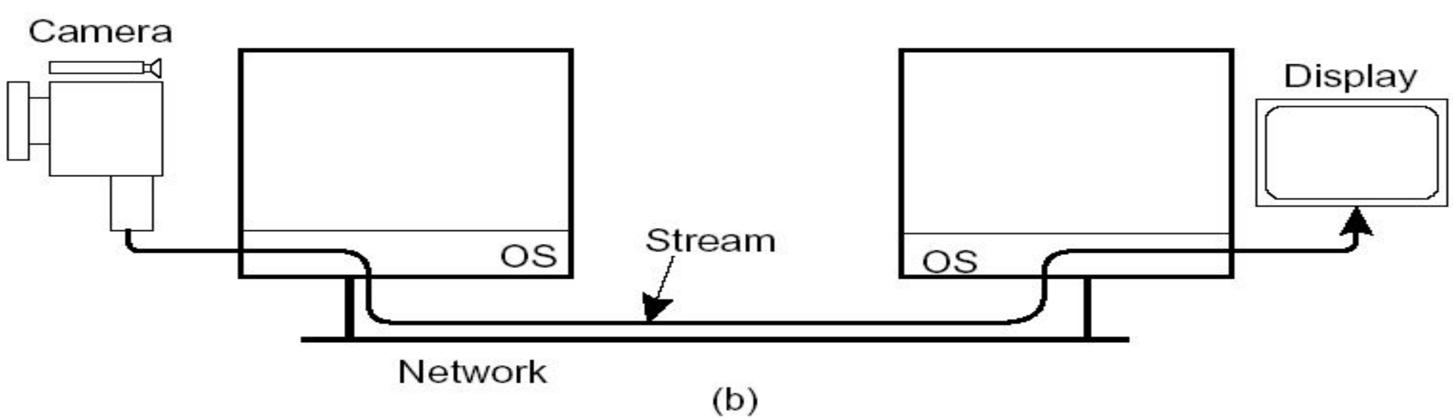
Stream types:

- **Simple**: consists of a single flow of data, e.g., audio or video
- **Complex**: multiple data flows, e.g., stereo audio or combination audio/video

Stream

Streams can be set up between two processes at different machines, or directly between two different devices. Combinations are possible as well.





Internet Group Management Protocol

• IP protocol can be involved in two types of communication: Unicasting and Multicasting.

•Multicasting has many applications. For example, multiple stockbrokers can simultaneously be informed of changes in a stock price.

•IGMP is a protocol that manages group membership. The IGMP protocol gives the multicast routers information about the membership status of hosts (routers) connected to the network.

Note:

IGMP is a group management protocol. It helps a multicast router create and update a list of loyal members related to each router interface.

IGMP message types