

# Multiple Processor Systems

## Chapter 8

# Multiple Processor Systems

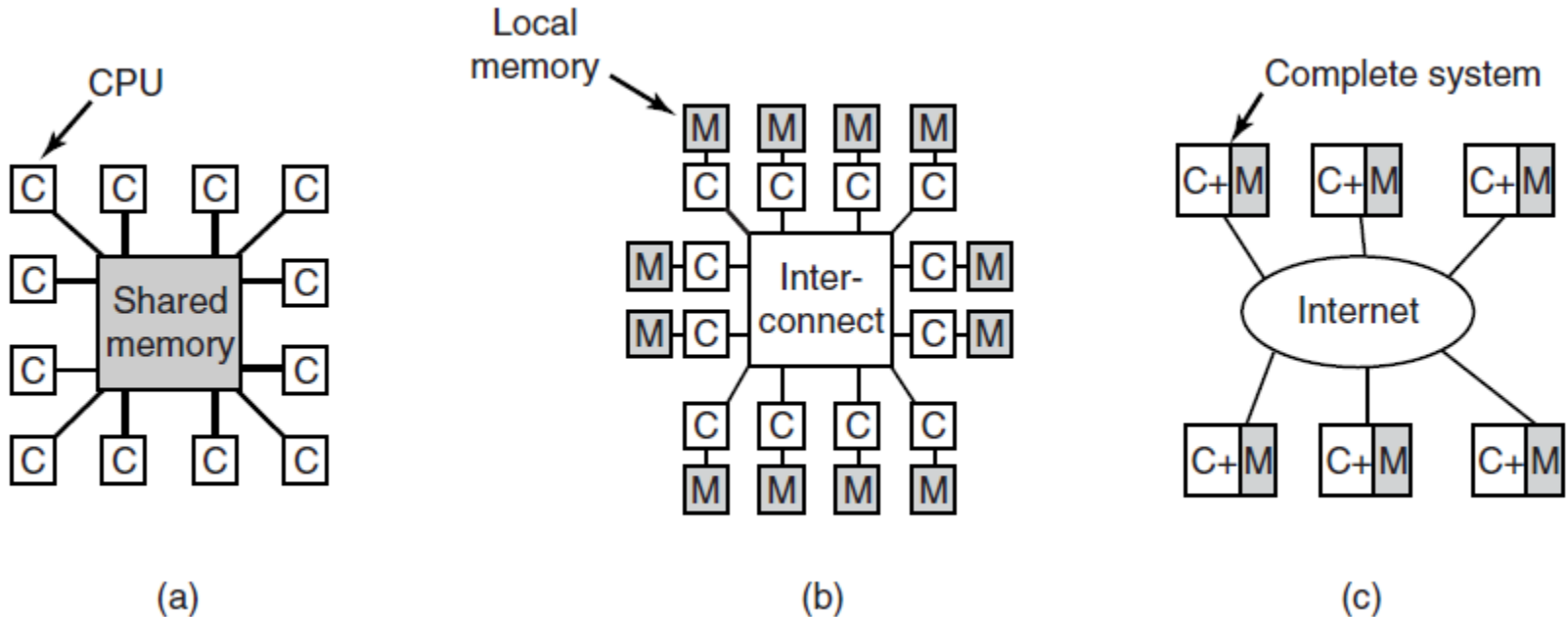


Figure 8-1. (a) A shared-memory multiprocessor. (b) A message-passing multicomputer. (c) A wide area distributed system

# Multiprocessor Hardware

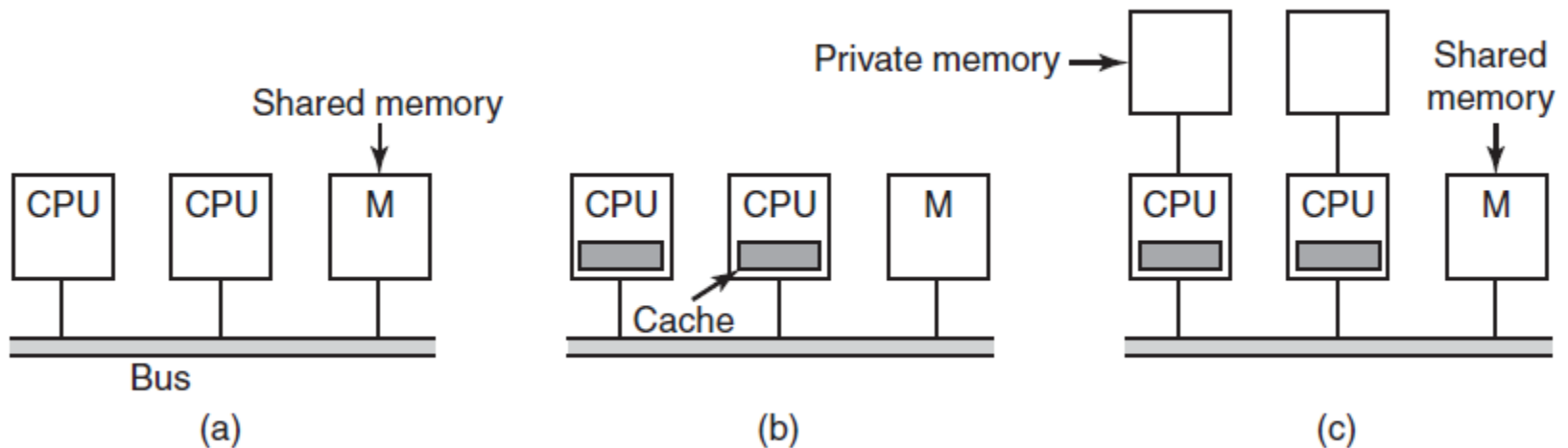


Figure 8-2. Three bus-based multiprocessors. (a) Without caching. (b) With caching. (c) With caching and private memories.

# UMA Multiprocessors Using Crossbar Switches

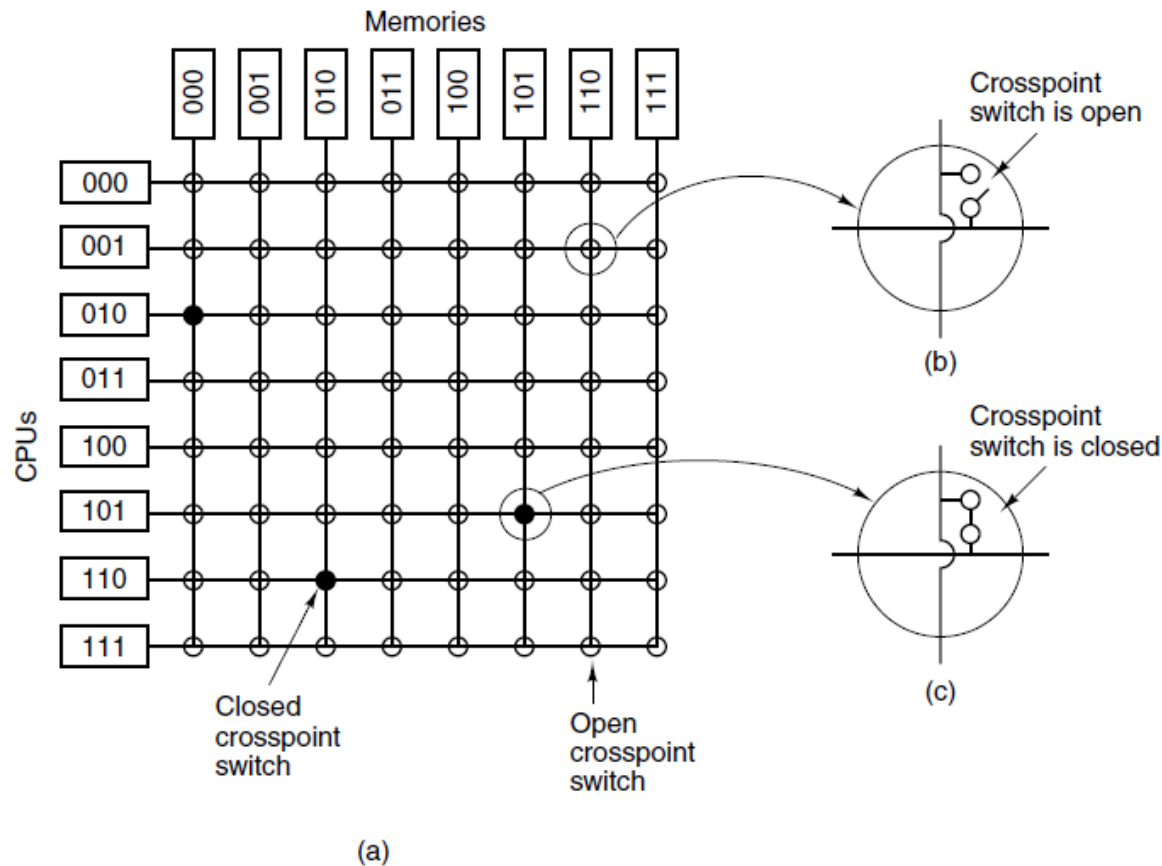


Figure 8-3. (a) An  $8 \times 8$  crossbar switch. (b) An open crosspoint. (c) A closed crosspoint.

# UMA Multiprocessors Using Multistage Switching Networks (1)

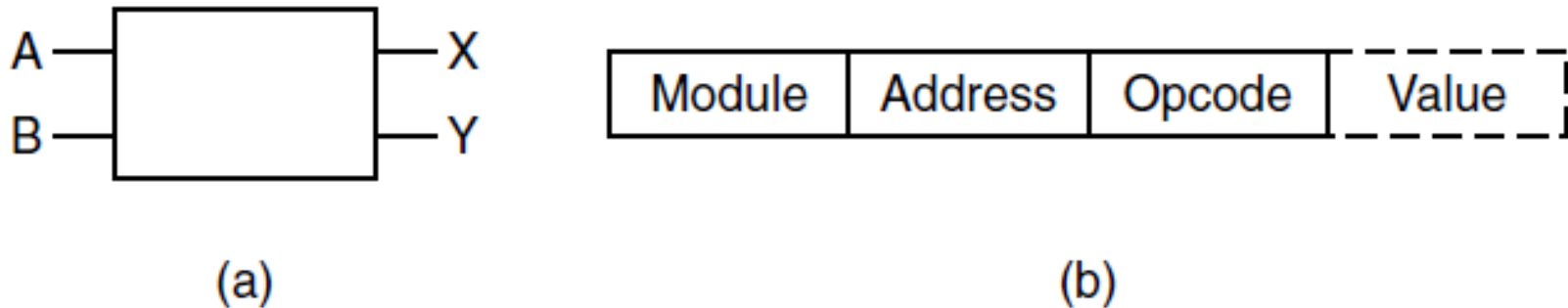


Figure 8-4. (a) A  $2 \times 2$  switch with two input lines, A and B, and two output lines, X and Y. (b) A message format.

# UMA Multiprocessors Using Multistage Switching Networks (2)

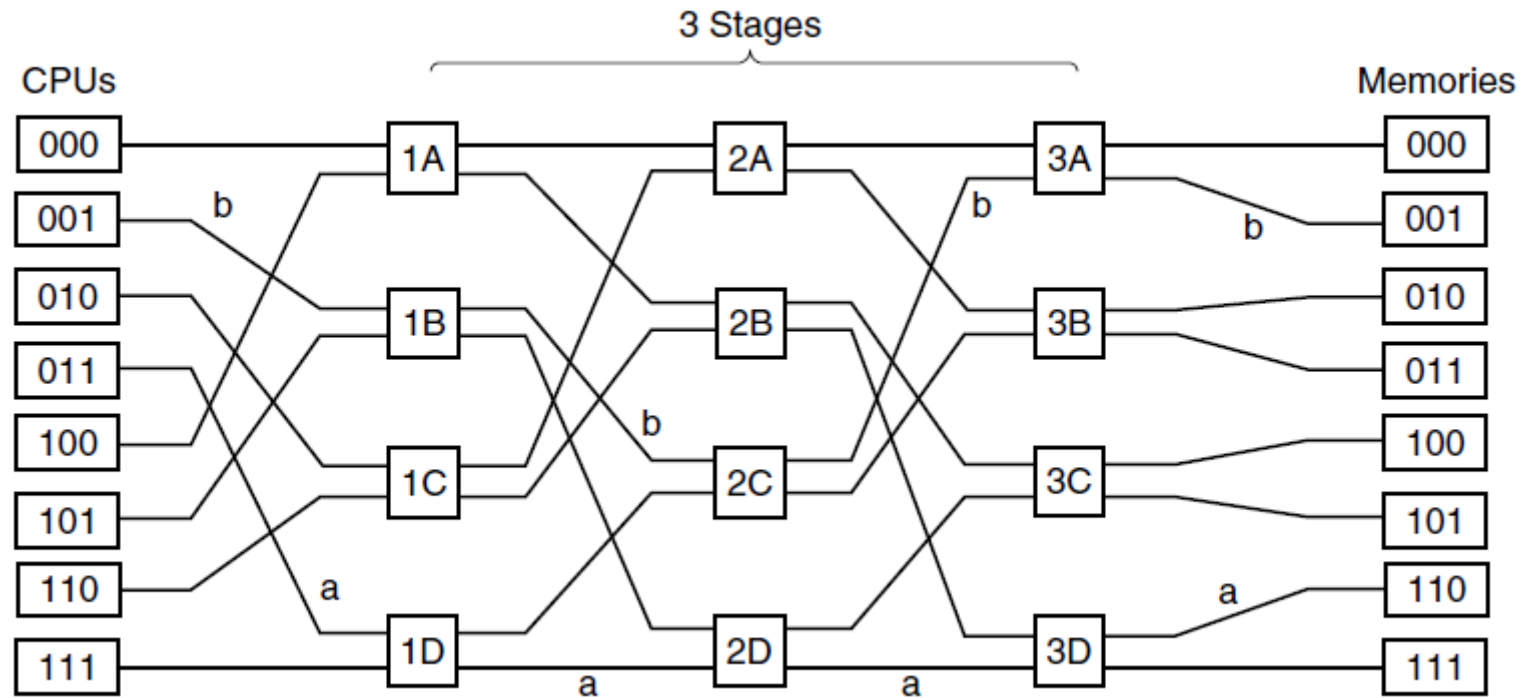


Figure 8-5. An omega switching network.

# NUMA Multiprocessors (1)

Characteristics of NUMA machines which distinguish them from other multiprocessors:

1. There is a single address space visible to all CPUs.
2. Access to remote memory is via LOAD and STORE instructions.
3. Access to remote memory is slower than access to local memory.

# NUMA Multiprocessors (2)

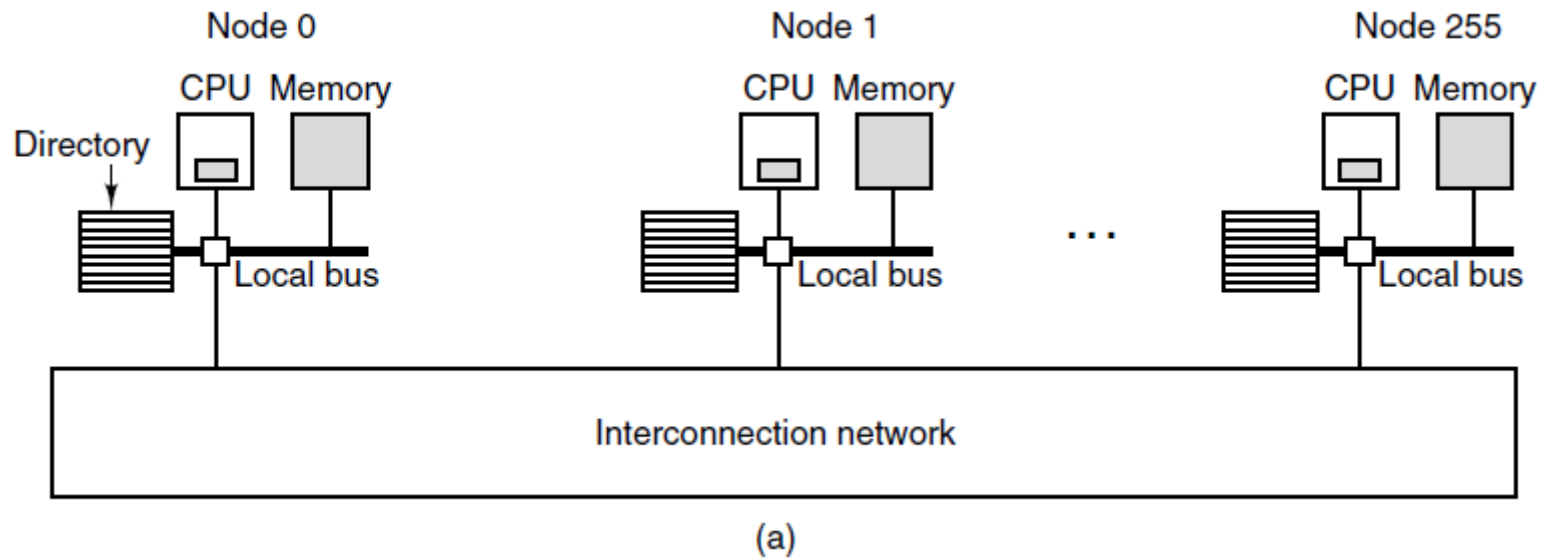
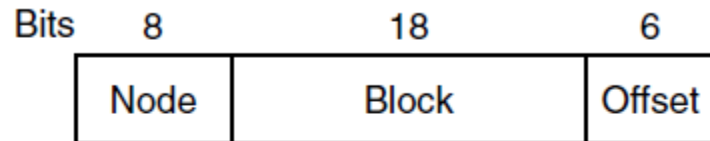


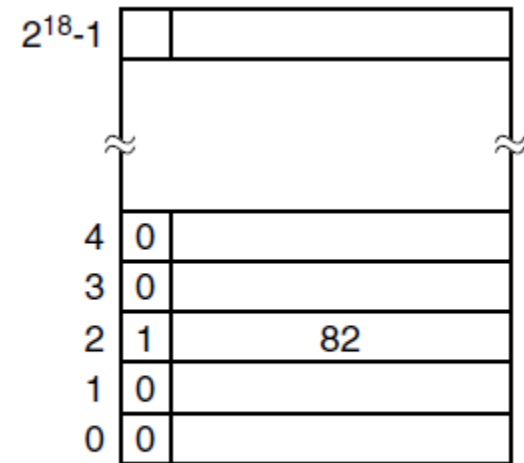
Figure 8-6. (a) A 256-node directory-based multiprocessor



# NUMA Multiprocessors (3)



(b)



(c)

Figure 8-6. (b) Division of a 32-bit memory address into fields. (c) The directory at node 36.

# Multiprocessor Operating System Types

## Each CPU Has Its Own Operating System

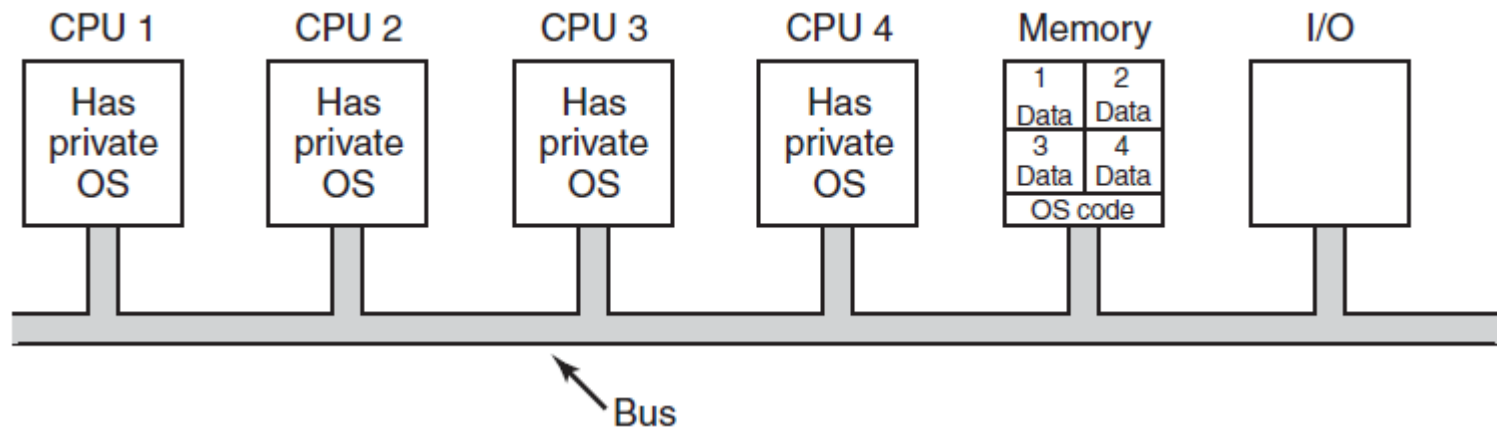


Figure 8-7. Partitioning multiprocessor memory among four CPUs, but sharing a single copy of the operating system code. The boxes marked Data are the operating system's private data for each CPU.

# Master-Slave Multiprocessors

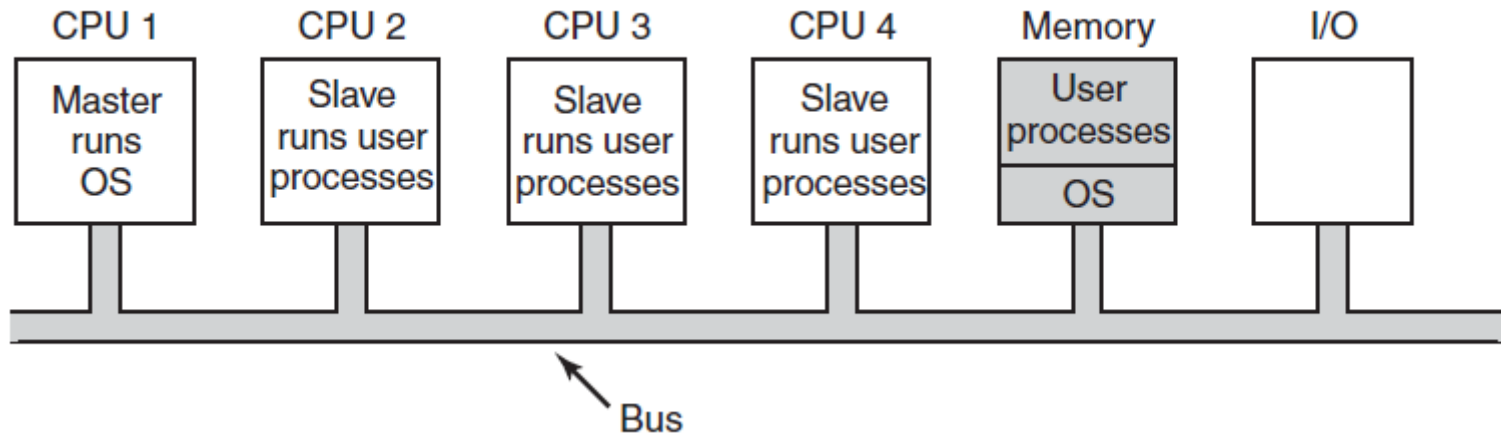


Figure 8-8. A master-slave multiprocessor model.

# Symmetric Multiprocessors

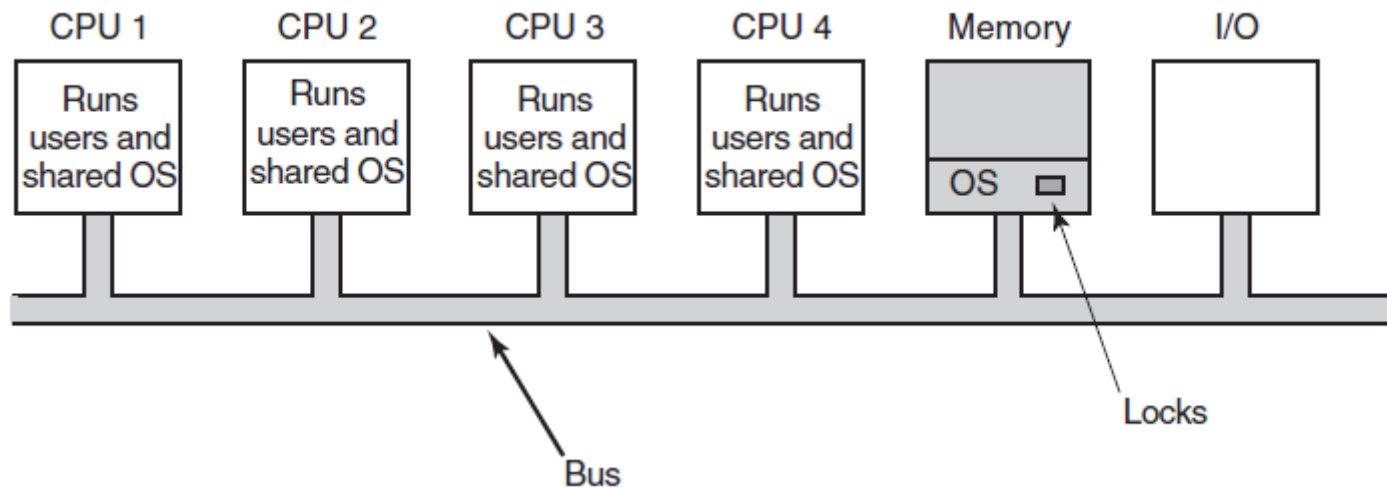


Figure 8-9. The SMP multiprocessor model.

# Multiprocessor Synchronization (1)

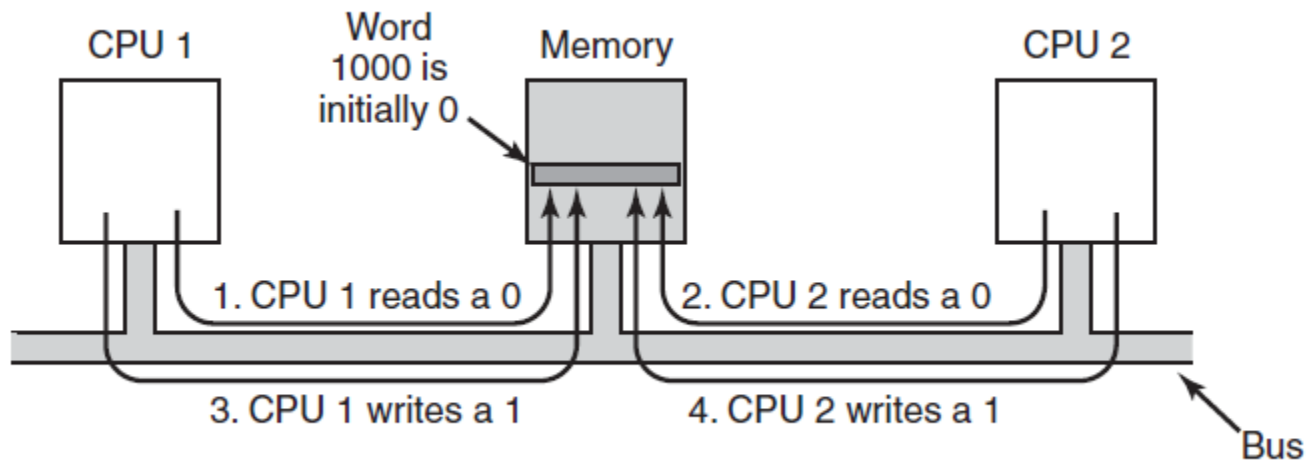


Figure 8-10. The TSL instruction can fail if the bus cannot be locked. These four steps show a sequence of events where the failure is demonstrated.

# Multiprocessor Synchronization (2)

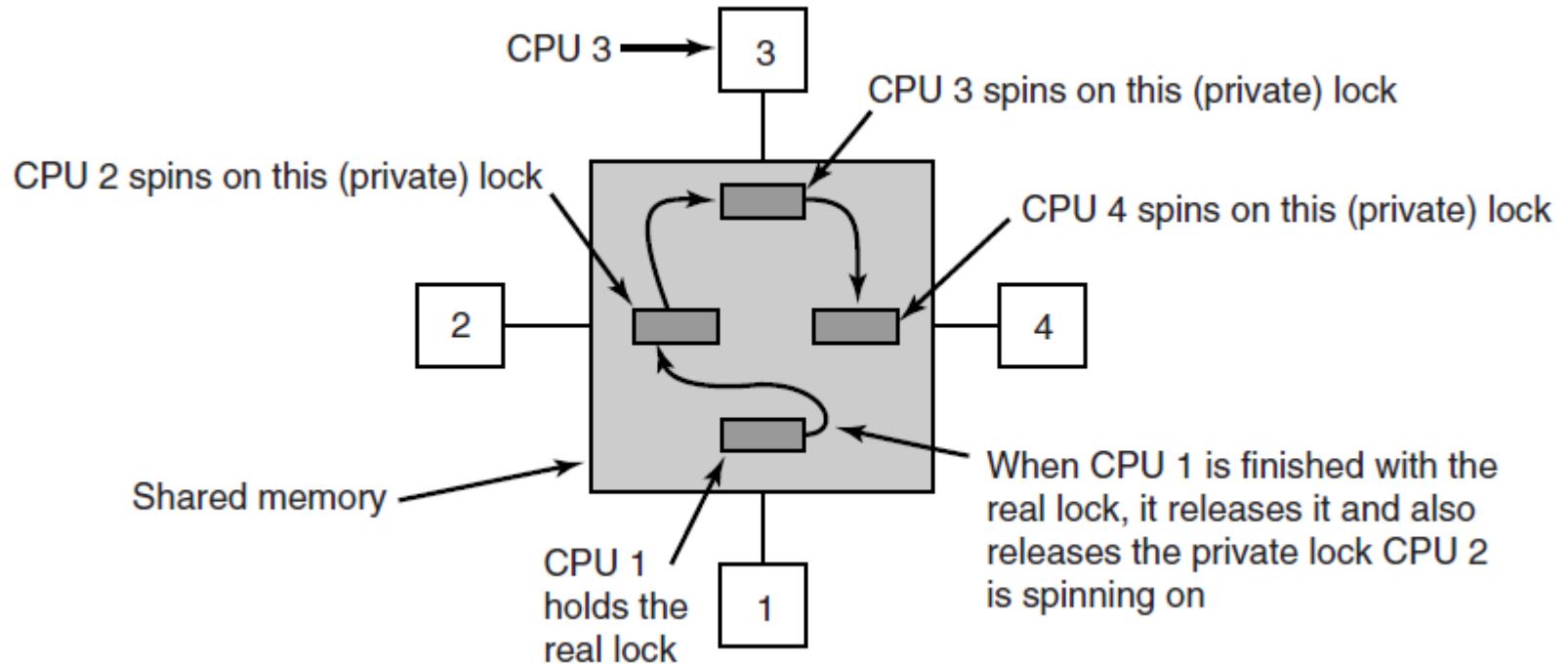


Figure 8-11. Use of multiple locks to avoid cache thrashing.

# Time Sharing

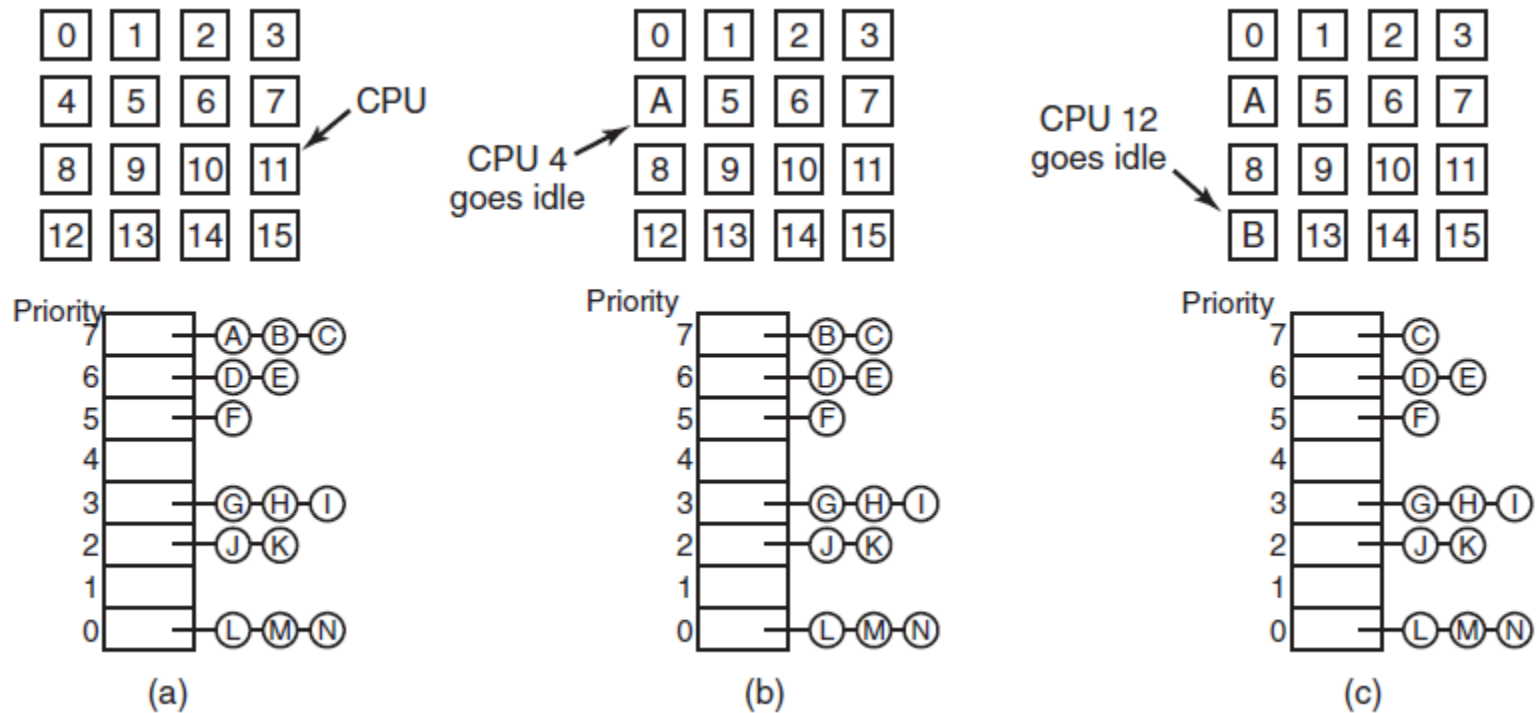


Figure 8-12. Using a single data structure for scheduling a multiprocessor.

# Space Sharing

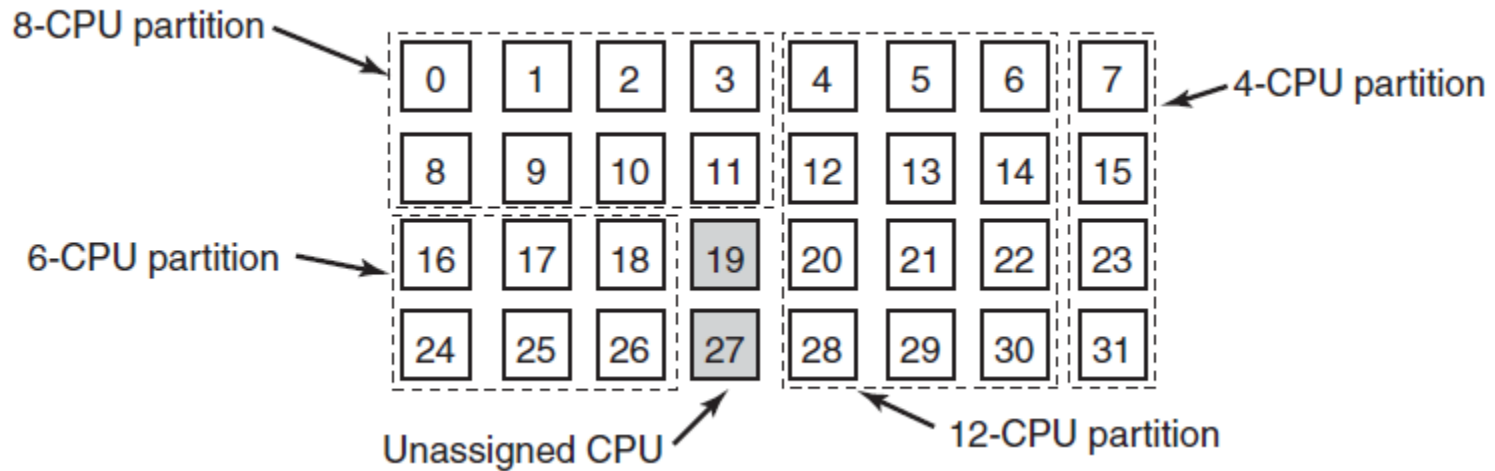


Figure 8-13. A set of 32 CPUs split into four partitions, with two CPUs available.



# Gang Scheduling (1)

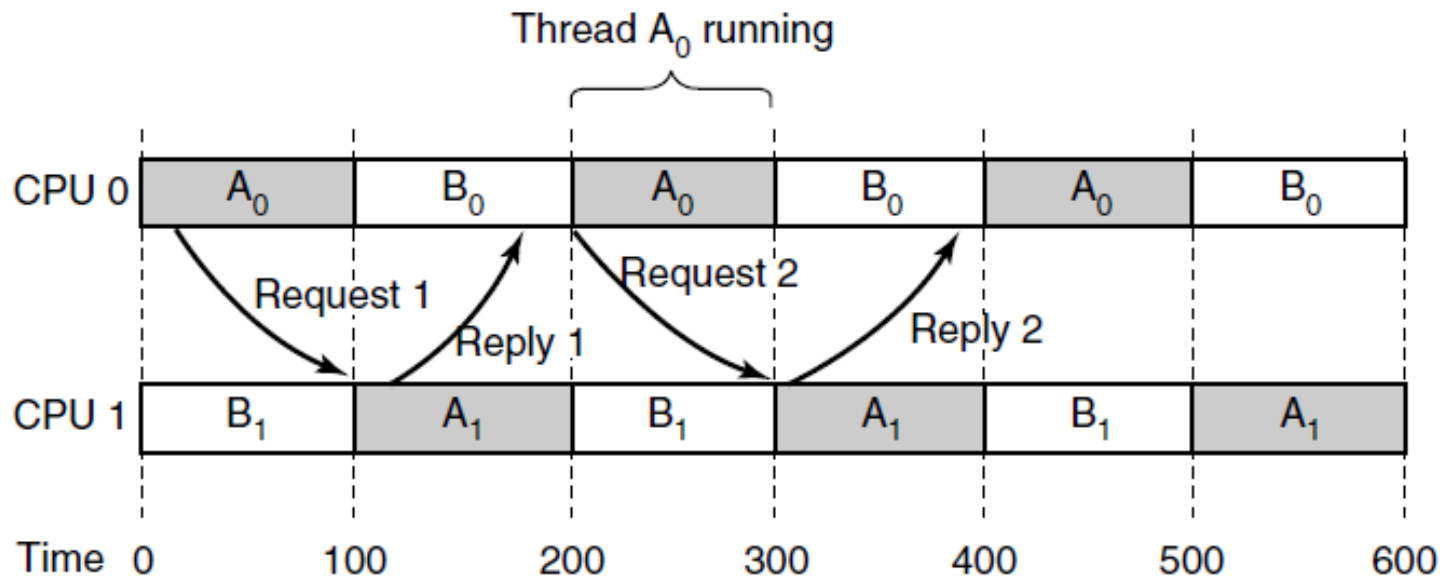


Figure 8-14. Communication between two threads belonging to thread A that are running out of phase.

# Gang Scheduling (2)

Gang scheduling has three parts:

- 1.Groups of related threads are scheduled as a unit, a gang.
- 2.All members of a gang run at once on different timeshared CPUs.
- 3.All gang members start and end their time slices together.

# Gang Scheduling (3)

		CPU					
		0	1	2	3	4	5
Time slot	0	A <sub>0</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>
	1	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	C <sub>0</sub>	C <sub>1</sub>	C <sub>2</sub>
	2	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	E <sub>0</sub>
	3	E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>
	4	A <sub>0</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>
	5	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	C <sub>0</sub>	C <sub>1</sub>	C <sub>2</sub>
	6	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	E <sub>0</sub>
	7	E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>

Figure 8-15. Gang scheduling.

# Interconnection Technology (1)

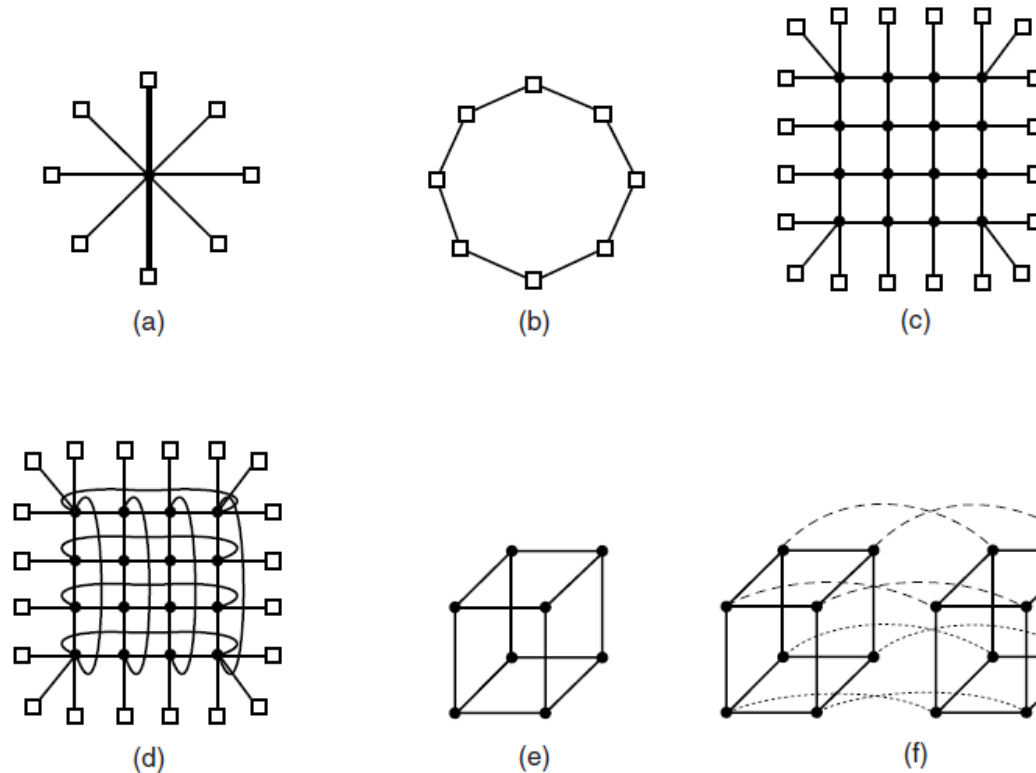


Figure 8-16. Various interconnect topologies. (a) A single switch. (b) A ring. (c) A grid. (d) A double torus. (e) A cube. (f) A 4D hypercube.

# Interconnection Technology (2)

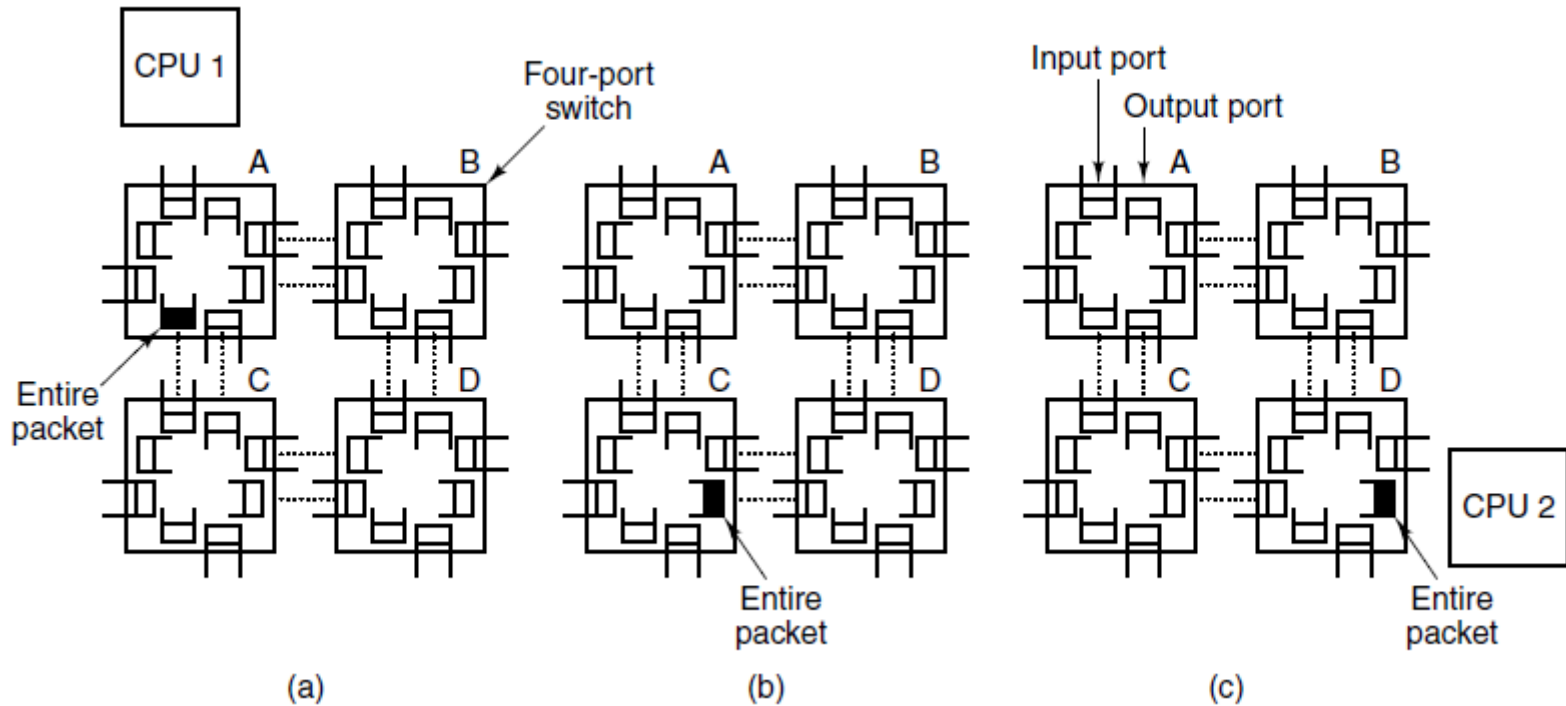


Figure 8-17. Store-and-forward packet switching.

# Network Interfaces

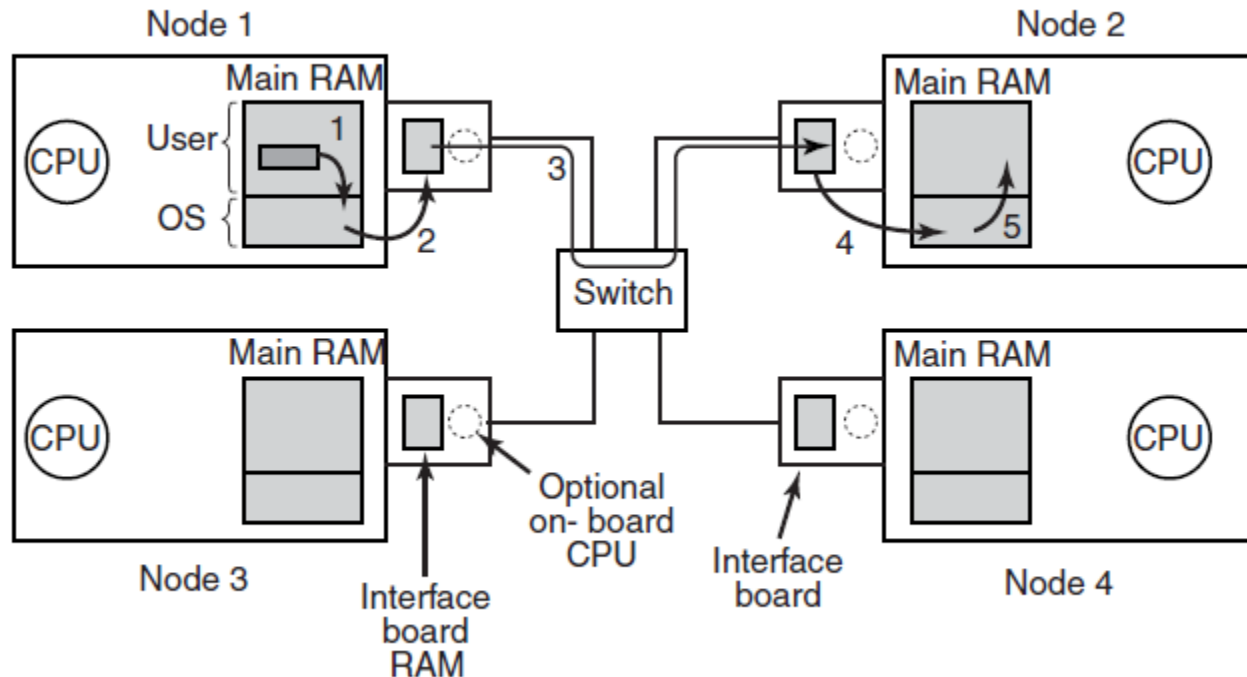


Figure 8-18. Position of the network interface boards in a multicomputer.

# Blocking versus Nonblocking Calls (1)

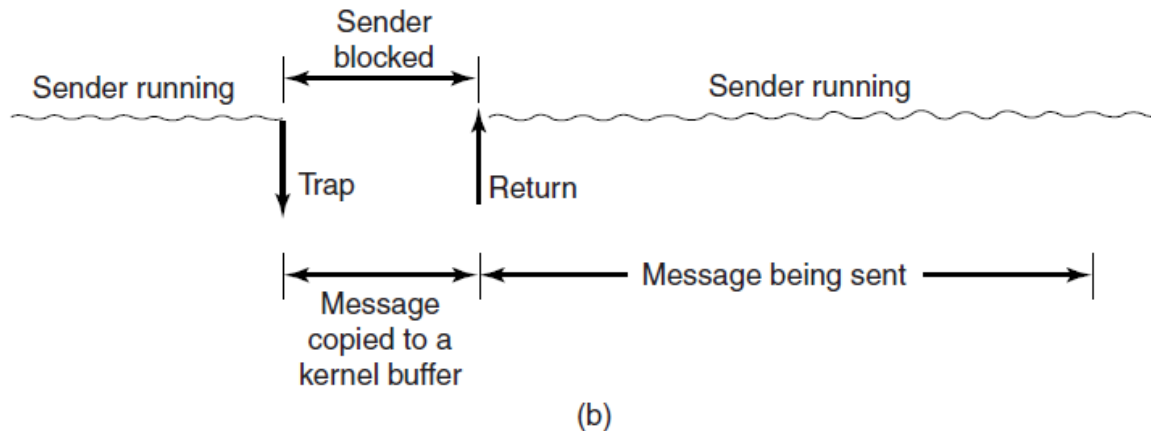
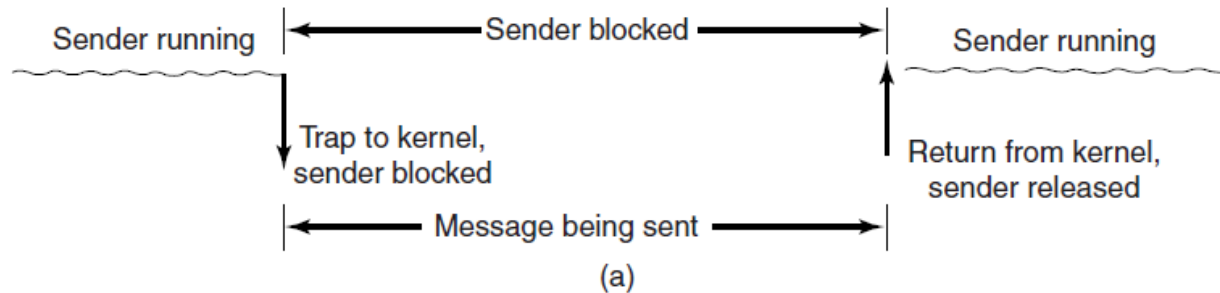


Figure 8-19. (a) A blocking send call.  
(b) A nonblocking send call.

# Blocking versus Nonblocking Calls (2)

Choices on the sending side:

1. Blocking send (CPU idle during transmission).
2. Nonblocking send with copy (CPU time wasted for the extra copy).
3. Nonblocking send with interrupt (makes programming difficult).
4. Copy on write (extra copy probably needed eventually).



# Remote Procedure Call

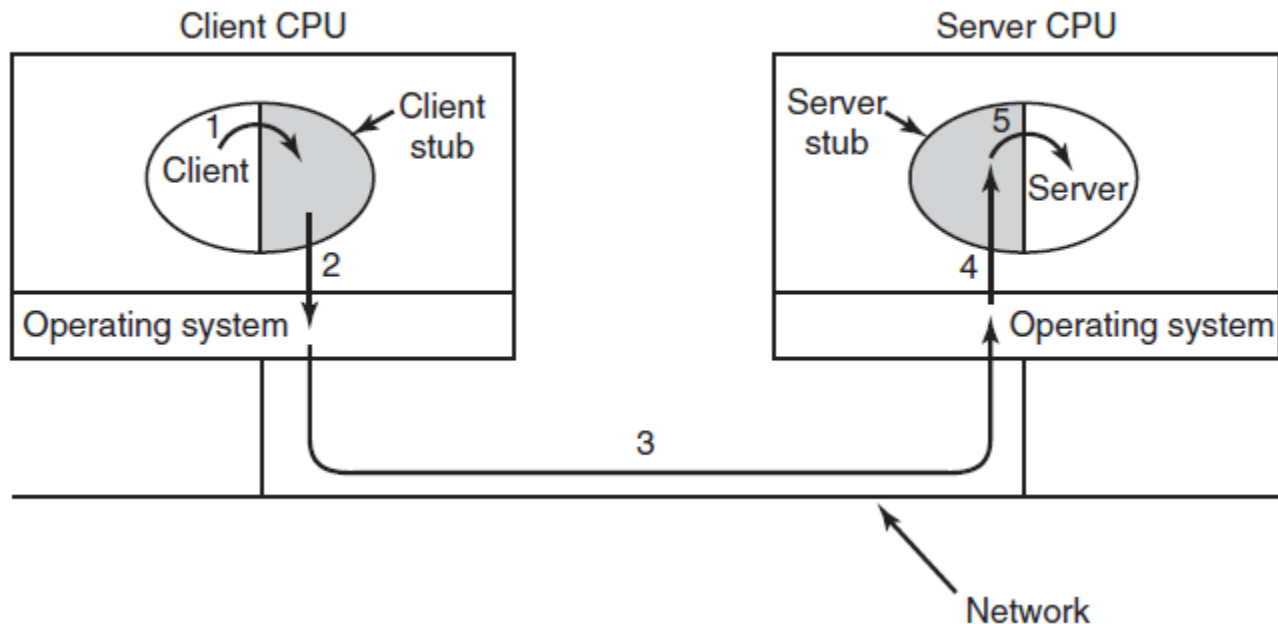


Figure 8-20. Steps in making a remote procedure call.  
The stubs are shaded gray.

# Distributed Shared Memory (1)

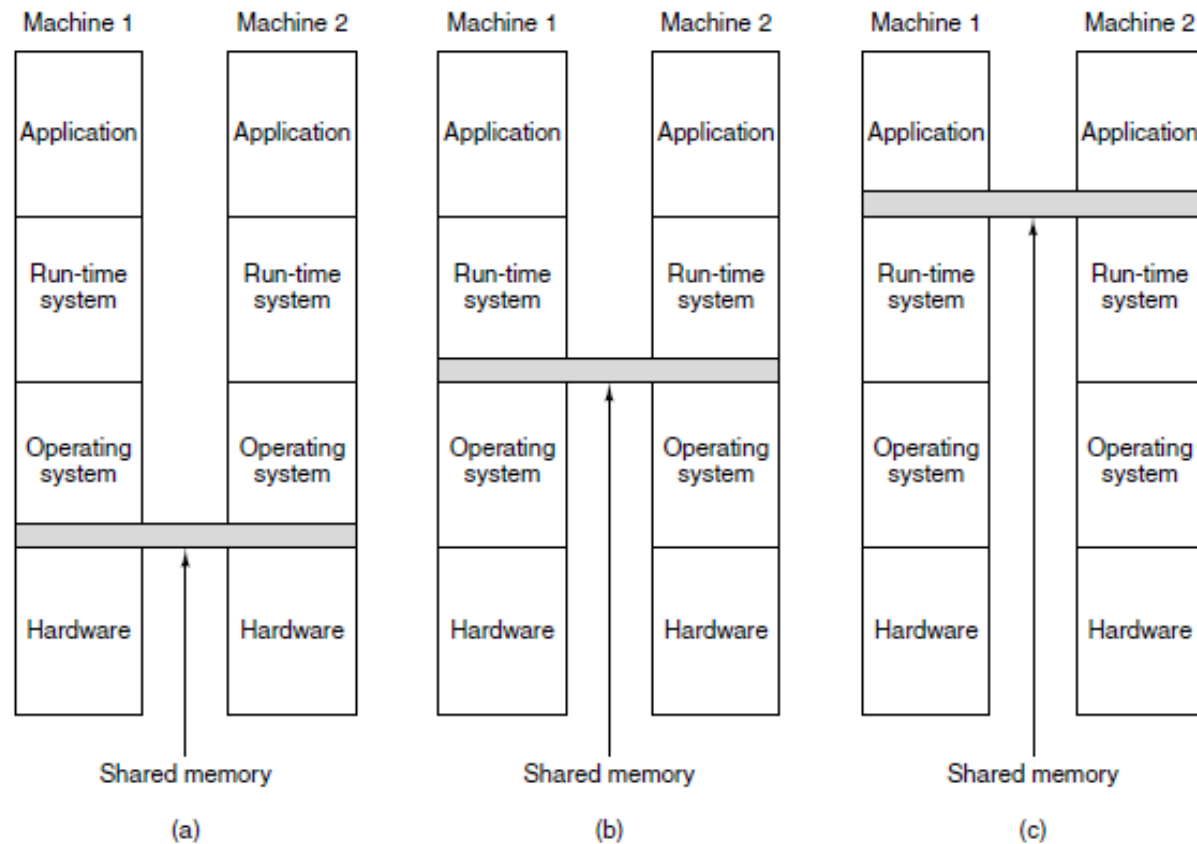


Figure 8-21. Various layers where shared memory can be implemented. (a) The hardware. (b) The operating system. (c) User-level software.

# Distributed Shared Memory (2)

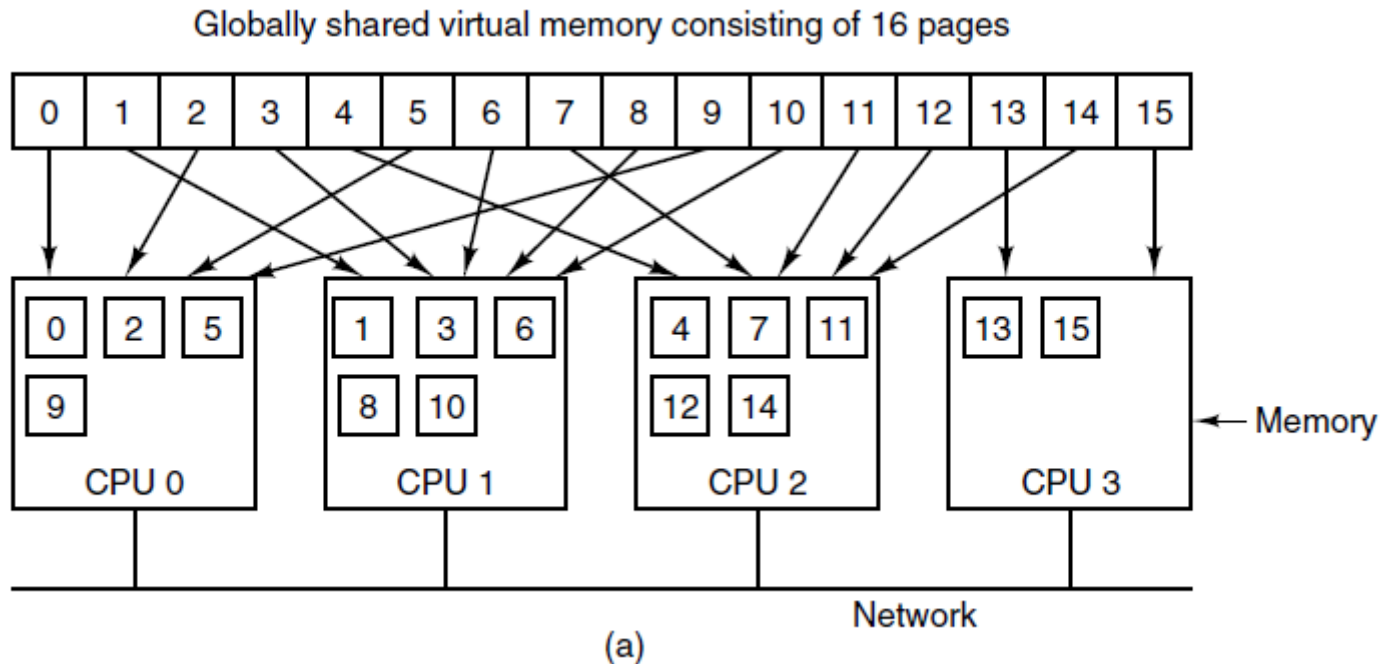


Figure 8-22. (a) Pages of the address space distributed among four machines.

# Distributed Shared Memory (3)

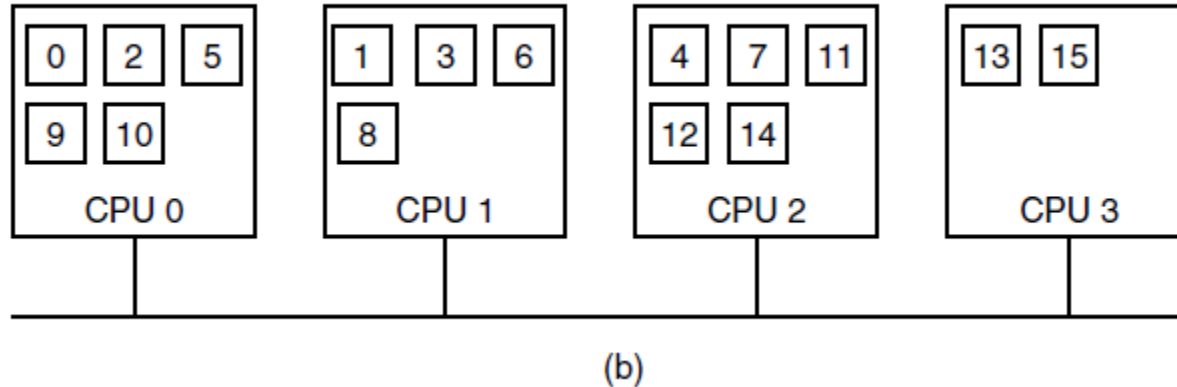


Figure 8-22. (b) Situation after CPU 1 references page 10 and the page is moved there.

# Distributed Shared Memory (4)

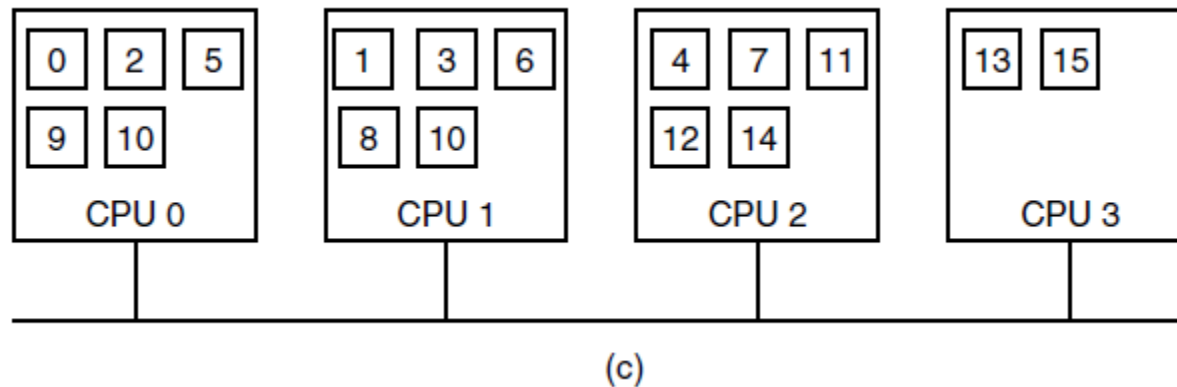


Figure 8-22. (c) Situation if page 10 is read only and replication is used.

# False Sharing

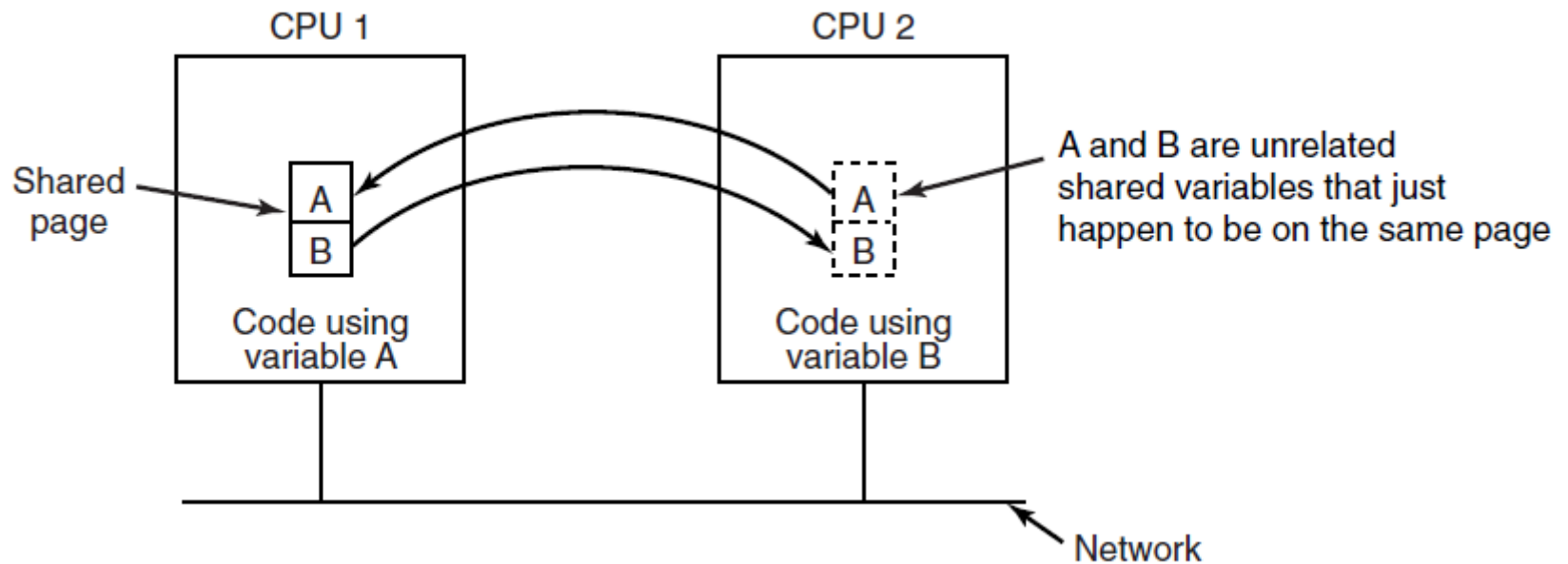


Figure 8-23. False sharing of a page containing two unrelated variables.

# Graph-Theoretic Deterministic Algorithm

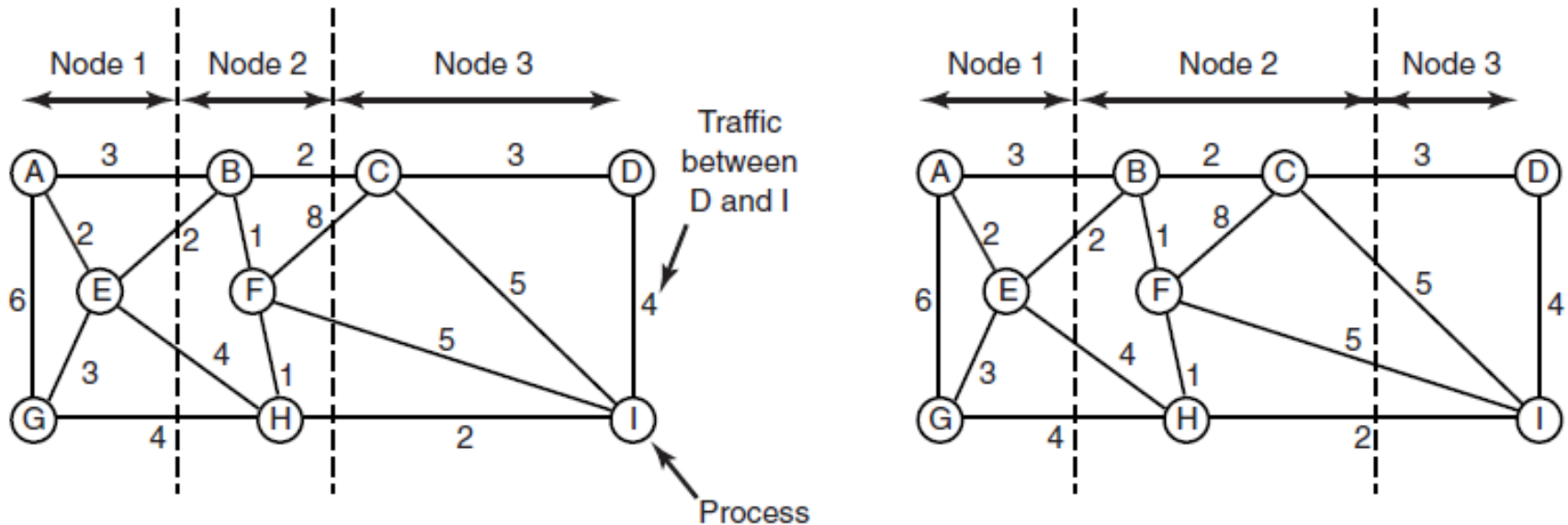


Figure 8-24. Two ways of allocating nine processes to three nodes.

# Sender-Initiated Distributed Heuristic Algorithm

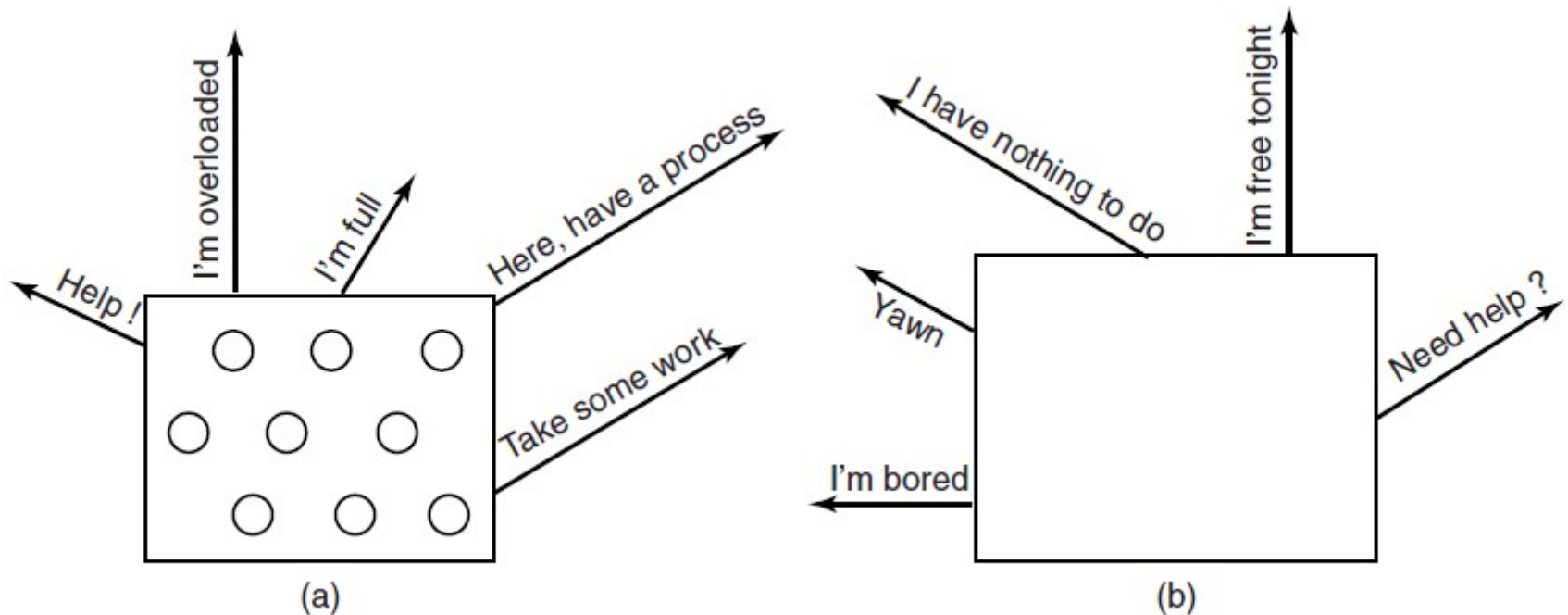


Figure 8-25. (a) An overloaded node looking for a lightly loaded node to hand off processes to. (b) An empty node looking for work to do.



# Distributed Systems (1)

Item	Multiprocessor	Multicomputer	Distributed System
Node configuration	CPU	CPU, RAM, net interface	Complete computer
Node peripherals	All shared	Shared exc. maybe disk	Full set per node
Location	Same rack	Same room	Possibly worldwide
Internode communication	Shared RAM	Dedicated interconnect	Traditional network
Operating systems	One, shared	Multiple, same	Possibly all different
File systems	One, shared	One, shared	Each node has own
Administration	One organization	One organization	Many organizations

Figure 8-26. Comparison of three kinds of multiple CPU systems.

# Distributed Systems (2)

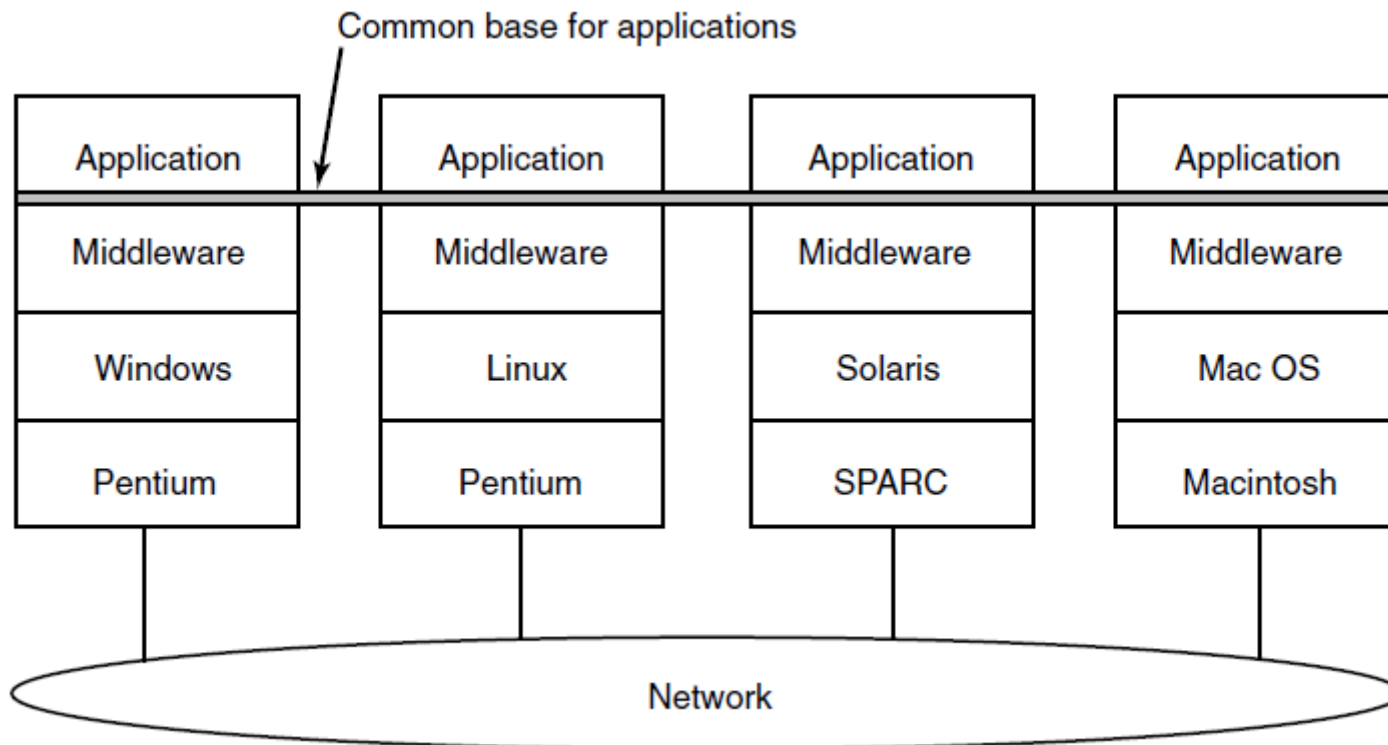


Figure 8-27. Positioning of middleware in a distributed system.

# Network Hardware

## Ethernet

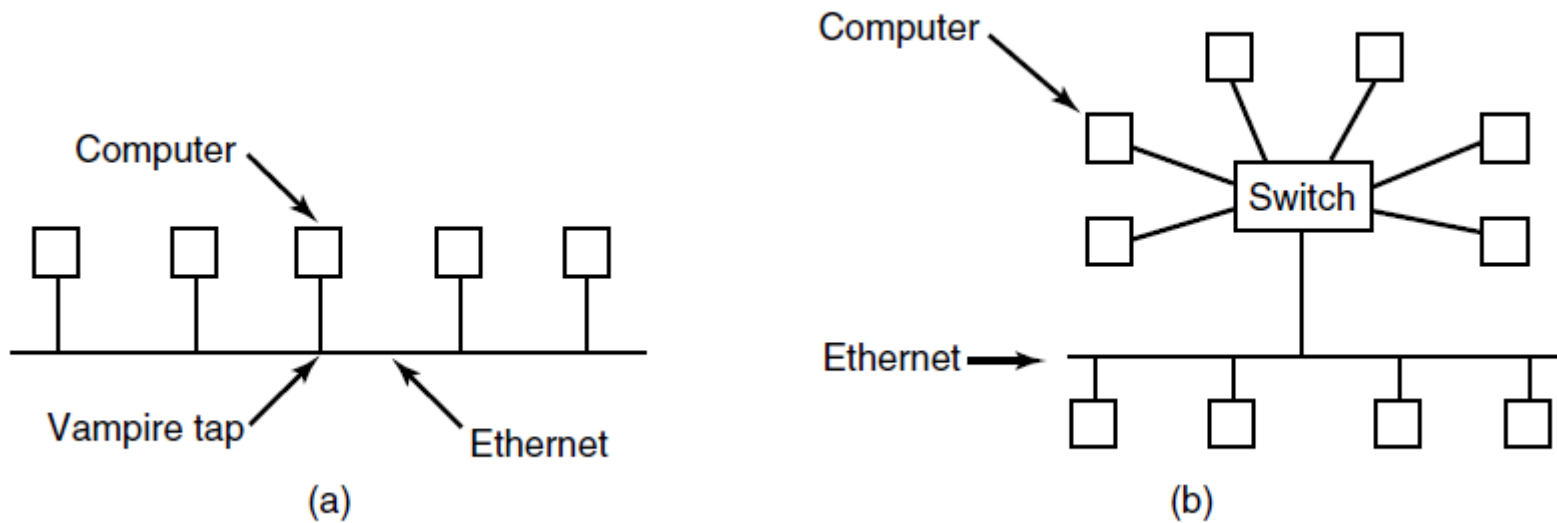


Figure 8-28. (a) Classic Ethernet. (b) Switched Ethernet.

# The Internet

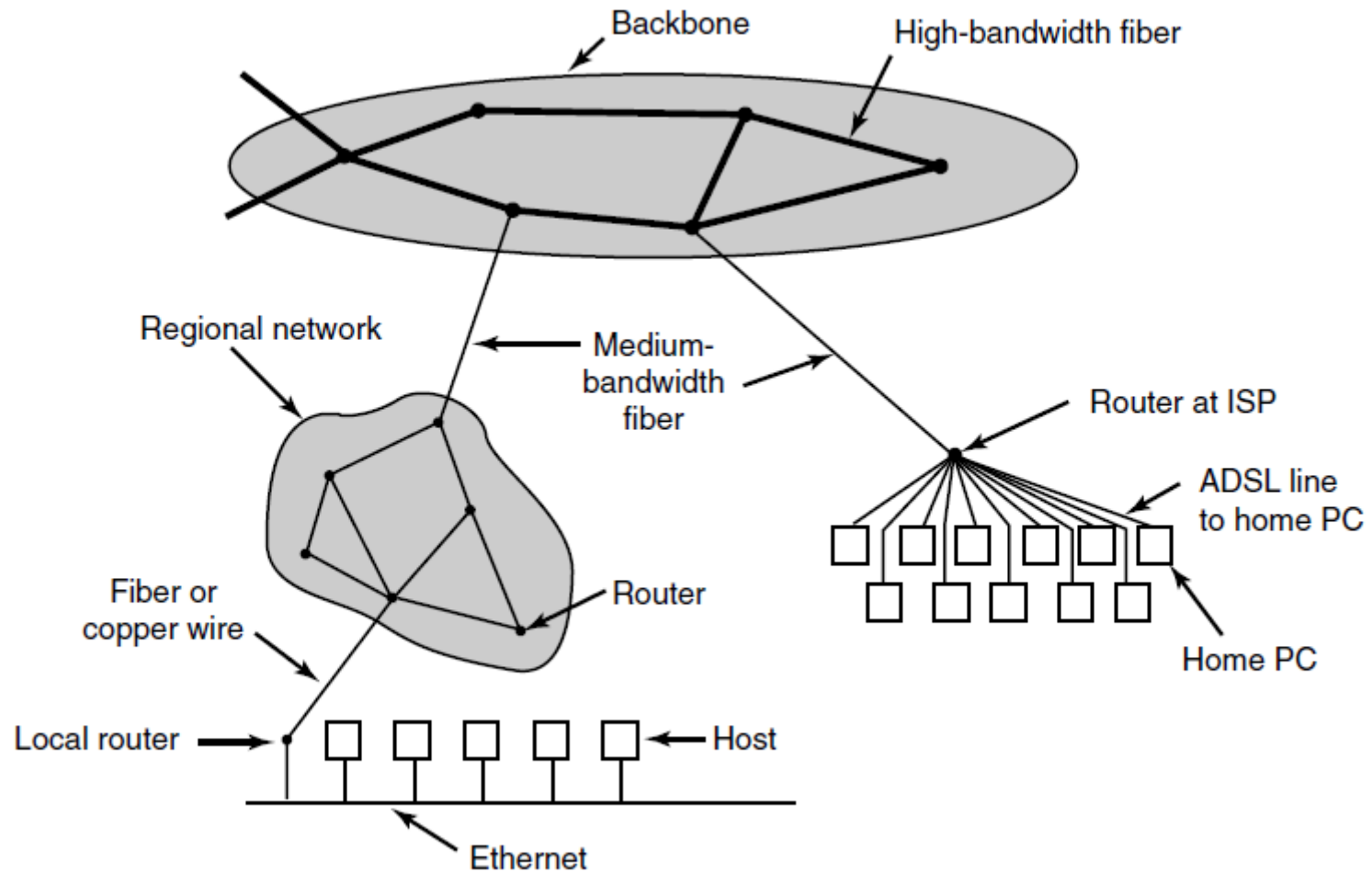


Figure 8-29. A portion of the Internet.

# Network Services

		Service	Example
Connection-oriented	{	Reliable message stream	Sequence of pages of a book
		Reliable byte stream	Remote login
		Unreliable connection	Digitized voice
Connectionless	{	Unreliable datagram	Network test packets
		Acknowledged datagram	Registered mail
		Request-reply	Database query

Figure 8-30. Six different types of network service.

# Network Protocols

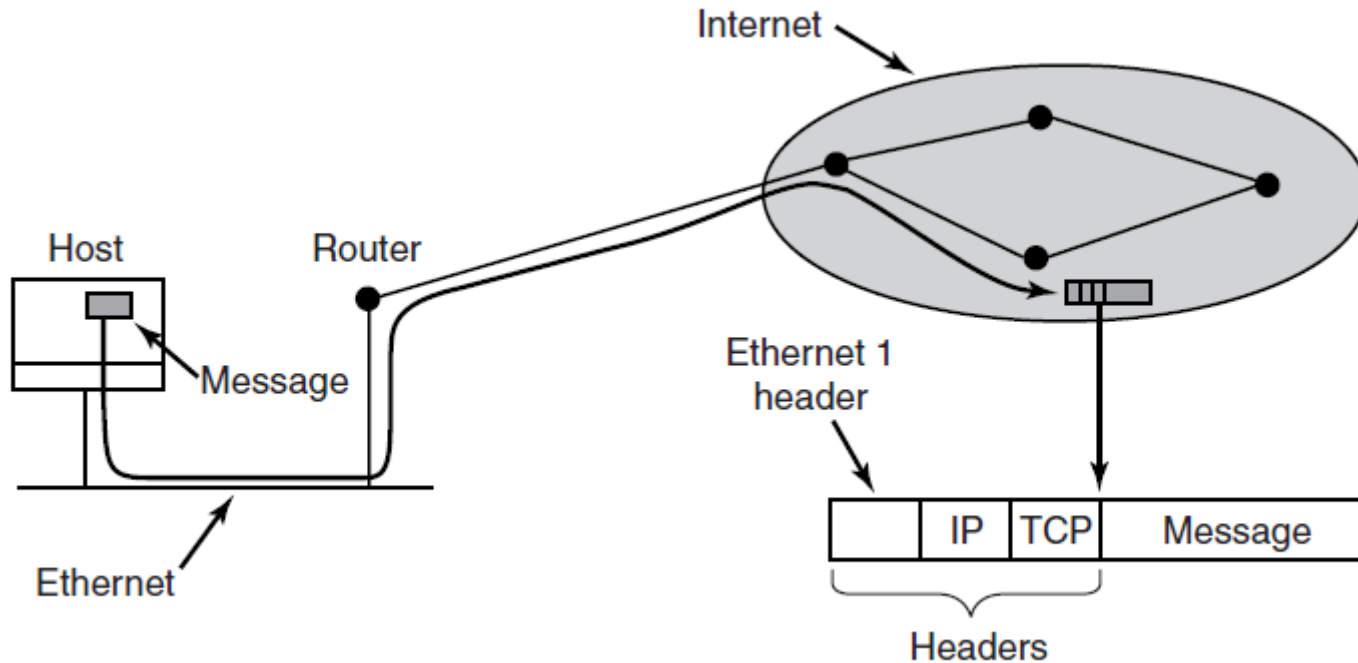


Figure 8-31. Accumulation of packet headers.

# Document-Based Middleware (1)

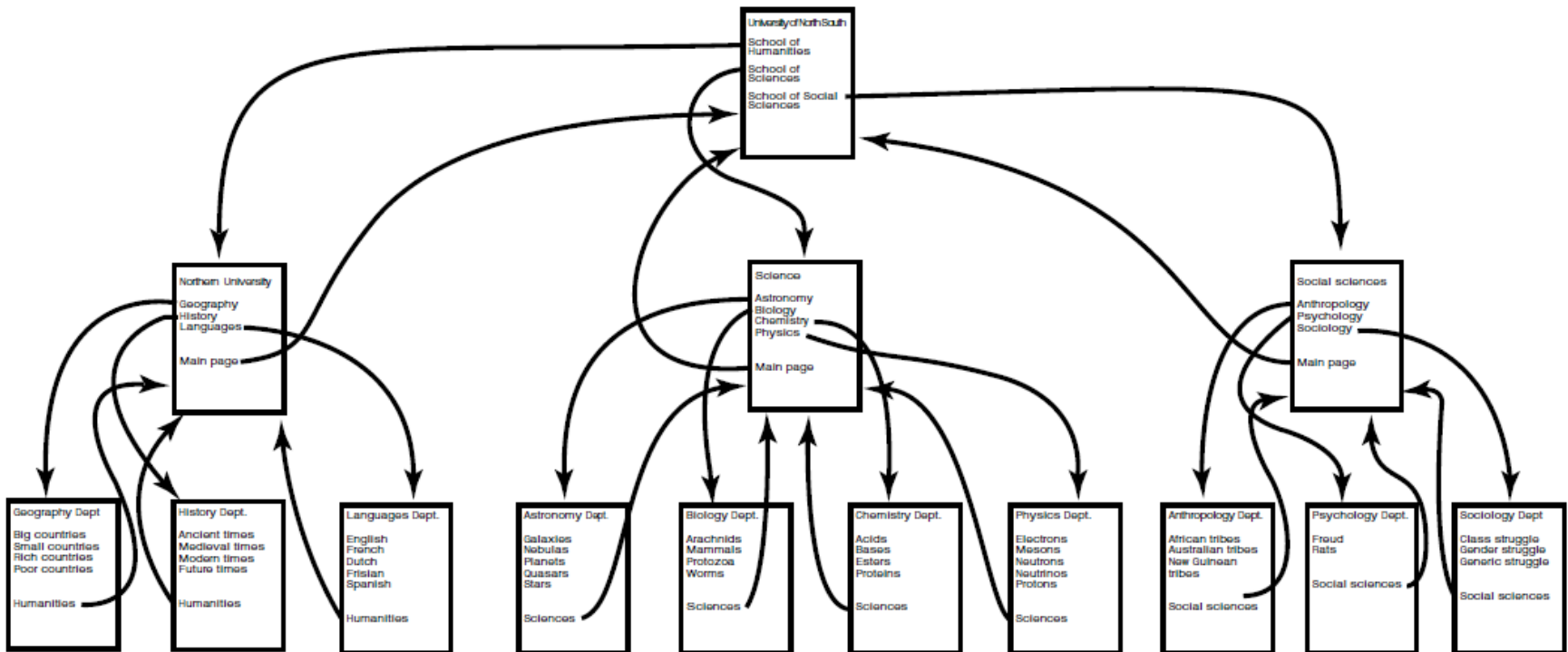


Figure 8-32. The Web is a big directed graph of documents.

# Document-Based Middleware (2)

For the browser to get the page

<http://www.minix3.org/getting-started/index.html>

1. Browser asks DNS for IP address of [www.minix3.org](http://www.minix3.org)

2. DNS replies with 66.147.238.215

3. Browser makes a TCP connection to port 80 on 66.147.238.215

4. Browser sends a request asking for the file [getting-started/index.html](http://www.minix3.org/getting-started/index.html)



# Document-Based Middleware (3)

5. The [www.minix3.org](http://www.minix3.org/getting-started/index.html) server sends the file [getting-started/index.html](http://www.minix3.org/getting-started/index.html)
6. Browser displays all the text in [getting-started/index.html](http://www.minix3.org/getting-started/index.html).
7. Browser also fetches and displays all images on the page
8. The TCP connection is released

# File-System-Based Middleware Transfer Model

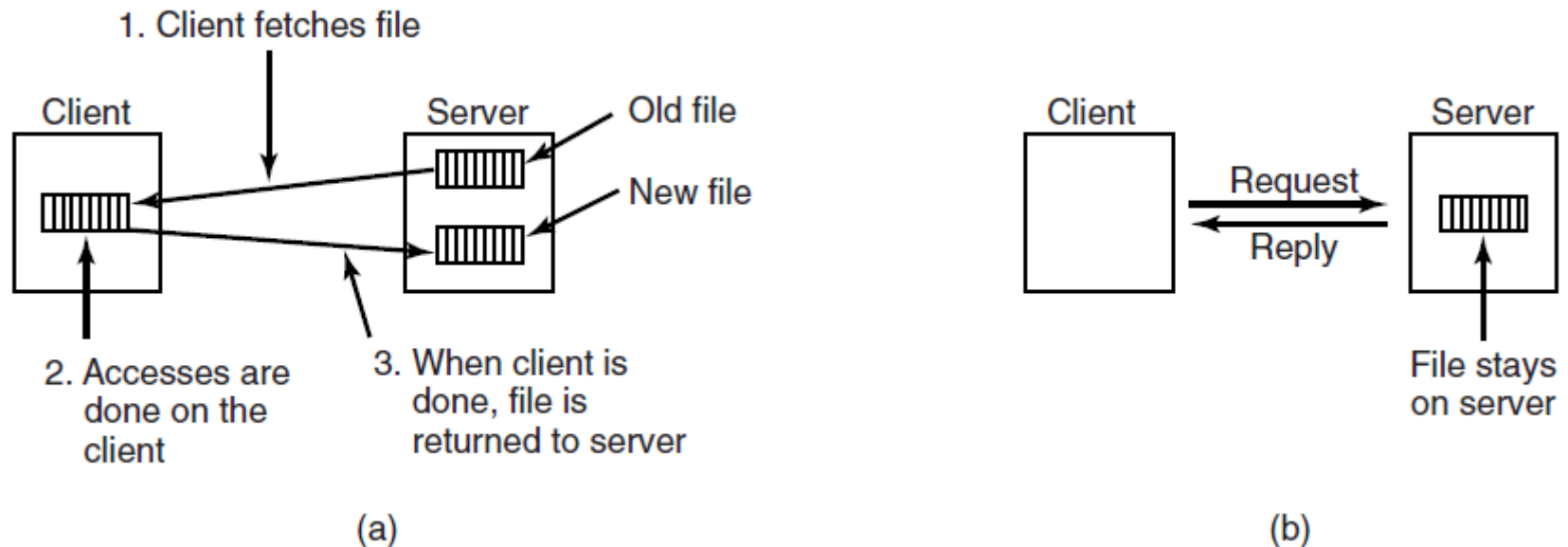


Figure 8-33. (a) The upload/download model.  
(b) The remote access model.

# The Directory Hierarchy

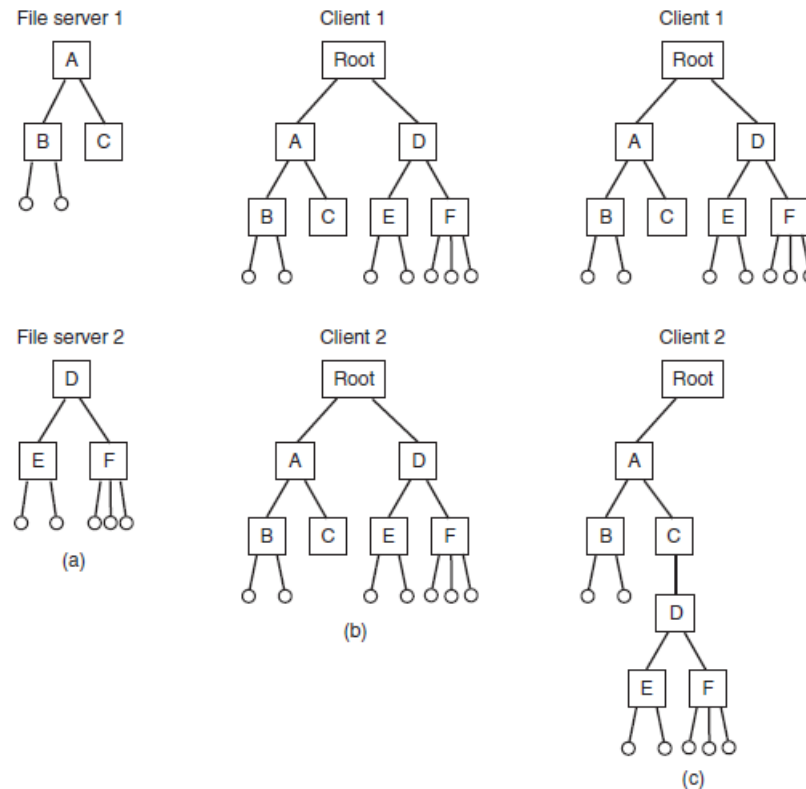


Figure 8-34. (a) Two file servers. The squares are directories and the circles are files. (b) A system in which all clients have the same view of the file system. (c) A system in which different clients may have different views of the file system.

# Naming Transparency

Common approaches to file and directory naming in a distributed system:

1. Machine + path naming, such as [/machine/path](#) or [machine:path](#).
2. Mounting remote file systems onto the local file hierarchy.
3. A single name space that looks the same on all machines.

# Semantics of File Sharing

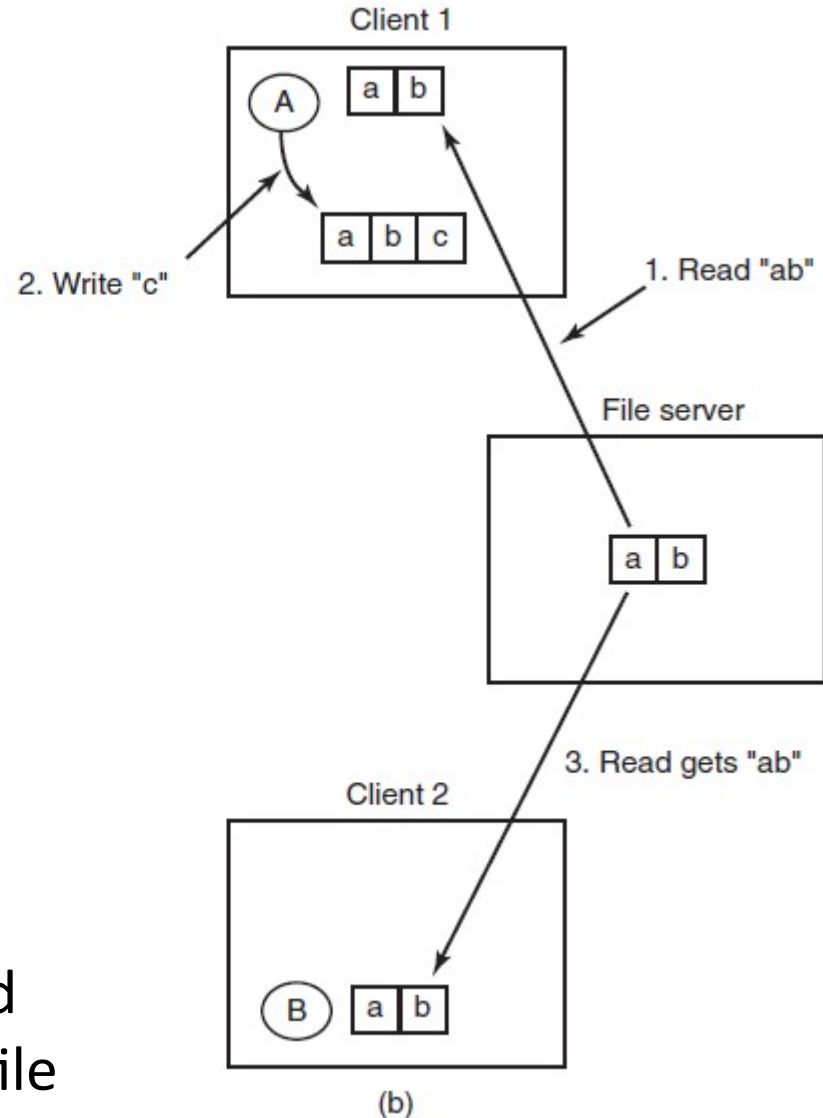
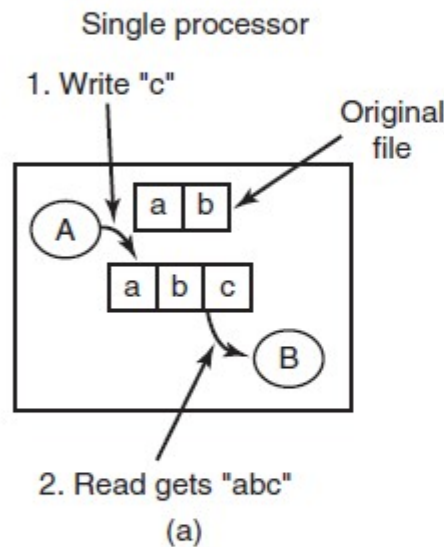


Figure 8-35. (a) Sequential consistency. (b) In a distributed system with caching, reading a file may return an obsolete value.

# Object-Based Middleware

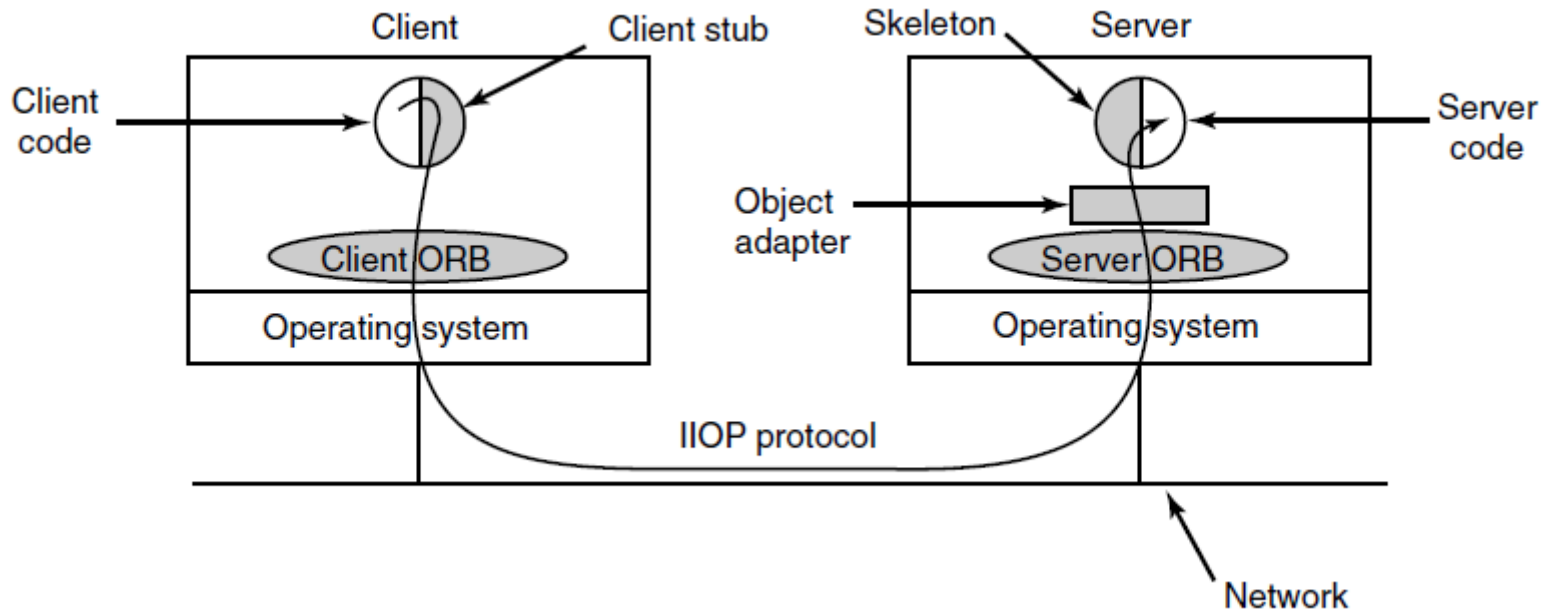


Figure 8-36. The main elements of a distributed system based on CORBA. The CORBA parts are shown in gray.

# Coordination-Based Middleware (1)

("abc", 2, 5)

("matrix-1", 1, 6, 3.14)

("family", "is-sister", "Stephany", "Roberta")

Figure 8-37. Three Linda tuples

# Coordination-Based Middleware (2)

A match occurs if the following three conditions are all met:

- 1.Template and tuple have the same number of fields.
- 2.Types of corresponding fields are equal.
- 3.Each constant or variable in the template matches its tuple field.



# Publish/Subscribe

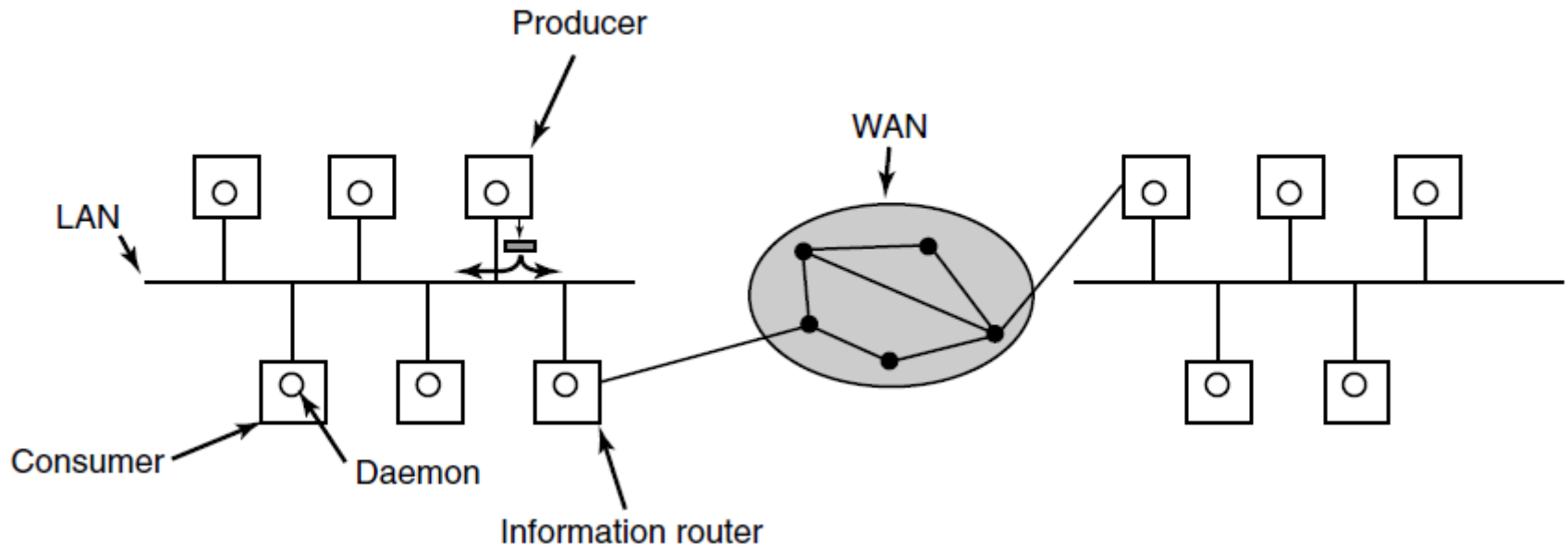


Figure 8-38. The publish/subscribe architecture.

End

## Chapter 8