

# Processes



# Overview

- ▶ Threads vs Processes
- ▶ Clients
- ▶ Servers
- ▶ Virtualization
- ▶ Code Migration

# Threads versus Processes

## *Threads:*

- ▶ Improve application responsiveness by allowing them to not block
- ▶ Allows for parallel computation resulting in higher speed on many-core systems
- ▶ Easier to structure many applications as a collection of cooperating threads
- ▶ Higher performance compared to multiple processes since switching between threads takes less time

## *Processes:*

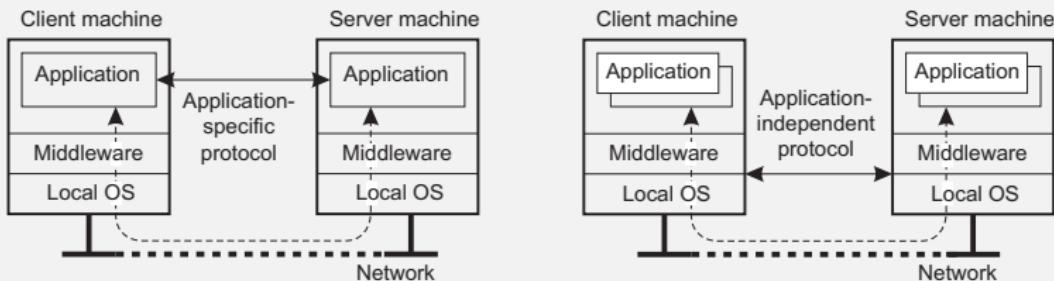
- ▶ Simpler to synchronize as processes have separate memory space
- ▶ Allows for parallel computation resulting in higher speed on many-core systems

# Thread Implementations

- ▶ **User-space threads:**
  - ▶ Creating/destroying threads is inexpensive
  - ▶ Switching context is very fast
  - ▶ But invocation of a blocking system call blocks all threads...
  - ▶ Cannot make use of multiple cores
- ▶ **Kernel threads:**
  - ▶ Overcomes the last two issues with user-space threads but loses performance
- ▶ **Light-Weight Processes (LWP)**: Hybrid model. Multiple LWP (threads) run inside a single (heavy-weight) process. Typically, a LWP runs on top of a kernel thread. In addition, the runtime system of a language can manage user-space threads placed on top of one or many LWPs.

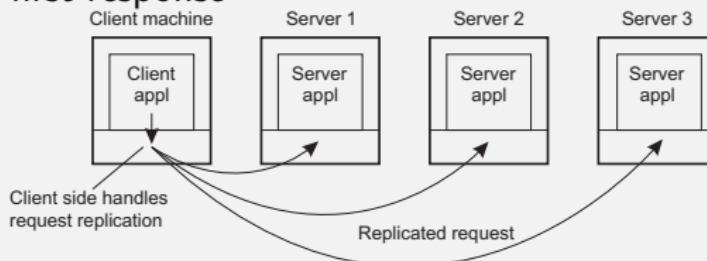
# Clients

- ▶ A networked client with its own protocol
- ▶ A middleware-based client



# Providing Transparency to Clients

- ▶ Clients can provide access transparency via a **stub** generated from interfaces offered by the server.
- ▶ Location transparency can be handled by the middleware on the client machines
- ▶ Client-side middleware can provide replication transparency by having multiple threads contact server replicas and providing the first response



- ▶ The client-side middleware can provide failure transparency by repeating attempts to connect to a server, or contacting another server. Or even provide data cached from the past in some cases.

# Design Issues for Servers(1)

- ▶ A **server** is a process implementing a specific service on behalf of a collection of clients
- ▶ A server can be **iterative** or **concurrent**. Concurrent servers can be *multi-threaded* or *multi-process*.
- ▶ Characteristics of server implementations.

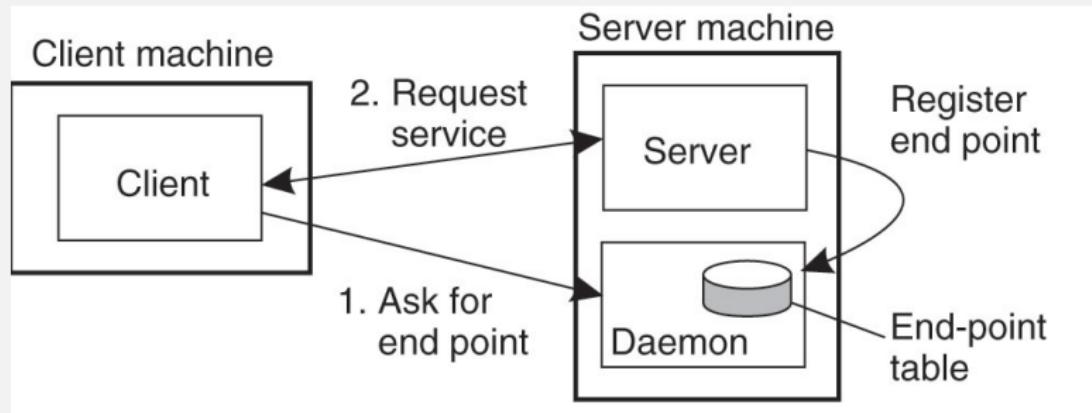
Model	Characteristics
Singlethreaded	No parallelism, blocking system calls, single data space
Multithreaded	Parallelism, blocking system calls, shared data space
Multiprocess	Parallelism, blocking system calls, separate data space
Finite state machine	Parallelism, nonblocking system calls, single data space

- ▶ See two simple examples of using a finite state machine to drive software development: [finite-state-machines](#)
- ▶ See example for a larger web server that uses finite state machine: [LargerHttpd.java](#) in folder sockets in package [tcp.largerhttpd](#).

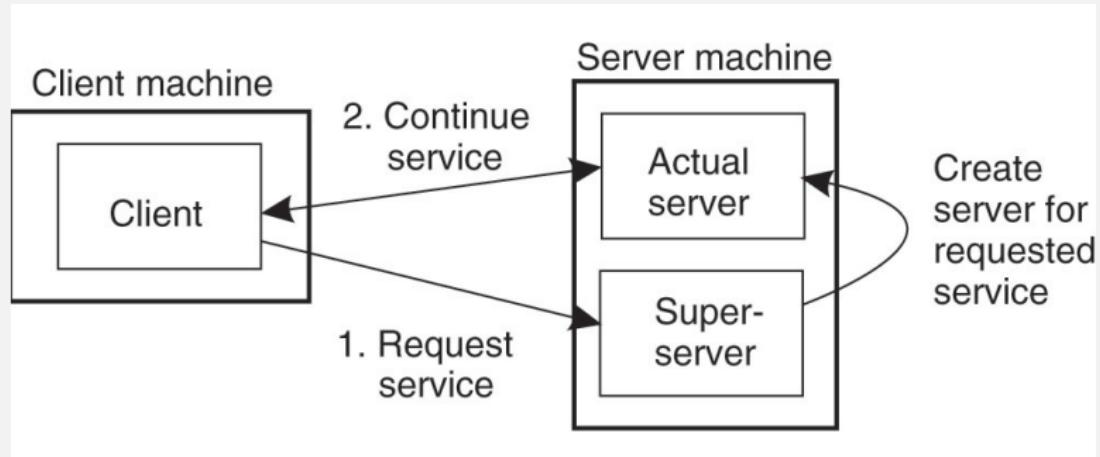
## Design Issues for Servers (2)

- ▶ How does a client find a server? Need to know the end-point or port and the host address.
  - ▶ Statically assigned like well known servers like HTTP on port 80.
  - ▶ Look-up service provided by a special **directory/registry server**.
  - ▶ Using a **superserver** that selects on multiple ports and forks off the appropriate server when a request comes in.

# Directory/Registry Server Setup



# SuperServer Setup



**systemd** and **xinetd** are examples of superservers

## Design Issues for Servers (3)

- ▶ **Stateless** server: A stateless server does not remember anything from one request to another.
  - ▶ For example, a HTTP server is stateless. **Cookies** can be used to transmit information specific to a client with a stateless server. Easy to recover from a crash.
- ▶ **Stateful** server: Maintains information about its clients. Performance improvement over stateless servers is often the reason for stateful servers. Needs to recover its entire state as it was just before crash. Can be quite complex for distributed servers.
  - ▶ Example: A file server that allows clients to cache a local copy for performance improvement.
- ▶ **Soft State** servers: The server promises to maintain state on behalf of the client, but only for a limited time.

## Design Issues for Servers (4)

- ▶ An **object server** by itself does not provide a specific service. Specific services are implemented by the objects that reside in the server. Design issues for object servers:
  - ▶ Makes it relatively easy to change services by simply adding and removing objects.
  - ▶ Multiple protocols can also be supported with different object types.
  - ▶ The objects can be transient (existing only in memory) or be stored in a database.
  - ▶ Each object may be handled by a separate thread, leading to simpler synchronization. This may lead to queuing of requests.
  - ▶ Each invocation may be handled by a separate thread. Then the objects must implement synchronization internally.
  - ▶ Use a thread pool to prevent denial-of-service attacks.

## Design Issues for Servers (5)

- ▶ How to handle communication interrupts? Use **out-of-band data**. Example: to cancel the upload of a huge file.
  - ▶ Server listens to separate endpoint, which has higher priority, while also listening to the normal endpoint (with lower priority).
  - ▶ Send urgent data on the same connection. Can be done with TCP, where the server gets a signal (**SIGURG**) on receiving urgent data. However, this isn't portable as not all socket implementations provide this feature.

## In-class Exercise (1)



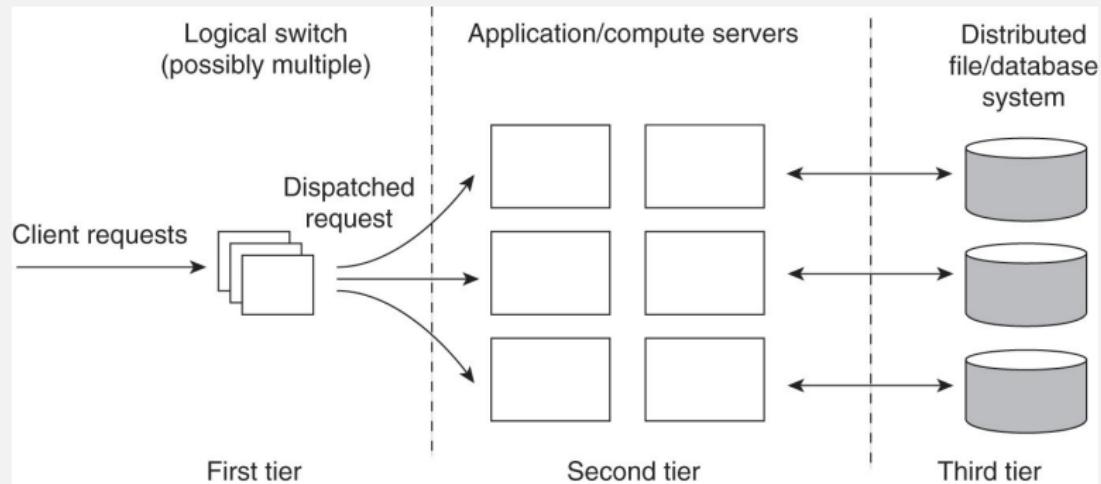
- ▶ Is a server that maintains a TCP/IP connection to a client stateful or stateless?
- ▶ Imagine a web server that maintains a table in which client IP addresses are mapped to the most recently accessed web pages. When a client connects to the webserver, the server looks up the client in its table, and if found, returns the registered page. Is the server stateful or stateless?

## In-class Exercise (2)



- ▶ Sketch the design of a multithreaded server that supports multiple protocols using sockets.

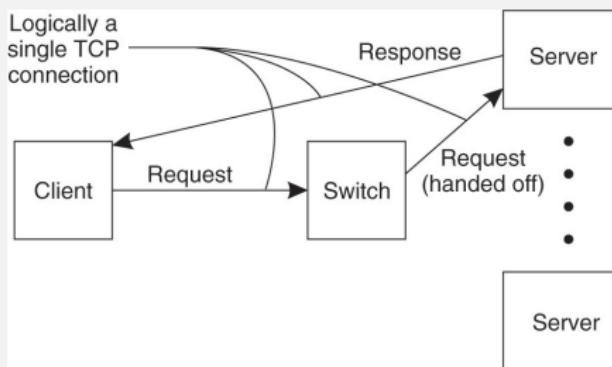
# Server Clusters (1)



Design of a Three-tiered Server Cluster

## Server Clusters (2)

- ▶ The switch sets up a TCP connection with a selected server and passes the requests and responses between the client and the selected server. This requires rewriting the source and destination addresses in the TCP segments (aka *Network Address Translation* or NAT)
- ▶ The switch can hand off the connection to a selected server such that all responses are directly communicated to the client from that server. This is known as a **TCP handoff**, which uses **IP forwarding and IP spoofing**.

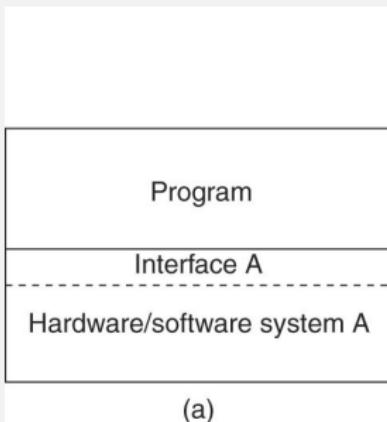


## Server Clusters (3)

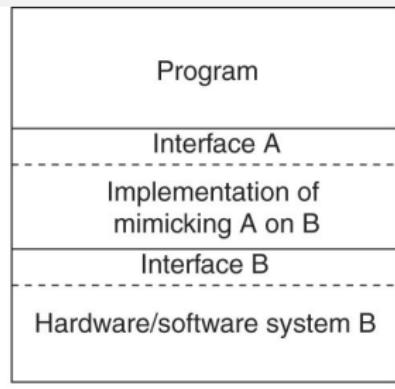
- ▶ Switch can hand off connections in round-robin and thus be oblivious of the service being provided
- ▶ Switch can handoff request based on type of service requested to the appropriate server
- ▶ Switch can handoff request based on server loads
- ▶ Switch can handoff request by being aware of the content
- ▶ Single point of access can be made better using DNS to map one hostname to several servers. But the client still has to try multiple servers in case some are down.

# Virtualization (1)

- ▶ **Virtualization** is the creation of a virtual version of something, such as a hardware platform, operating system, a storage device or network resources.



(a)



(b)

## Virtualization (2)

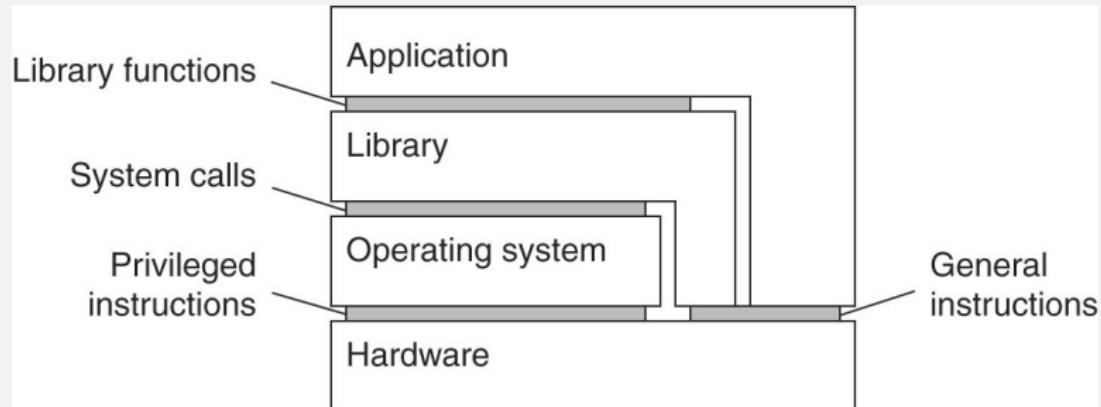
Benefits of virtualization:

- ▶ Allows software at higher level (like middleware and applications) to be supported on changing hardware and lower level systems software.
- ▶ Eases administration of large number of servers (or resources).
- ▶ Helps with scalability and better utilization of hardware resources.
- ▶ The main driver behind the growth in **cloud computing** and **utility computing**.

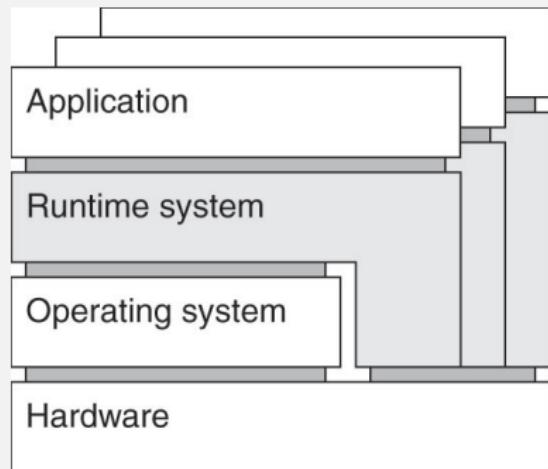
# Architectures for Virtual Machines (1)

- ▶ An interface between the hardware and software consisting of machine instructions that can be invoked by any program.
- ▶ An interface between the hardware and software, consisting of machine instructions that can be invoked only by privileged programs, such as an operating system.
- ▶ An interface consisting of system calls as offered by an operating system.
- ▶ An interface consisting of library calls generally forming what is known as an application programming interface (API). In many cases, the aforementioned system calls are hidden by an API.

# Architectures for Virtual Machines (2)

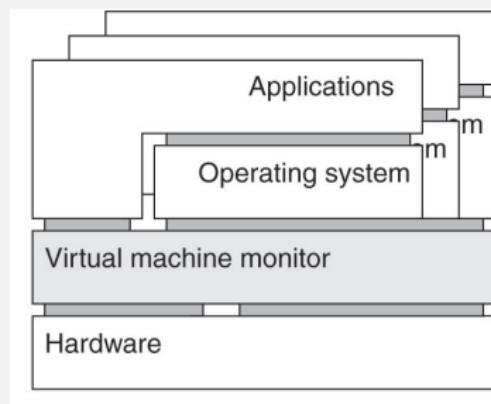


# Architectures for Virtual Machines (3)



- ▶ **Process Virtual Machine**: An abstract instruction set that is to be used for executing applications. For example: Java Virtual Machine.

# Architectures for Virtual Machines (4)

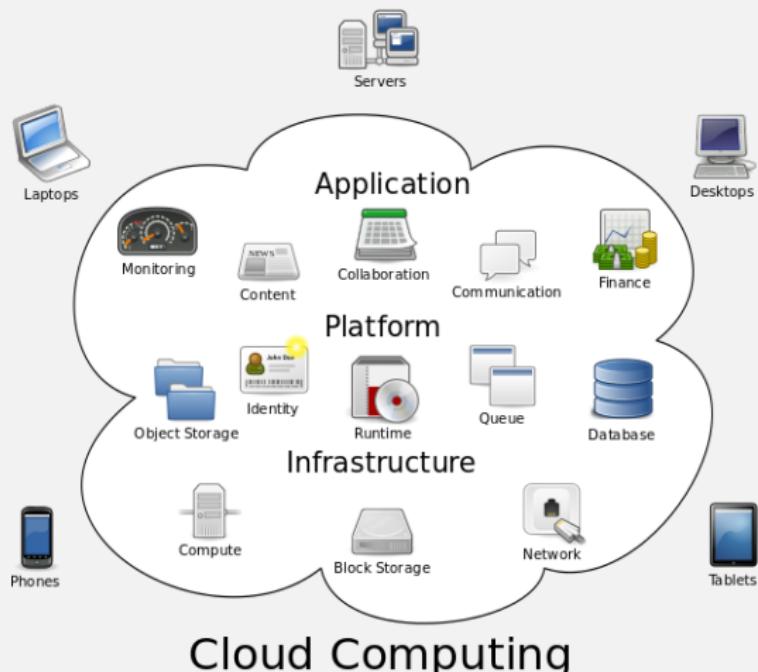


- ▶ **Virtual Machine Monitor:** A layer completely shielding the original hardware but offering the complete instruction set of that same (or other hardware) as an interface.
- ▶ Makes it possible to have multiple instances of different operating systems run simultaneously on the same platform.
- ▶ *Monolithic Examples:* VMware Workstation, VMware Fusion, Virtual Box, Parallels, Windows Virtual PC, etc
- ▶ *Microkernel Examples:* Hyper-V, VMware ESX/ESXi, Xen, z/VM.

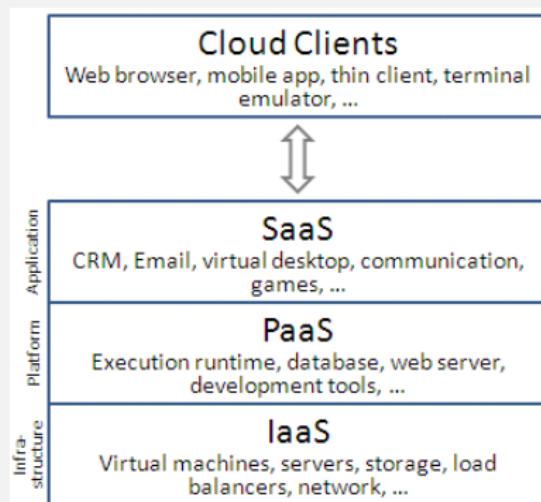
## Architectures for Virtual Machines (5)

- ▶ **Sandbox** (Application-level). Examples: Citrix XenApp, ZeroVM.
- ▶ **Containers** (Environment-level). Examples: *cgroups*-based Docker and LXC (Linux Containers). Lighter weight compared to Virtual Machine Monitors.

# Cloud Computing



# Cloud Computing Layers



**IaaS**: Amazon Web Services, Microsoft Azure.

**PaaS**: Google App Engine, Microsoft Azure, Salesforce.

**SaaS**: Many companies!

# Case Study: Amazon Elastic Compute Cloud

- ▶ **EC2** (*Elastic Compute Cloud*): Makes it easy to create a collection of networked virtual servers.
- ▶ **AMI** (*Amazon Machine Image*): Preconfigured machine images consisting of an operating system along with preinstalled services. For example, a basic AMI is a *LAMP* image with a Linux kernel, the Apache Web Server, a MySQL database system and PHP.
- ▶ The user selects an AMI and then launches it, thus creating a **EC2 instance**. The physical location of the instance is transparent.
- ▶ Each EC2 instance has a private and public IP address. The public address is mapped to the private one using **NAT** (*Network Address Translation*). We can manage an EC2 instance using an SSH connection.
- ▶ Data stored in an EC2 instance is transient, that is, the data is lost when the instance stops. To persist the data, we have to use the **S3** (*Simple Storage Service*) or the **EBS** (*Elastic Block Store*) service or **EFS** (*Elastic File Storage*).

# Code Migration

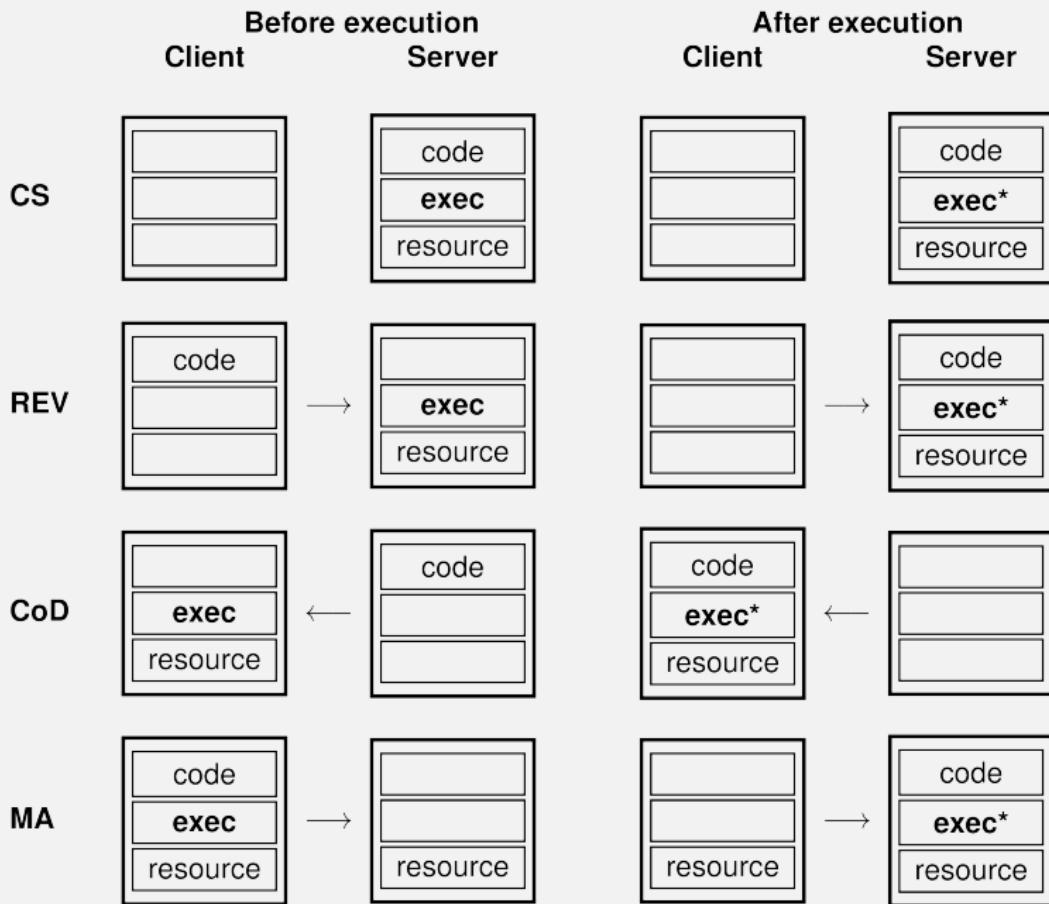
- ▶ Improve computing performance by moving processes from heavily-loaded machines to lightly loaded machines.
- ▶ Improve communication times by shipping code to systems where large data sets reside. E.g. a client ships code to a database server or vice versa.
- ▶ **Mobile Agents**: small piece of code that moves from site to site for a web search. Several copies can be made to improve performance.
- ▶ *Flexibility to dynamically configure distributed systems*. E.g. a server can provide interface code to a client dynamically. This does require that the protocol for downloading and initializing the code is standardized. Allows the interface to be changed as often as desired without having to rebuild applications or servers.

# Code Migration Models (1)

Recall that a process consists of three segments: *code segment*, *resource segment*, *execution segment*.

- ▶ **Weak mobility**: Only the code segment (and some initialization data) can be transferred. Transferred program always starts at one of the predefined starting positions.
- ▶ **Strong mobility**: Code and execution segments can both be transferred.
- ▶ **Sender-initiated versus receiver-initiated**: Uploading code to a server versus downloading code from a server by a client.

# Code Migration Models (2)



## Exercises

- ▶ Consider a process  $P$  that requires access to file  $F$ , which is locally available on the machine that  $P$  is currently running on. When  $P$  moves to another machine, it still requires access to  $F$ . If the file-to-machine binding is fixed, how could the system wide reference to  $F$  be implemented?
- ▶ Ask your virtual assistant the above question and compare the answer with your own answer.
- ▶ Is your chat server implementation *stateless* or *stateful*? Discuss.
- ▶ Read the Wikipedia article on [cloud computing](#).
- ▶ Read the Wikipedia article on [proxy server](#). Now ask your virtual assistant to explain what a proxy server is and compare the answer with the Wikipedia article.