Middleware and Distributed Systems

System Models

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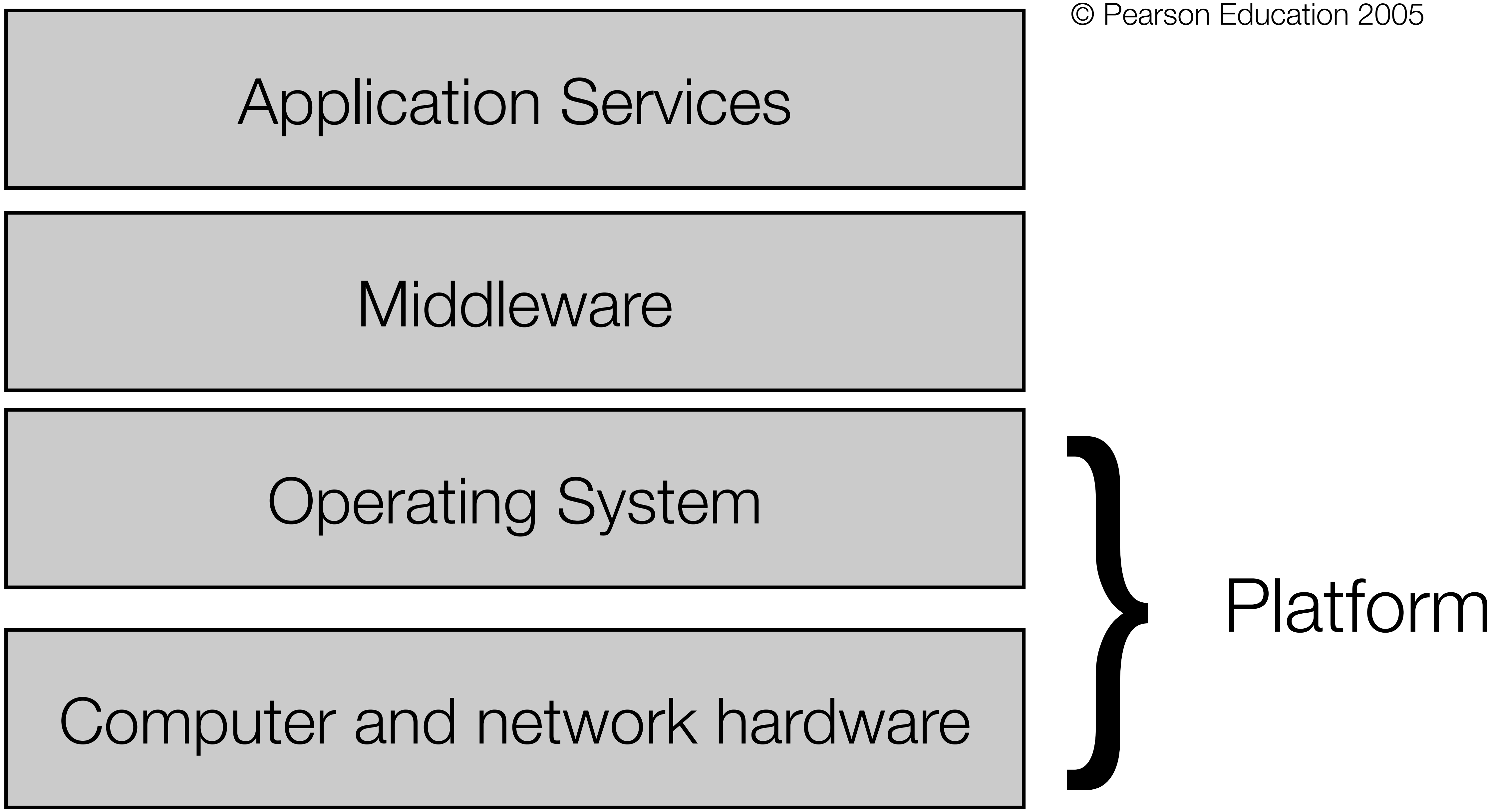
System Models (Coulouris et al.)

- Architectural models of distributed systems
  - placement of parts and relationships between them
  - e.g. client-server, peer-to-peer
- Fundamental models
  - formal description of properties common to all architectural models
  - addresses correctness, reliability, and security
- Selected drawings taken from Coulouris, Dollimore and Kindberg Distributed Systems: Concepts and Design, Edition 4, © Pearson Education 2005

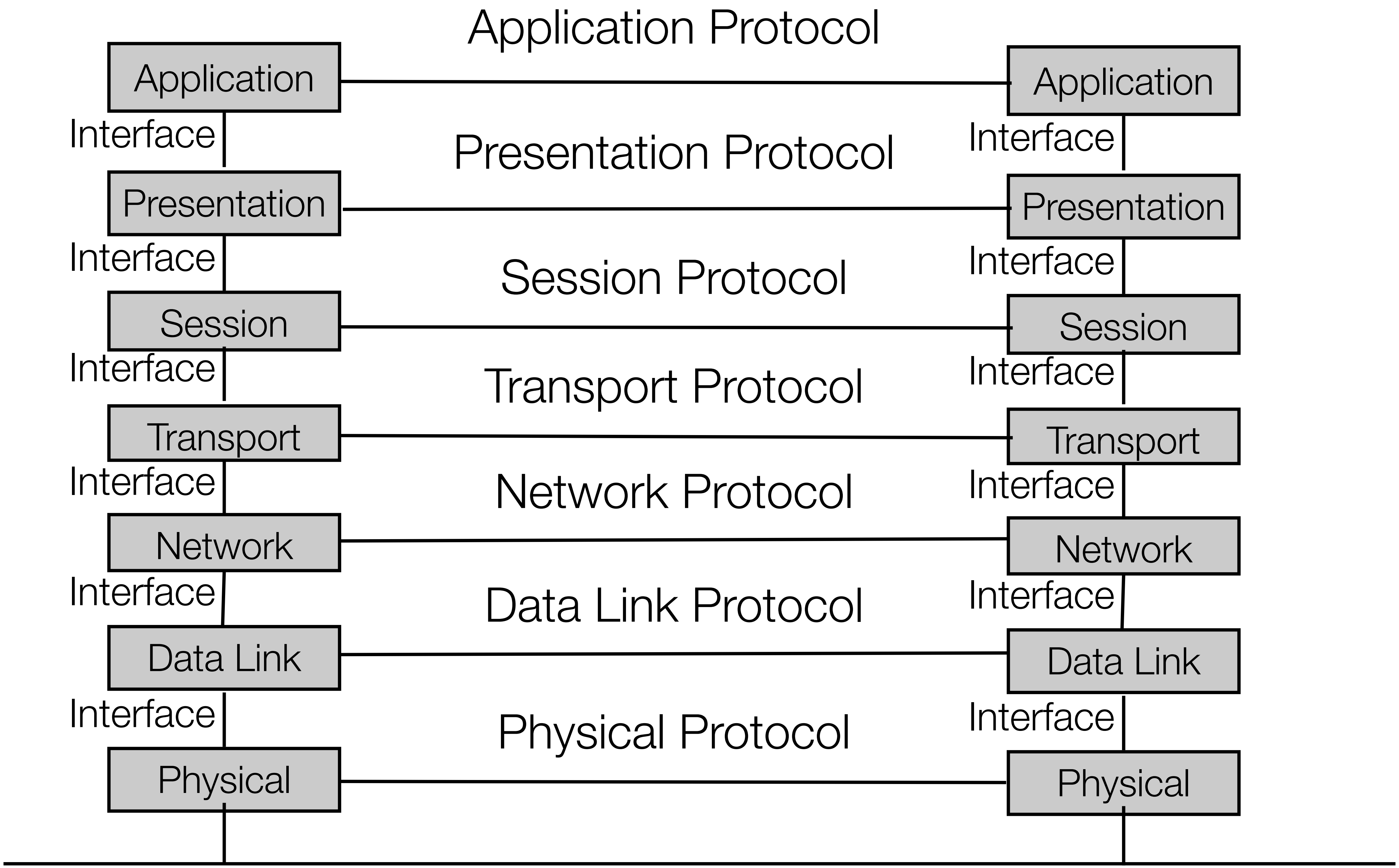
Architectural Models

- placement of components across a network of computers
  - define useful patterns for the distribution of data and workload
- interrelationships between components
  - functional roles, patterns of communication
- abstraction: server processes, client processes, peer processes
- variation of models, e.g. for client-server architecture
  - define mobile code to have some part of the application run on the client
  - support mobile clients to allow matching of clients and servers dynamically

Software Layers

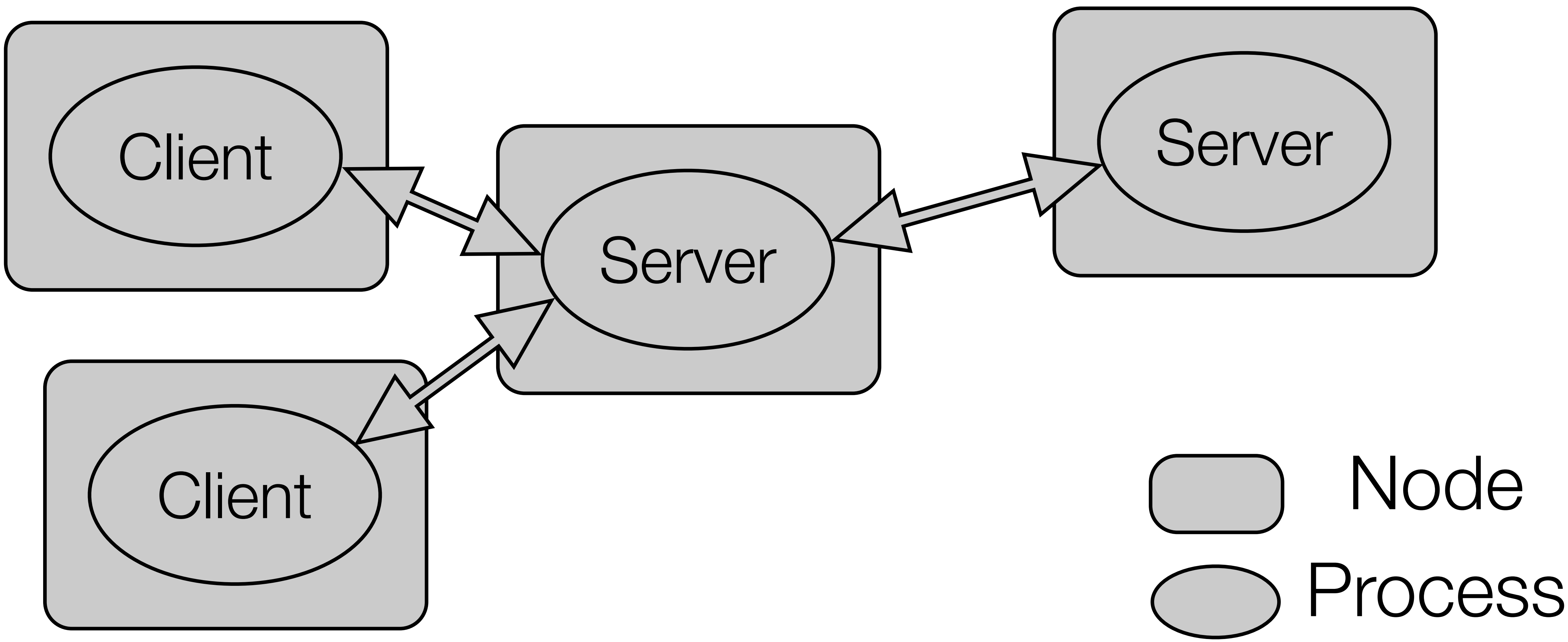


Protocol Layers: OSI-RM

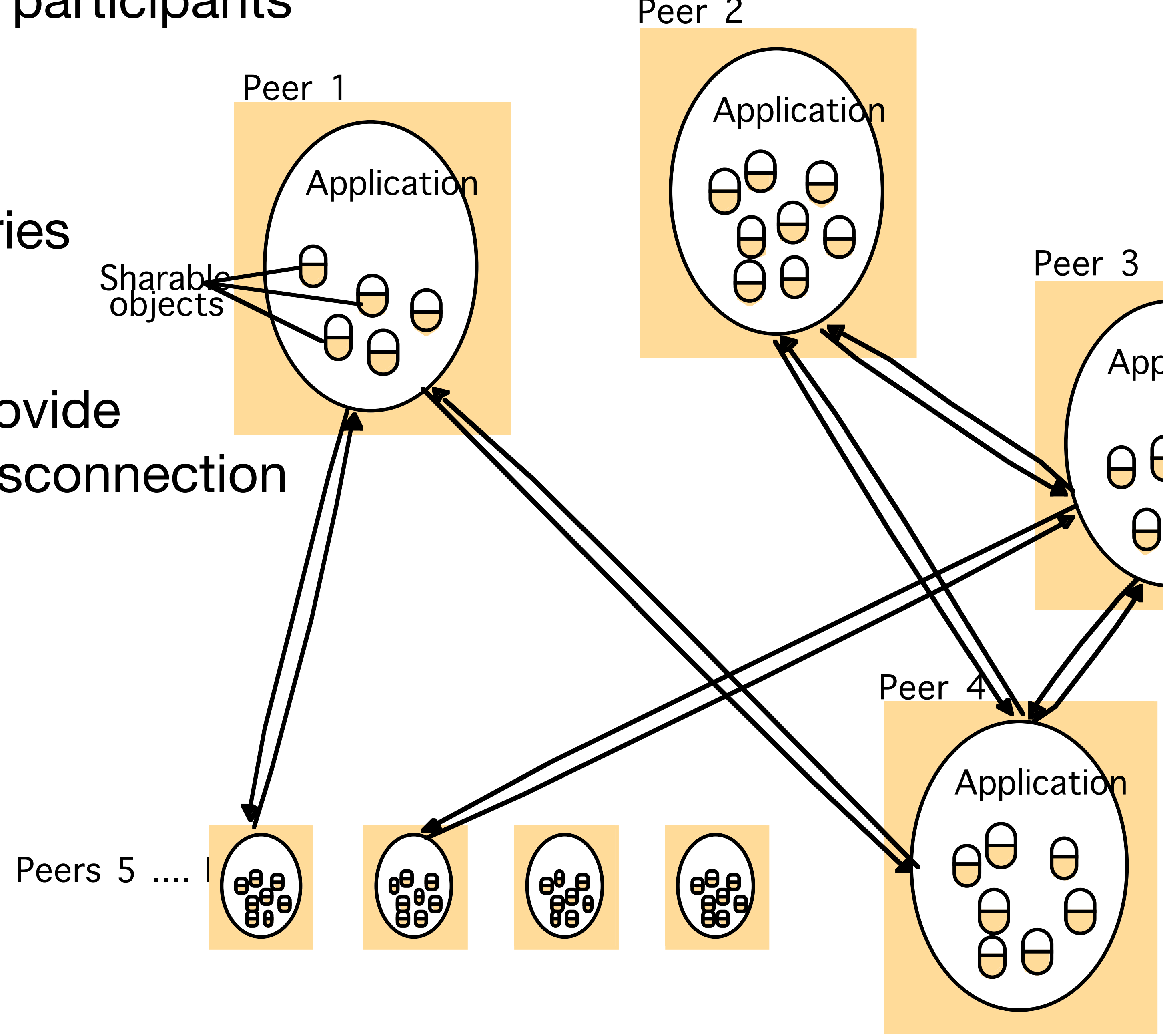


Client - Server Model

- Client: consumer process, uses remote services / information
- Server: provider process, offers a service / information
  - may in turn be client of another server

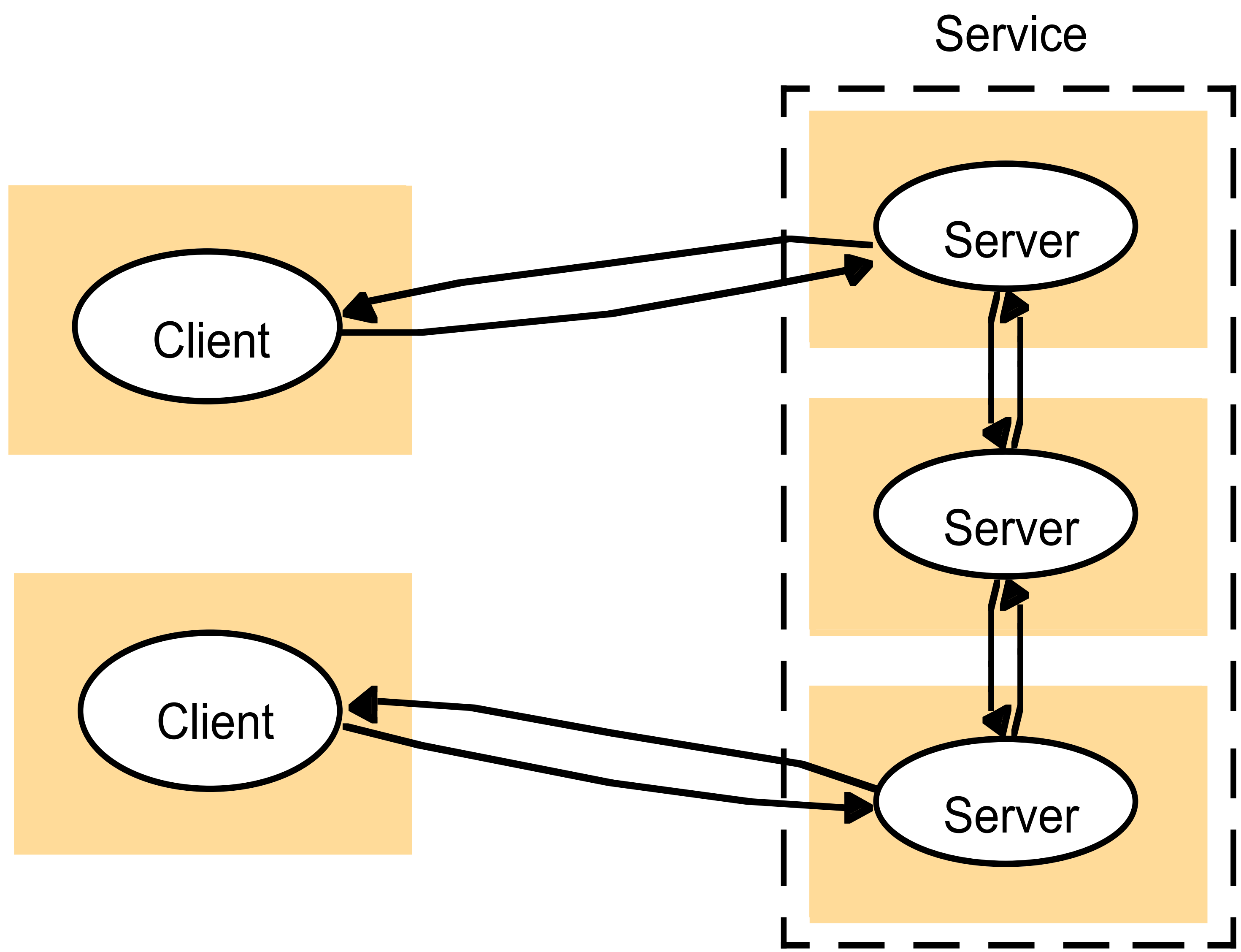


- potentially large number of participants
    - often, home users
- communication pattern varies over time
- replication necessary to provide resilience in the event of disconnection

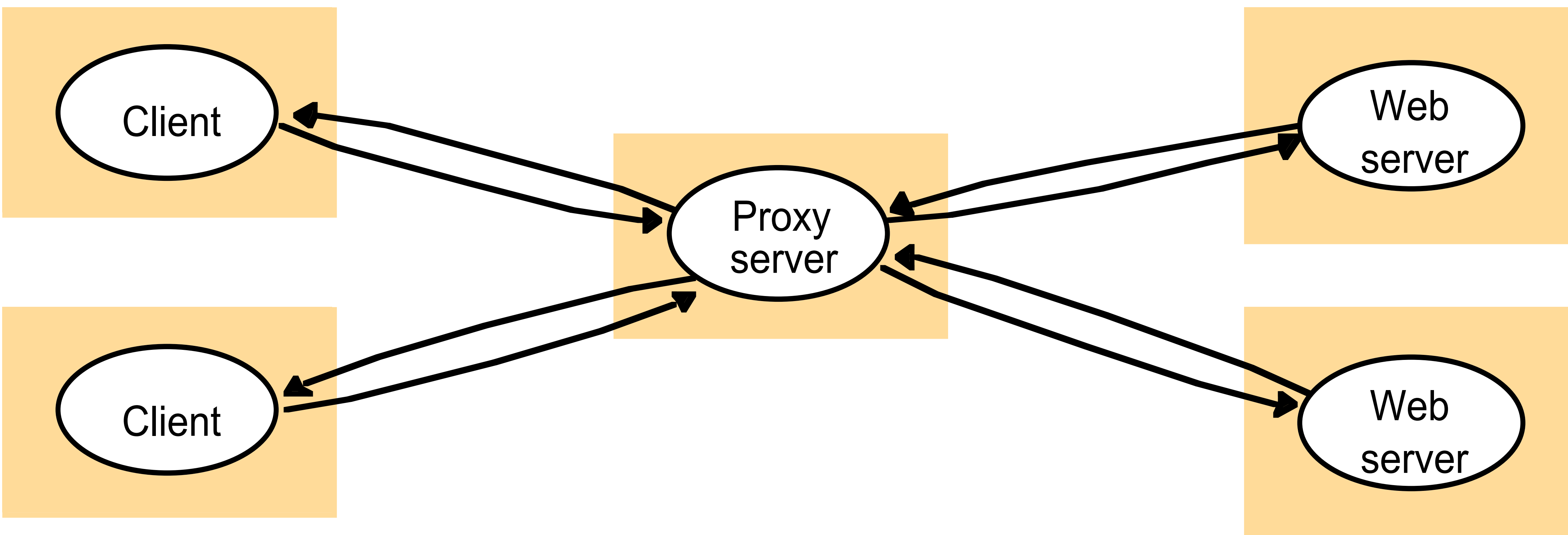


Variation: Services provided by multiple servers

- Services provided by multiple servers

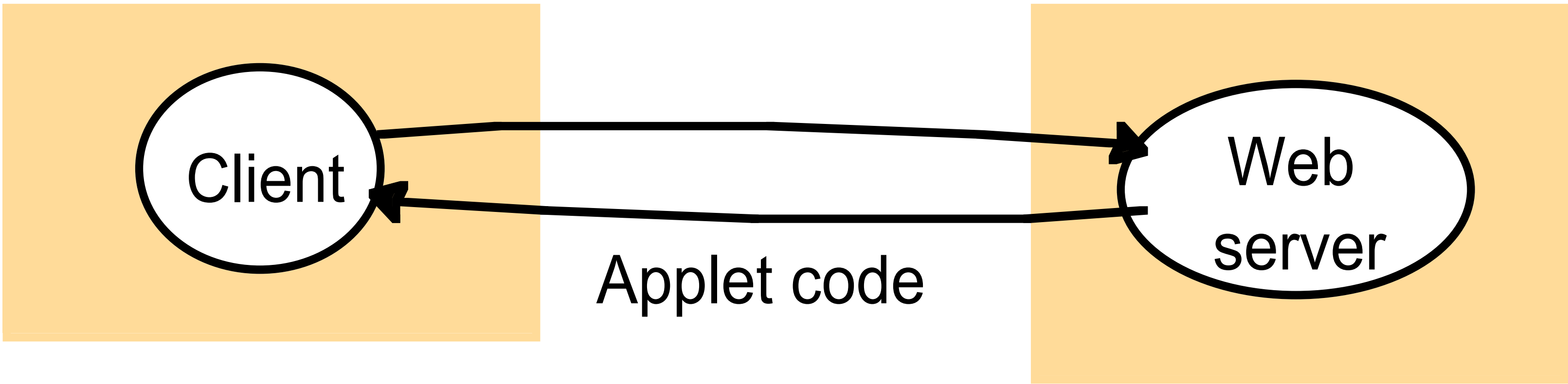


Variation: Proxy Servers and Caches



Variation: Mobile Code

a) client request results in the downloading of applet code



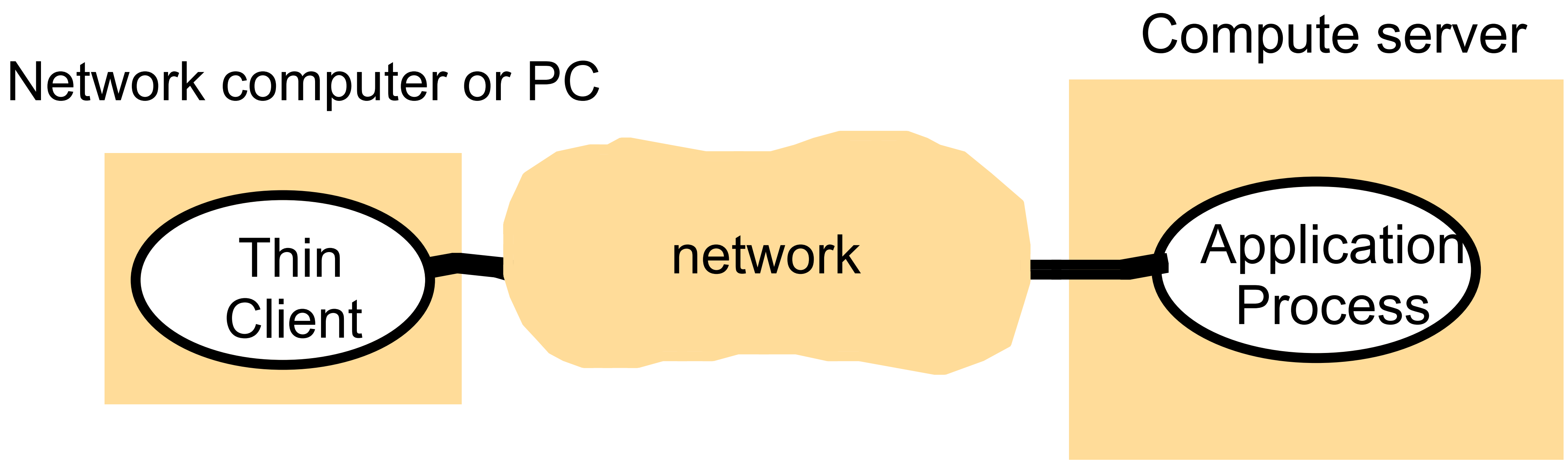
b) client interacts with the applet

Variation: Mobile Agent

- running program is moved from node to node (with both code and data)
- security challenge to the server: client gets hold of the entire state of the agent
  - only have non-secret data in the agent
- security challenge to the client: client node runs arbitrary server-defined code
  - need to establish trust in agent code
  - need to restrict agent's access to local resources (sandboxing)

Variation: Thin Clients

- Client performs just I/O, no computation



Interfaces and Objects

- Set of operations offered by a process is defined by its interface
  - more precisely: set of messages it is able to send and receive
- often formally specified in interface definitions
- object-oriented middleware applications: interfaces get implemented by classes

Design Requirements for Distributed Architectures

- Various objectives for creation of distributed systems
  - sharing of computational resources (e.g. cluster computing)
  - sharing of data
  - sharing of services
- Performance issues: responsiveness, throughput, load balancing
- Quality of Service (QoS): reliability, security, performance, adaptability, time-critical data
- Dependability: correctness, security, fault tolerance, (maintainability)
- Caching and Replication

Fundamental Models

- Model: abstraction of essential properties of a natural phenomenon, for the purpose of understanding and analysis
  - make explicit all relevant assumptions
  - make generalizations concerning what is possible or impossible
- Models of distributed systems: Reasoning about
  - Interaction (e.g. communication involves delays)
  - Failure (node and network failure threatens correct operation of system)
  - Security (consider attacks by both internal and external agents)

Interaction

- Notion of distributed algorithm:
  - each node has a set of data, and runs a program
    - state of each node not accessible to any other node
  - nodes interchange messages
    - assume that all activity in the system is driven by message reception (may need to consider system boundaries specially)
- relative speed of nodes should assumed to be unknown
- performance of network: latency, bandwidth, jitter
- each node has its own internal clock
  - with specific drift rate - clock synchronization is necessary

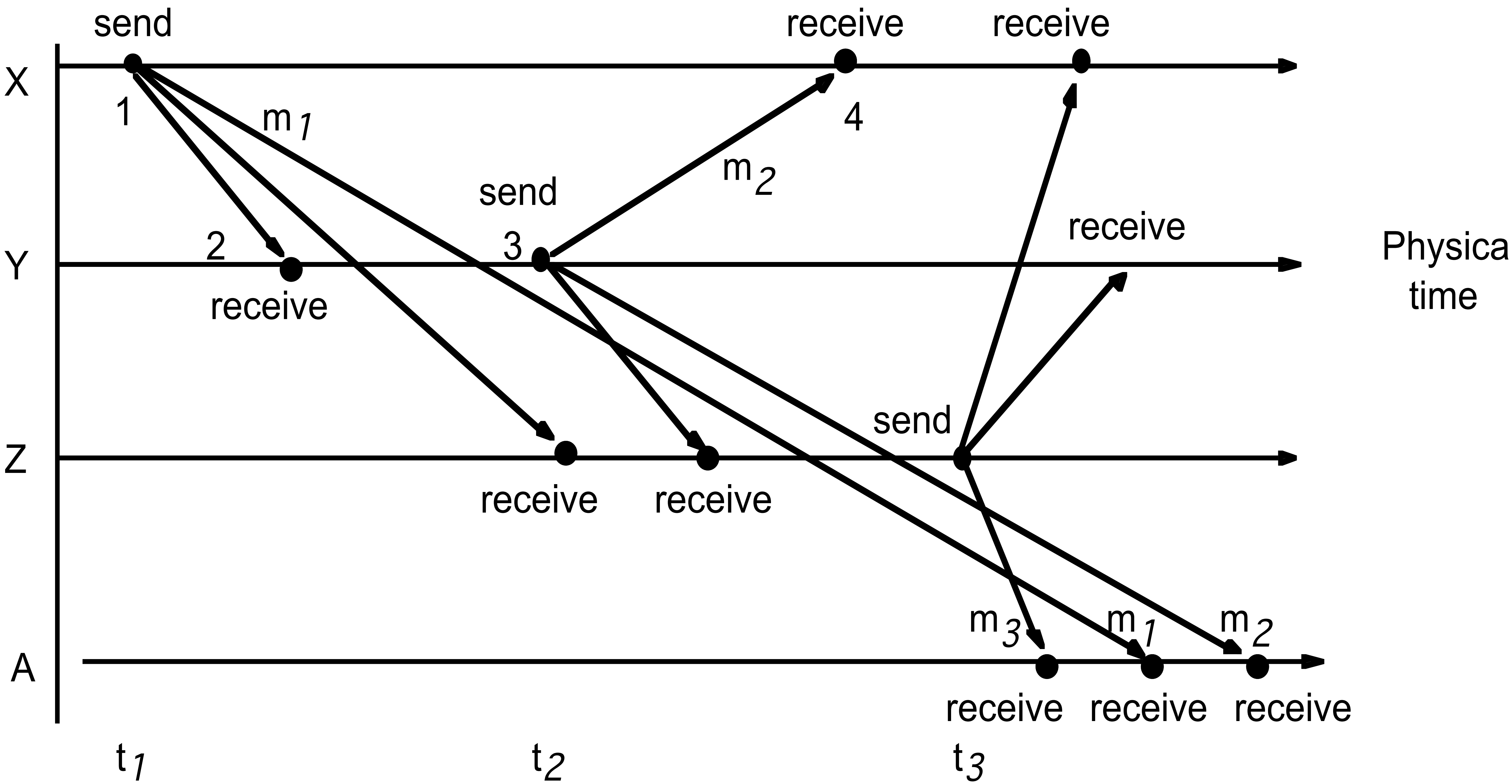
Interaction (cntd.)

- two variants of interaction: synchronous and asynchronous
- synchronous systems:
  - known lower and upper time bound for each execution step, for each message transmission, and for the clock drift
  - consequence: can introduce a pulsed execution system
  - practically difficult to build, may help in simplifying analysis
- asynchronous systems: messages can arrive and be sent at any time
- event ordering: can usually assume no relative order of reception wrt. sending of messages
  - exception: messages sent on an order-preserving channel

Interaction: Lamport's "Logical Time" (1978)

- happens-before relation: e1 happens before e2, iff
  - e1 is executed by the same process before e2, or
  - e1 is a send operation, and e2 is the corresponding receive operation, or
  - there is an e3 such that e1 happens before e3, and e3 happens before e2
- logical time: Assign a number L to each event, such that L(e1) < L(e2) if e1 happens before e2

Logical Time (cntd.)



Failure Model

- Omission Failures: process or channels fails to perform an operation
  - process omission failure (e.g. crash failure)
    - fail-stop: other processes can detect crash (requires guaranteed delivery of messages)
  - communication omission failures (message drop)
- Arbitrary Failures (Byzantine failure): anything may happen
- Timing Failures:
  - synchronous system: activities not completed within pulse
  - real-time systems: activity not completed within promised time

Failure Model (cntd.)

- Masking failures: reconstruct reliable services on top of unreliable ones
  - through retries, error correction, ...
- Reliability of one-to-one communication:
  - validity (messages are eventually delivered to the receiver)
  - integrity (received message identical to sent one, and no message is delivered twice)

Security Model

- securing processes and channels against unauthorized access
- protecting objects: access rights given to a principal
- assumption of an enemy (aka adversary), capable of (threat model)
    - sending messages to any process
    - reading and copying any message between a pair of processess
- enemy may operate either legitimitely-connected node, or illegal node

Security Model (cntd.)

- threat to processes: may receive messages sent by enemy
  - may not be able to reliably determine identity of sender
  - server: may not be able to identify principal
  - client: may fall to "spoofing"
- Threats to communication channels: enemy may
  - copy, alter, inject, or delete messages
  - gain information only intended for the communication partner
- Other threats: denial of service, trojan horses, ...
- Defeating security threats: cryptography, authentication, secure channels