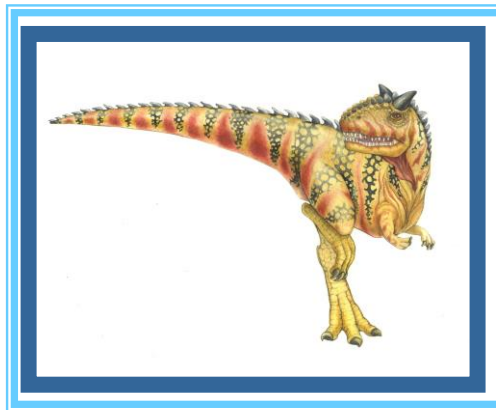


Threads

Day5: March 2022

Kiran Waghmare





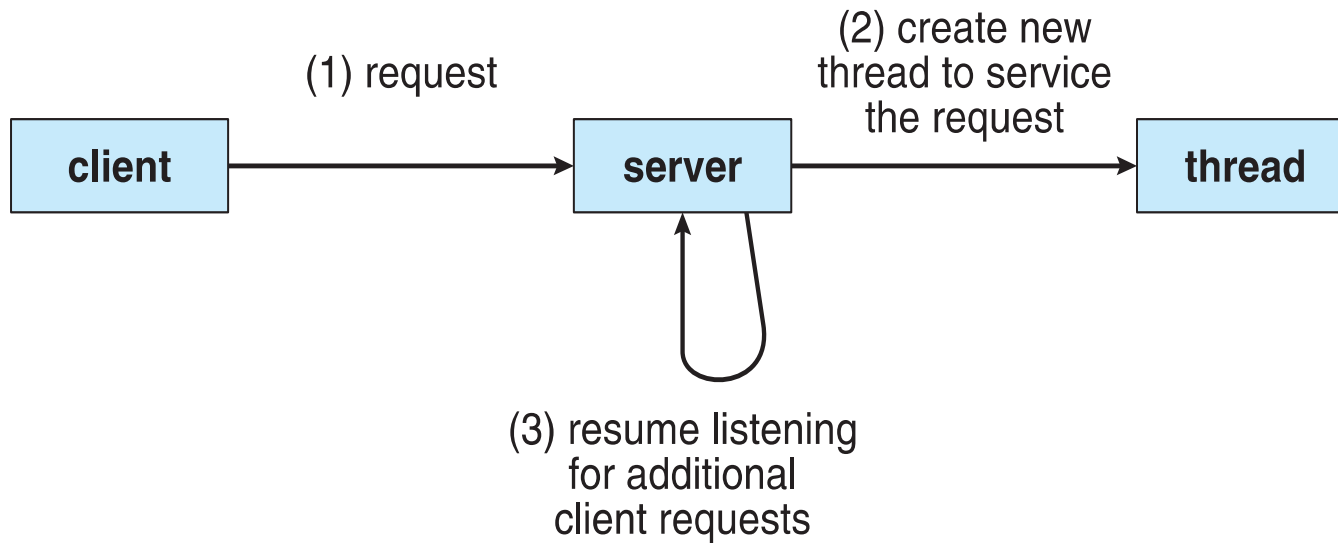
Threads

- Overview
- Multicore Programming
- Multithreading Models
- Thread Libraries





Multithreaded Server Architecture





Benefits

- **Responsiveness** – may allow continued execution if part of process is blocked, especially important for user interfaces
- **Resource Sharing** – threads share resources of process, easier than shared memory or message passing
- **Economy** – cheaper than process creation, thread switching lower overhead than context switching
- **Scalability** – process can take advantage of multiprocessor architectures





Multicore Programming

- **Multicore** or **multiprocessor** systems putting pressure on programmers, challenges include:
 - **Dividing activities**
 - **Balance**
 - **Data splitting**
 - **Data dependency**
 - **Testing and debugging**
- **Parallelism** implies a system can perform more than one task simultaneously
- **Concurrency** supports more than one task making progress
 - Single processor / core, scheduler providing concurrency





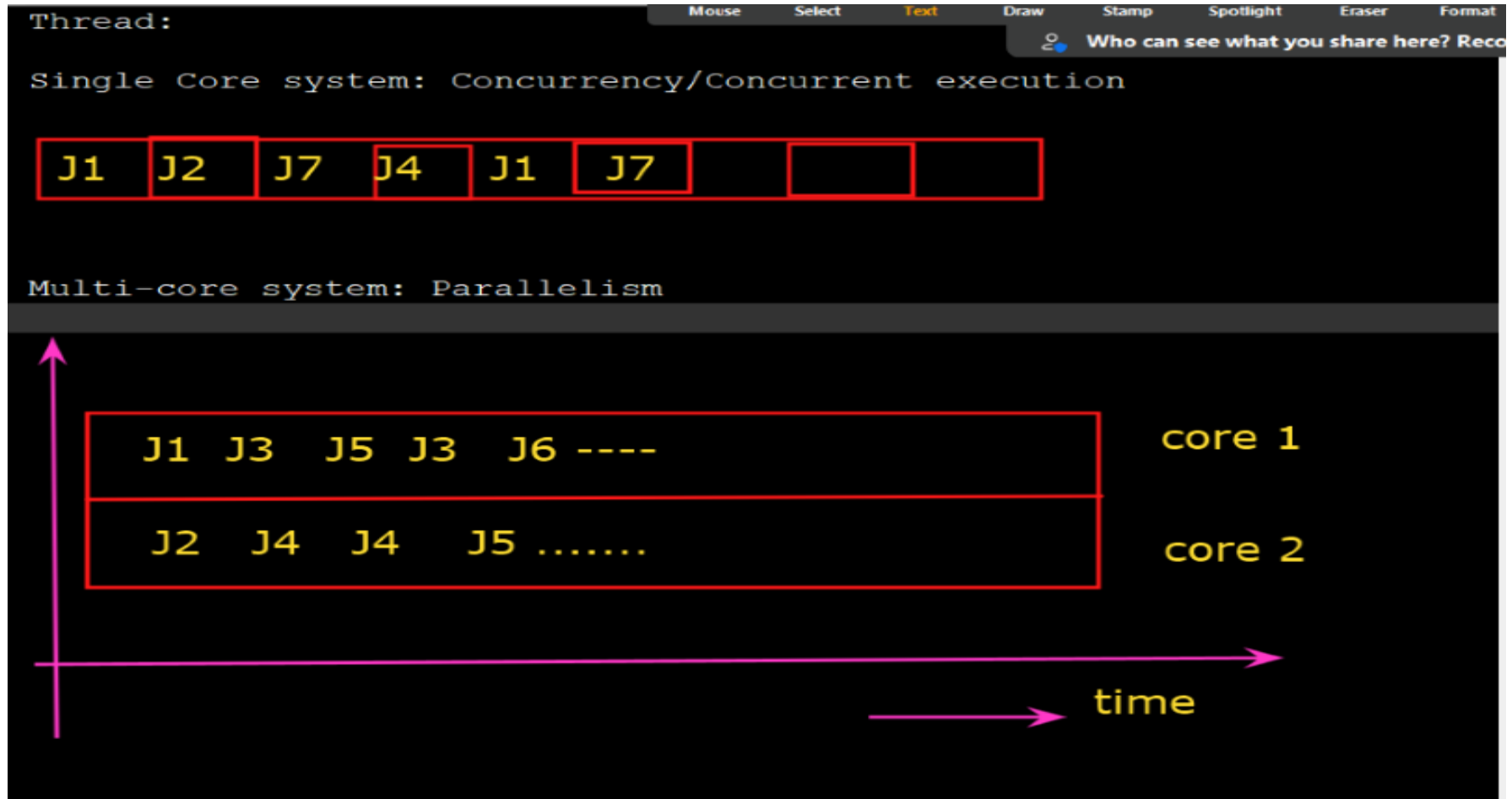
Multicore Programming (Cont.)

- Types of parallelism
 - **Data parallelism** – distributes subsets of the same data across multiple cores, same operation on each
 - **Task parallelism** – distributing threads across cores, each thread performing unique operation
- As # of threads grows, so does architectural support for threading
 - CPUs have cores as well as ***hardware threads***
 - Consider Oracle SPARC T4 with 8 cores, and 8 hardware threads per core



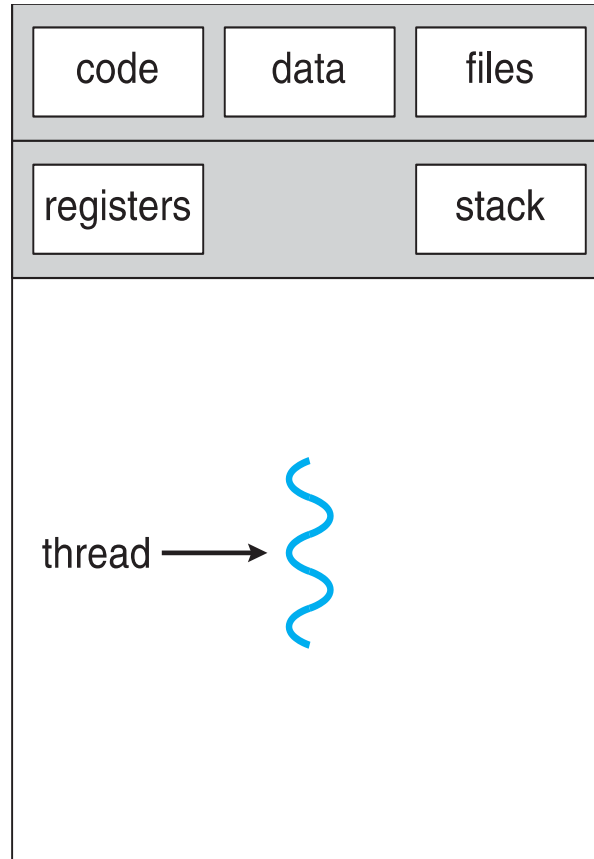


Concurrency vs. Parallelism

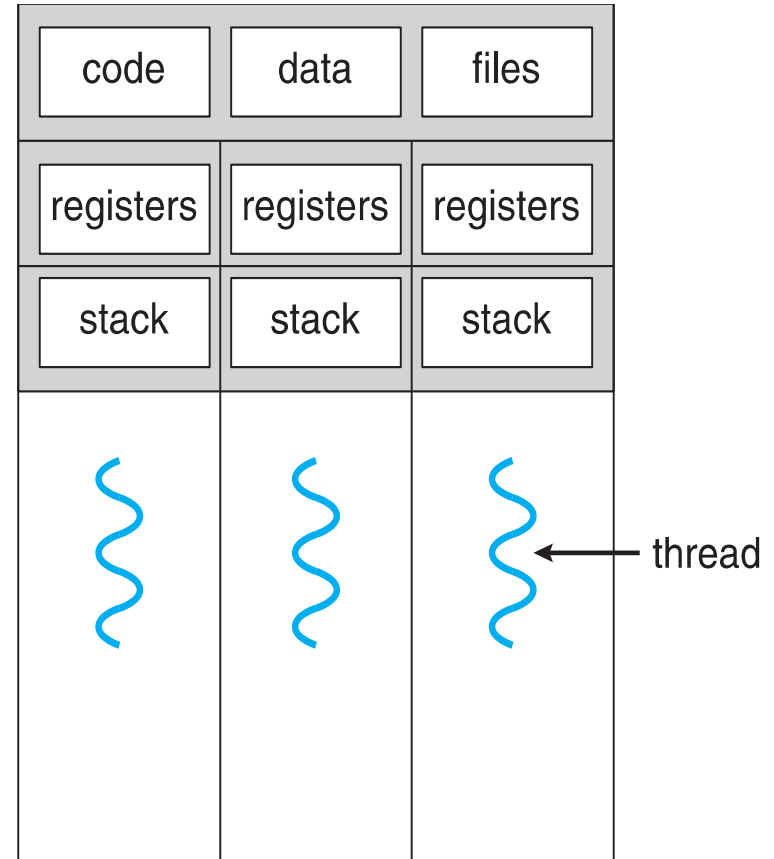




Single and Multithreaded Processes



single-threaded process



multithreaded process

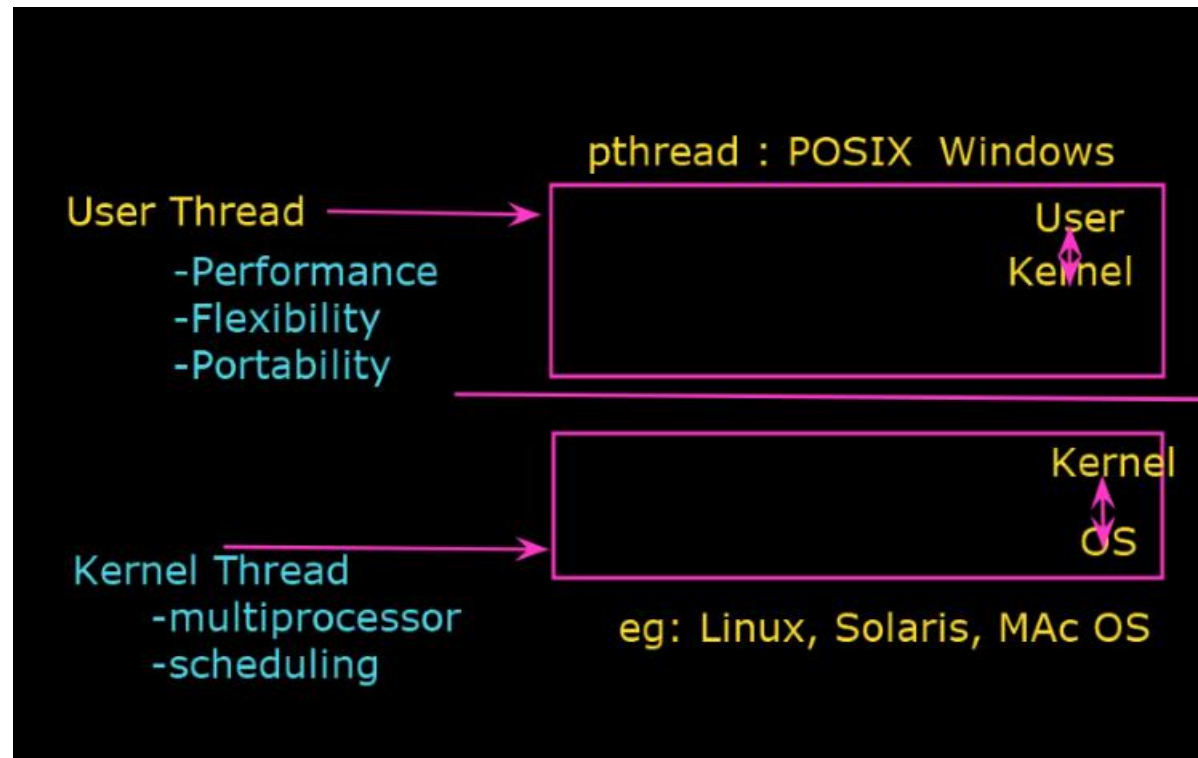




Types of Thread

■ There are two types of threads:

- User Threads
- Kernel Threads





User Threads and Kernel Threads

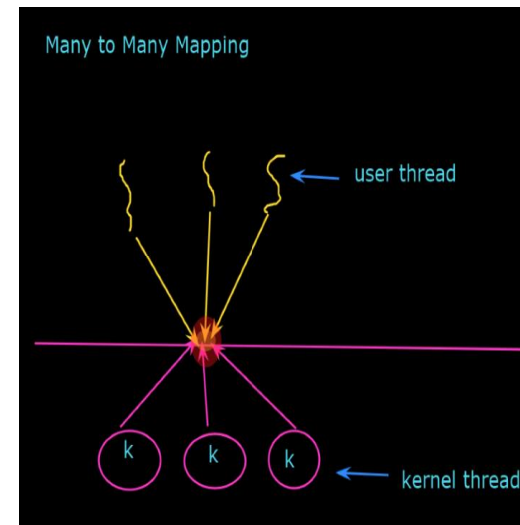
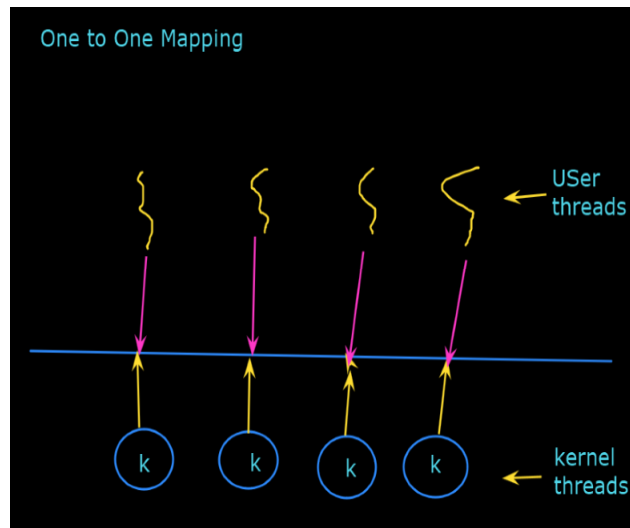
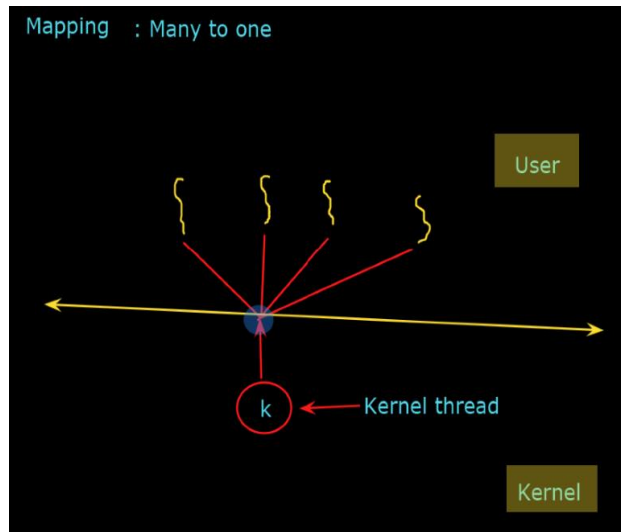
- **User threads** - management done by user-level threads library
- Three primary thread libraries:
 - POSIX **Pthreads**
 - Windows threads
 - Java threads
- **Kernel threads** - Supported by the Kernel
- Examples – virtually all general purpose operating systems, including:
 - Windows
 - Solaris
 - Linux
 - Tru64 UNIX
 - Mac OS X





Multithreading Models

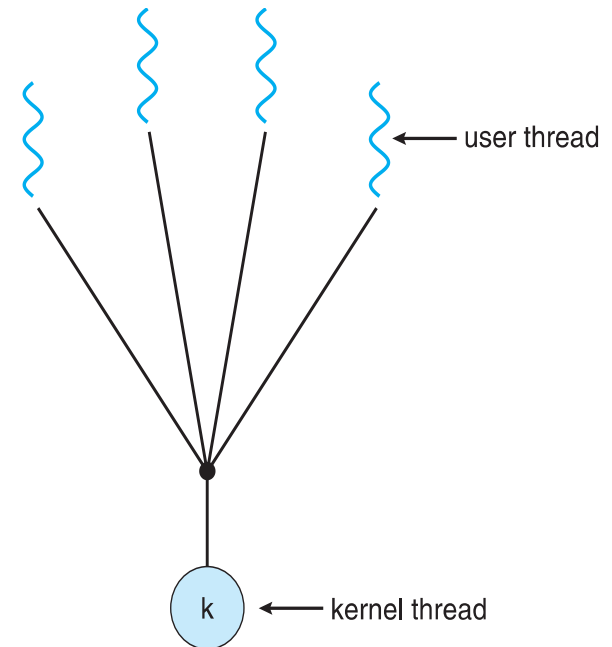
- Many-to-One
- One-to-One
- Many-to-Many





Many-to-One

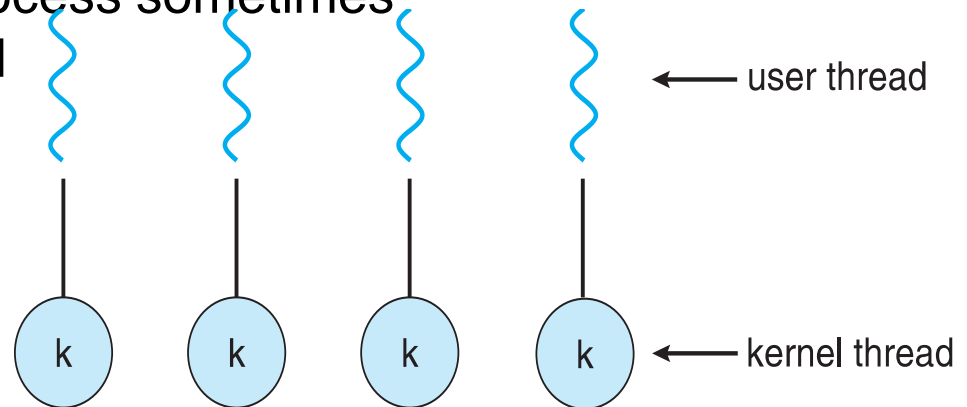
- Many user-level threads mapped to single kernel thread
- One thread blocking causes all to block
- Multiple threads may not run in parallel on muticore system because only one may be in kernel at a time
- Few systems currently use this model
- Examples:
 - **Solaris Green Threads**
 - **GNU Portable Threads**





One-to-One

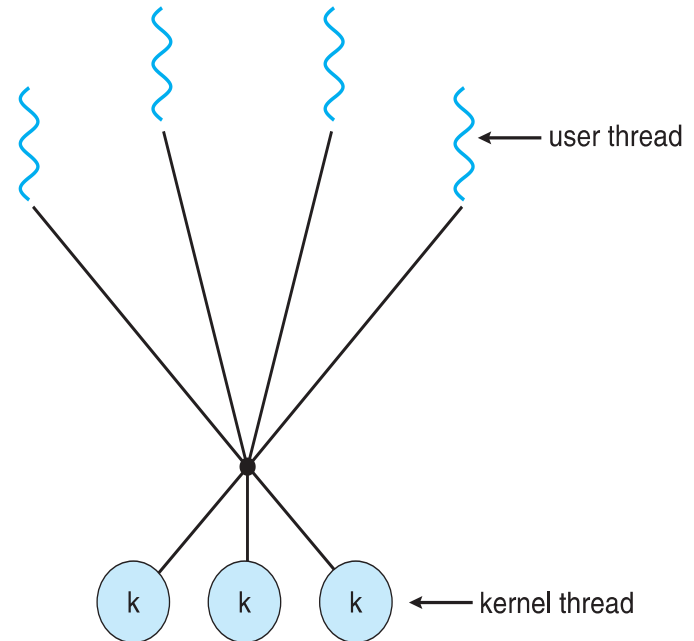
- Each user-level thread maps to kernel thread
- Creating a user-level thread creates a kernel thread
- More concurrency than many-to-one
- Number of threads per process sometimes restricted due to overhead
- Examples
 - Windows
 - Linux
 - Solaris 9 and later





Many-to-Many Model

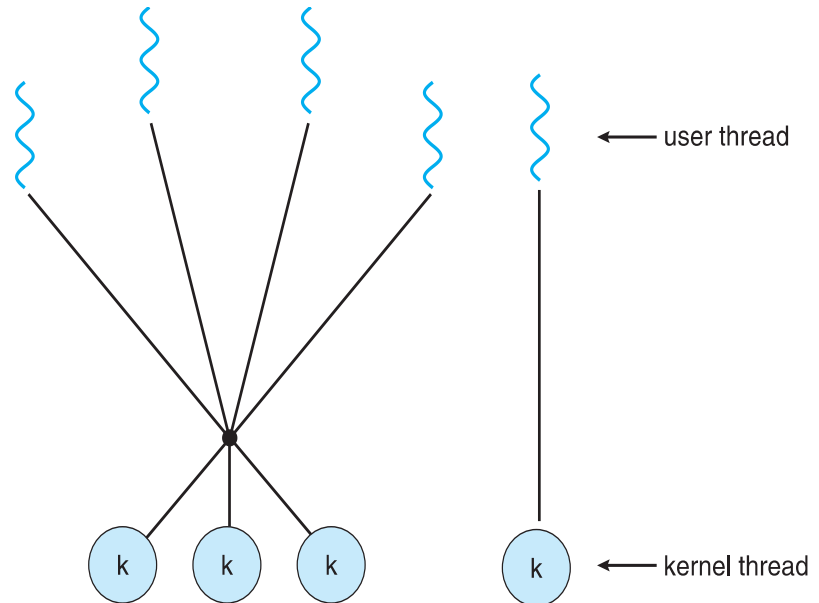
- Allows many user level threads to be mapped to many kernel threads
- Allows the operating system to create a sufficient number of kernel threads
- Solaris prior to version 9
- Windows with the *ThreadFiber* package





Two-level Model

- Similar to M:M, except that it allows a user thread to be **bound** to kernel thread
- Examples
 - IRIX
 - HP-UX
 - Tru64 UNIX
 - Solaris 8 and earlier





Thread Libraries

- **Thread library** provides programmer with API for creating and managing threads
- Two primary ways of implementing
 - Library entirely in user space
 - Kernel-level library supported by the OS



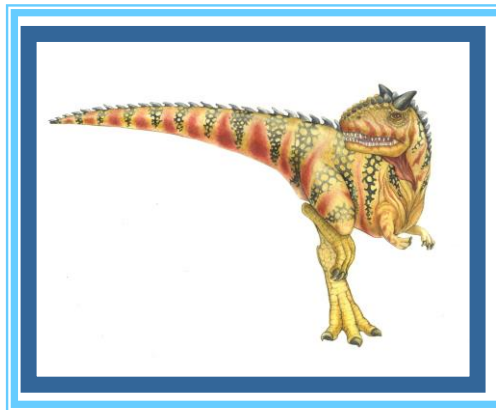


Pthreads

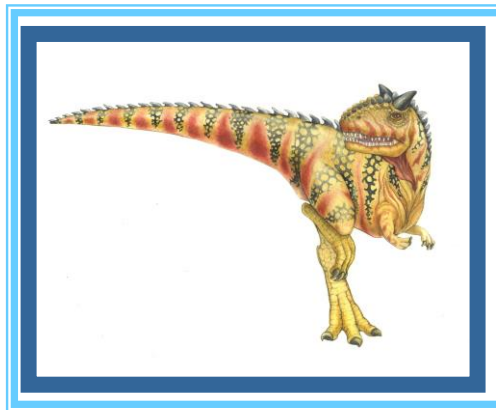
- May be provided either as user-level or kernel-level
- A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization
- ***Specification***, not ***implementation***
- API specifies behavior of the thread library, implementation is up to development of the library
- Common in UNIX operating systems (Solaris, Linux, Mac OS X)



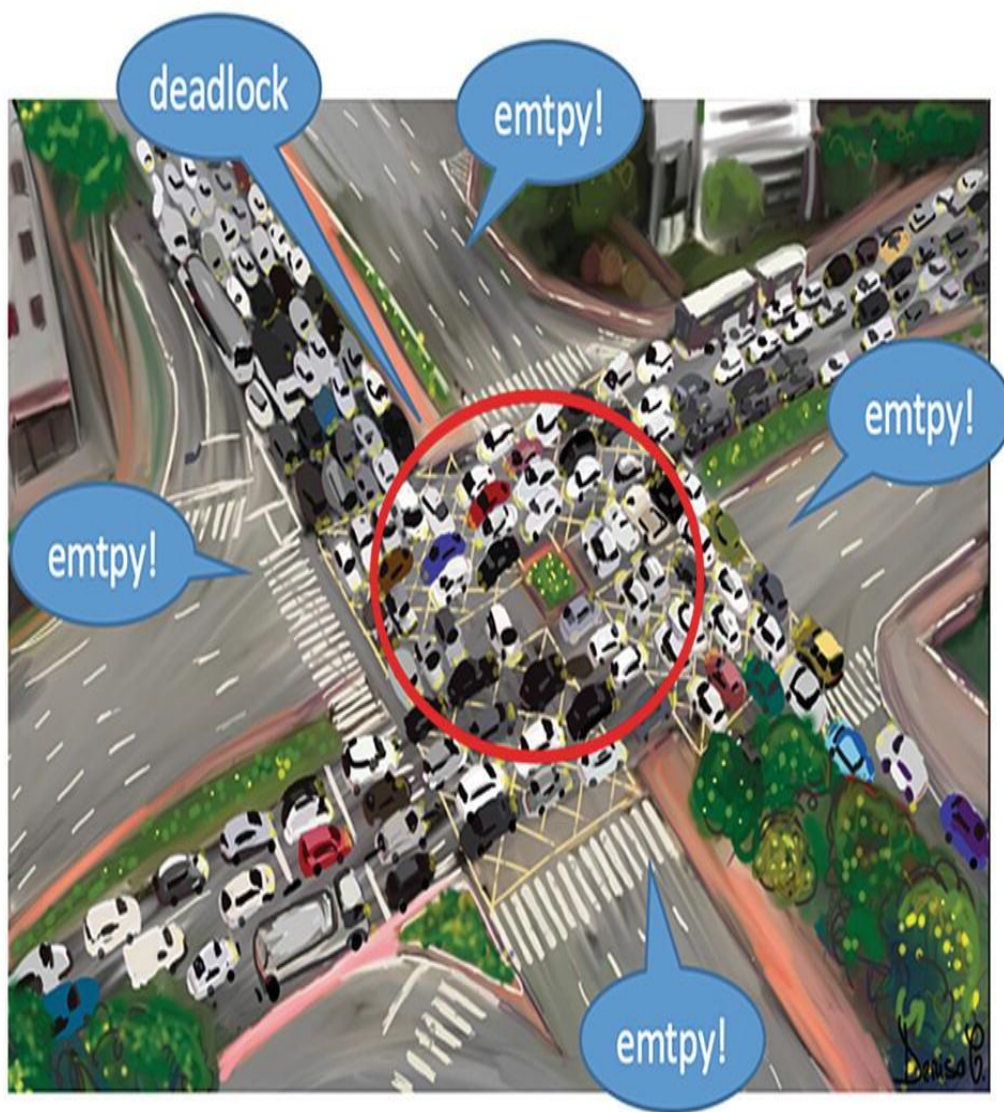
End of Chapter 4



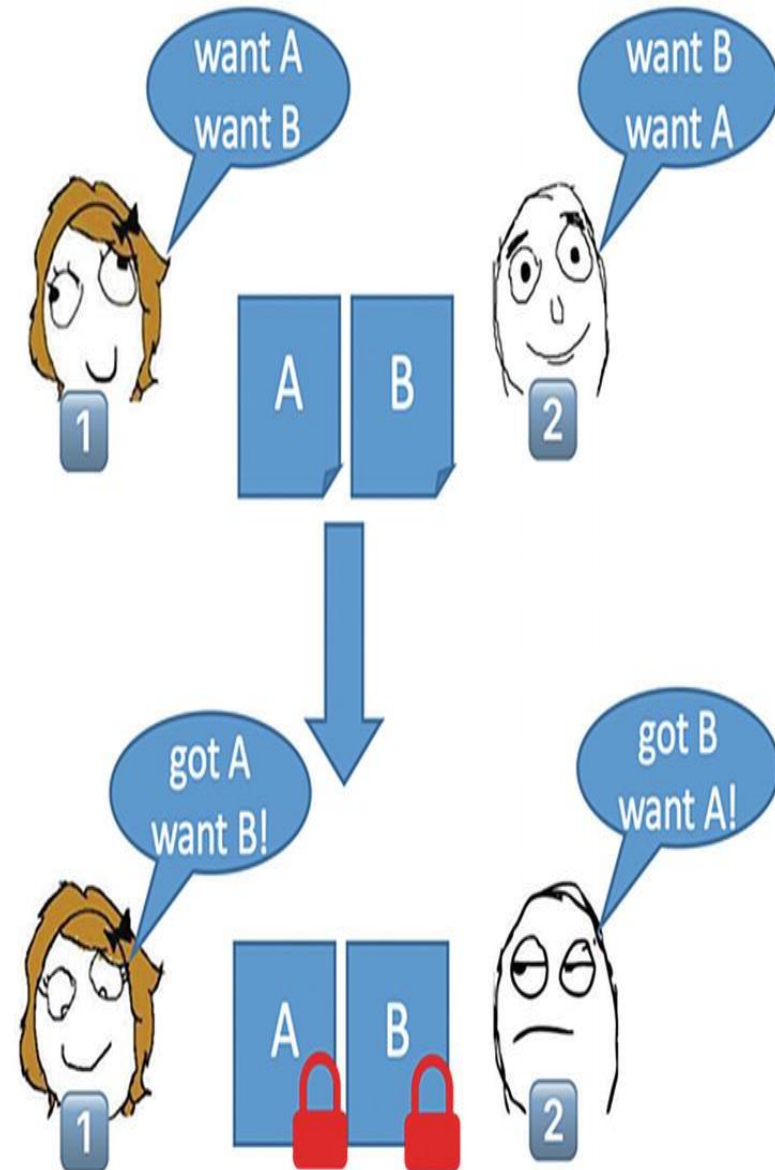
Chapter 7: Deadlocks







(a) Deadlock in real life



(b) Deadlock in virtual life

Deadlock:

A process in Operating System uses different resources and uses resources in following way

- Request a resource
- Use the resource
- Release the resource

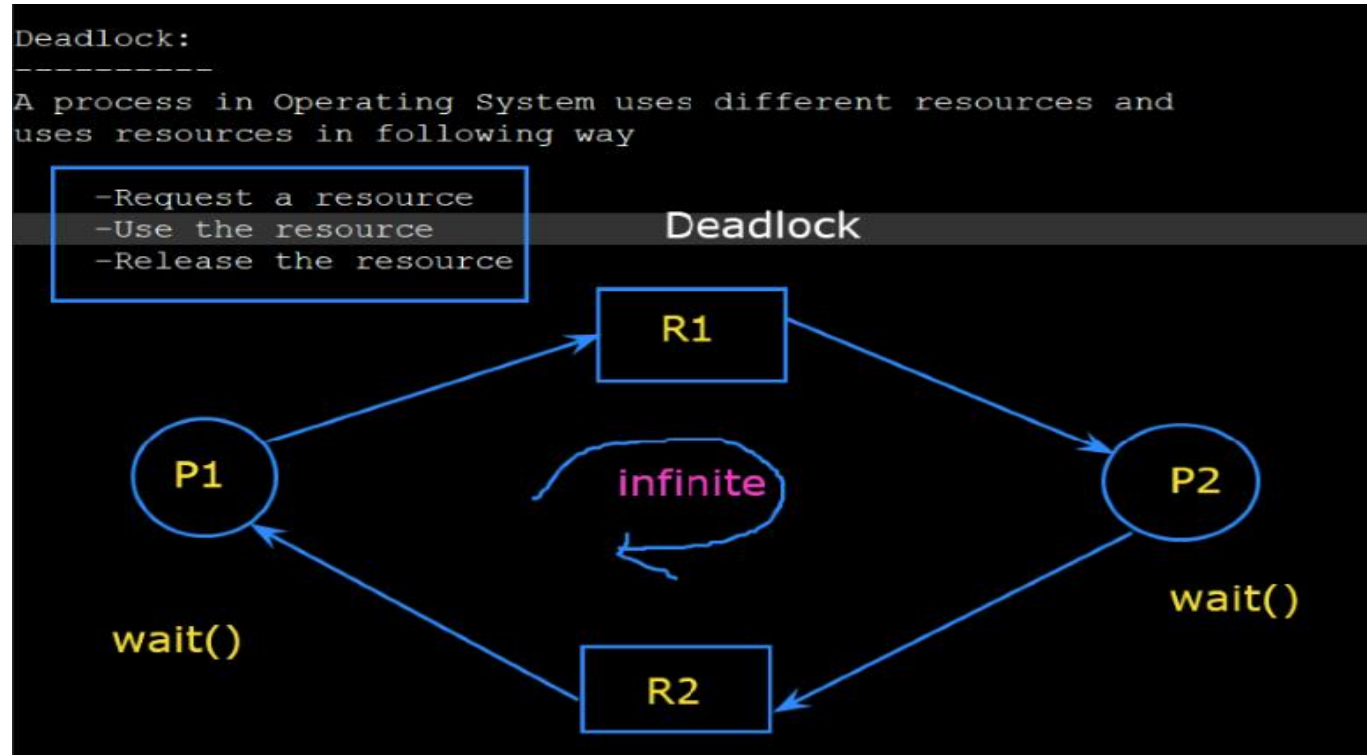
Deadlock: Resources, Process

request
use
release



System Model

- System consists of resources
- Resource types R_1, R_2, \dots, R_m
CPU cycles, memory space, I/O devices
- Each resource type R_i has W_i instances.
- Each process utilizes a resource as follows:
 - request
 - use
 - release





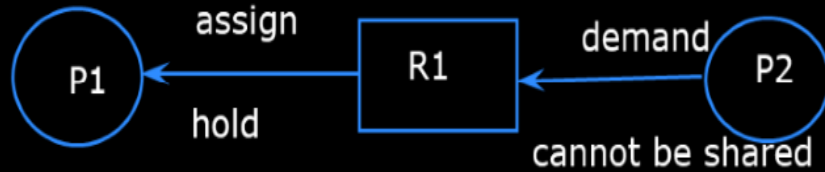
Deadlock Characterization

Deadlock can arise if four conditions hold simultaneously.

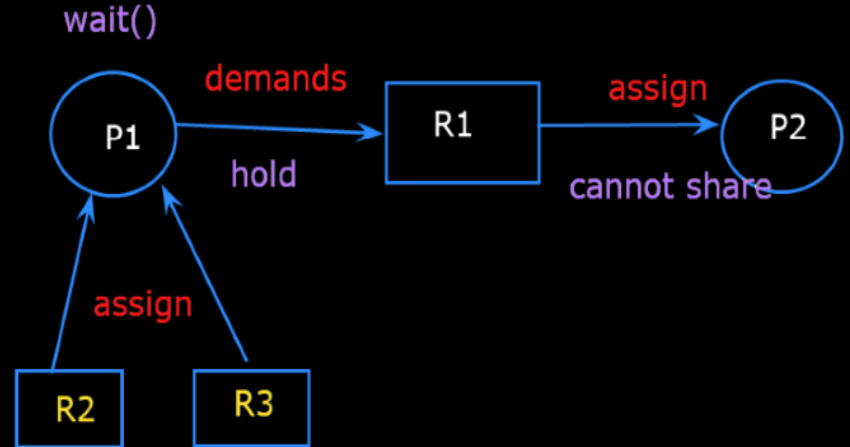
- **Mutual exclusion:** only one process at a time can use a resource
- **Hold and wait:** a process holding at least one resource is waiting to acquire additional resources held by other processes
- **No preemption:** a resource can be released only voluntarily by the process holding it, after that process has completed its task
- **Circular wait:** there exists a set $\{P_0, P_1, \dots, P_n\}$ of waiting processes such that P_0 is waiting for a resource that is held by P_1 , P_1 is waiting for a resource that is held by P_2 , ..., P_{n-1} is waiting for a resource that is held by P_n , and P_n is waiting for a resource that is held by P_0 .



Mutual Exclusion



Hold and wait



one or more than one resources are non-sharable

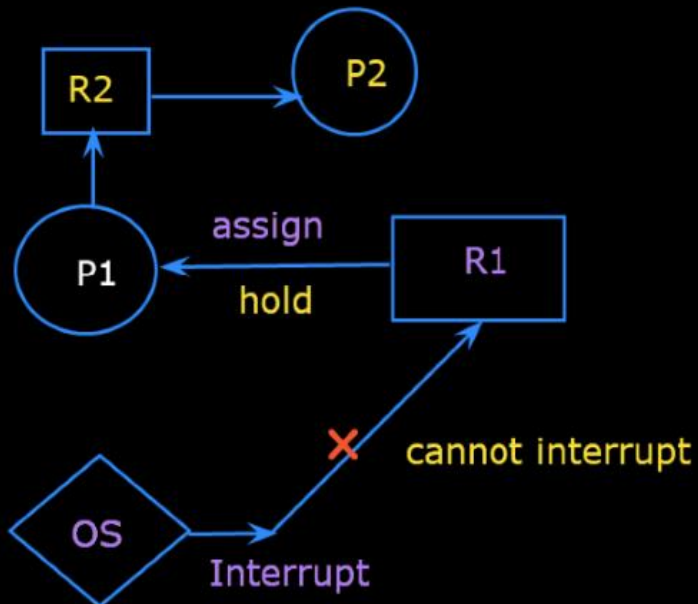
1. Mutual Exclusion

2. Hold and Wait

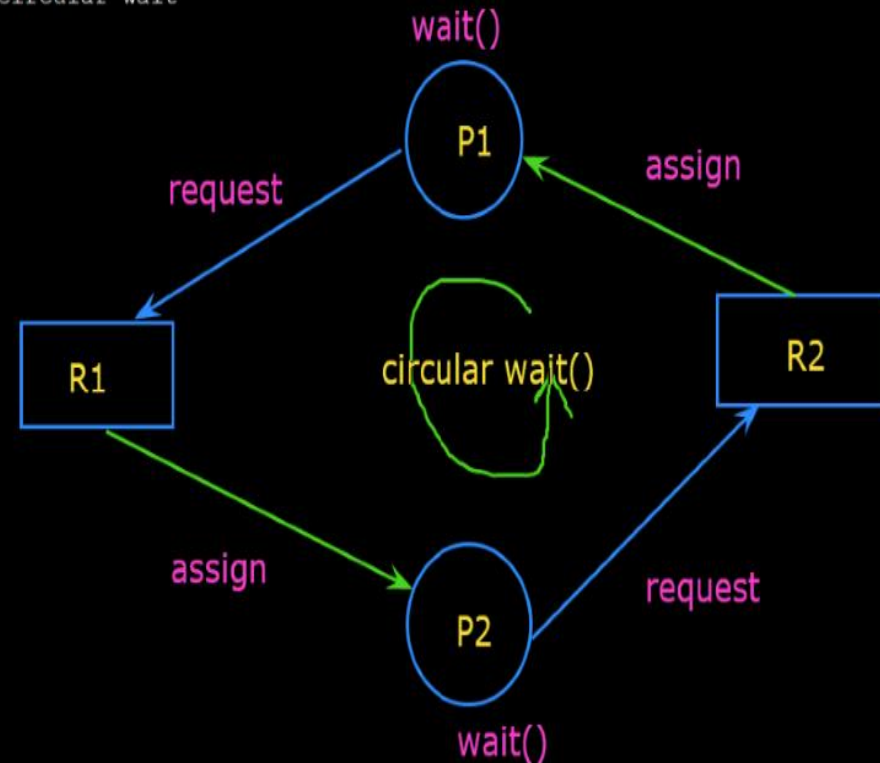
3. No Preemption

4. Circular wait

No Preemption



4. Circular wait





Resource-Allocation Graph

A set of vertices V and a set of edges E .

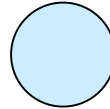
- V is partitioned into two types:
 - $P = \{P_1, P_2, \dots, P_n\}$, the set consisting of all the processes in the system
 - $R = \{R_1, R_2, \dots, R_m\}$, the set consisting of all resource types in the system
- **request edge** – directed edge $P_i \rightarrow R_j$
- **assignment edge** – directed edge $R_j \rightarrow P_i$





Resource-Allocation Graph (Cont.)

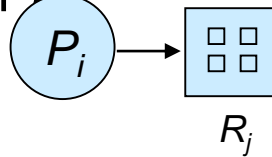
- Process



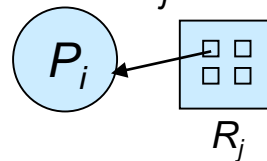
- Resource Type with 4 instances



- P_i requests instance of R_j

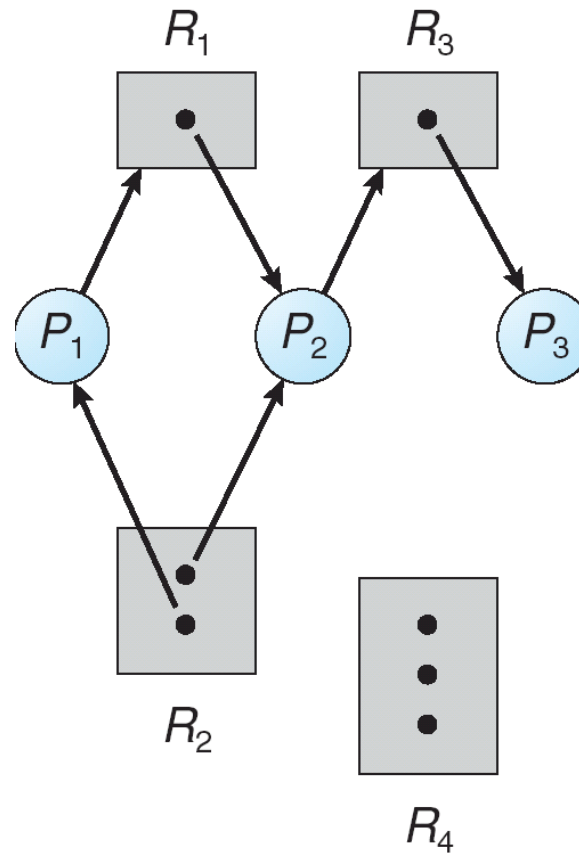


- P_i is holding an instance of R_j



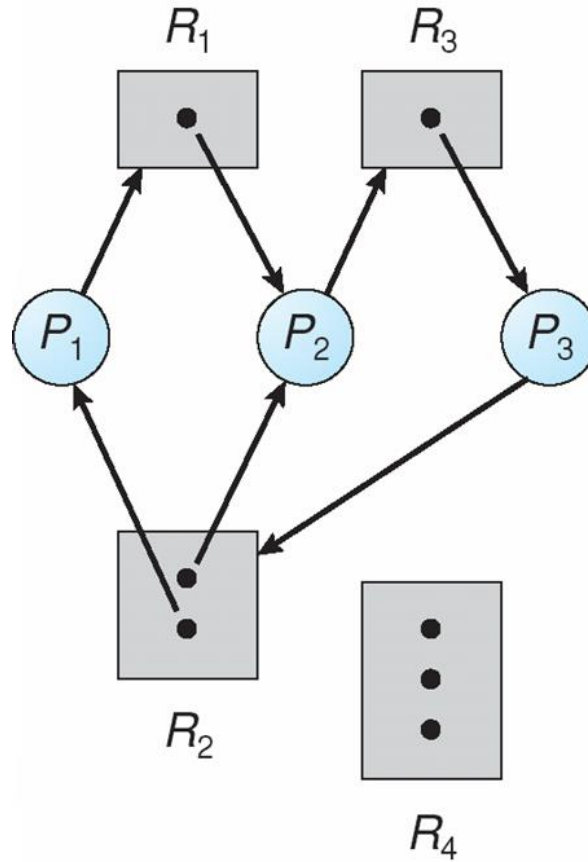


Example of a Resource Allocation Graph



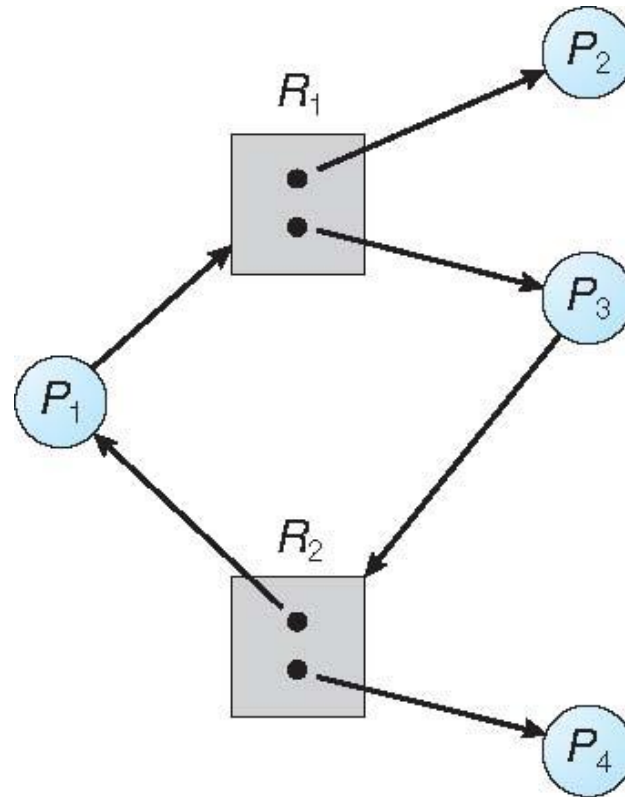


Resource Allocation Graph With A Deadlock



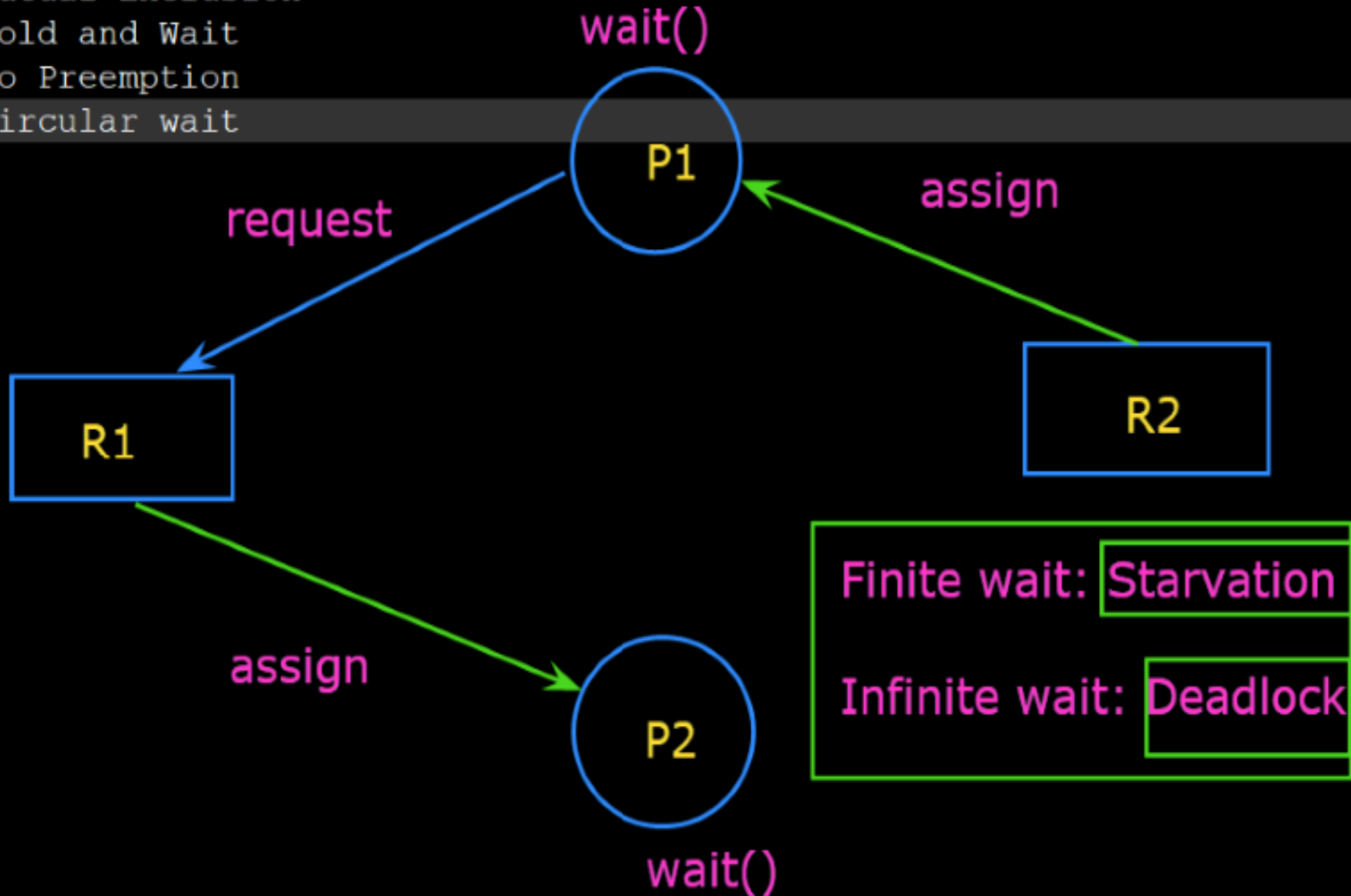


Graph With A Cycle But No Deadlock



Deadlock Characterization:

- 1. Mutual Exclusion
- 2. Hold and Wait
- 3. No Preemption
- 4. Circular wait





Basic Facts

- If graph contains no cycles \Rightarrow no deadlock
- If graph contains a cycle \Rightarrow
 - if only one instance per resource type, then deadlock
 - if several instances per resource type, possibility of deadlock





Methods for Handling Deadlocks

- Ensure that the system will *never* enter a deadlock state:
 - Deadlock prevention
 - Deadlock avoidance
- Allow the system to enter a deadlock state and then recover
- Ignore the problem and pretend that deadlocks never occur in the system; used by most operating systems, including UNIX





Deadlock Prevention

Restrain the ways request can be made

- **Mutual Exclusion** – not required for sharable resources (e.g., read-only files); must hold for non-sharable resources
- **Hold and Wait** – must guarantee that whenever a process requests a resource, it does not hold any other resources
 - Require process to request and be allocated all its resources before it begins execution, or allow process to request resources only when the process has none allocated to it.
 - Low resource utilization; starvation possible





Deadlock Prevention (Cont.)

■ No Preemption –

- If a process that is holding some resources requests another resource that cannot be immediately allocated to it, then all resources currently being held are released
- Preempted resources are added to the list of resources for which the process is waiting
- Process will be restarted only when it can regain its old resources, as well as the new ones that it is requesting

■ Circular Wait – impose a total ordering of all resource types, and require that each process requests resources in an increasing order of enumeration





Deadlock Avoidance

Requires that the system has some additional ***a priori*** information available

- Simplest and most useful model requires that each process declare the ***maximum number*** of resources of each type that it may need
- The deadlock-avoidance algorithm dynamically examines the resource-allocation state to ensure that there can never be a circular-wait condition
- Resource-allocation *state* is defined by the number of available and allocated resources, and the maximum demands of the processes





Safe State

- When a process requests an available resource, system must decide if immediate allocation leaves the system in a safe state
- System is in **safe state** if there exists a sequence $\langle P_1, P_2, \dots, P_n \rangle$ of ALL the processes in the systems such that for each P_i , the resources that P_i can still request can be satisfied by currently available resources + resources held by all the P_j , with $j < i$
- That is:
 - If P_i resource needs are not immediately available, then P_i can wait until all P_j have finished
 - When P_j is finished, P_i can obtain needed resources, execute, return allocated resources, and terminate
 - When P_i terminates, P_{i+1} can obtain its needed resources, and so on





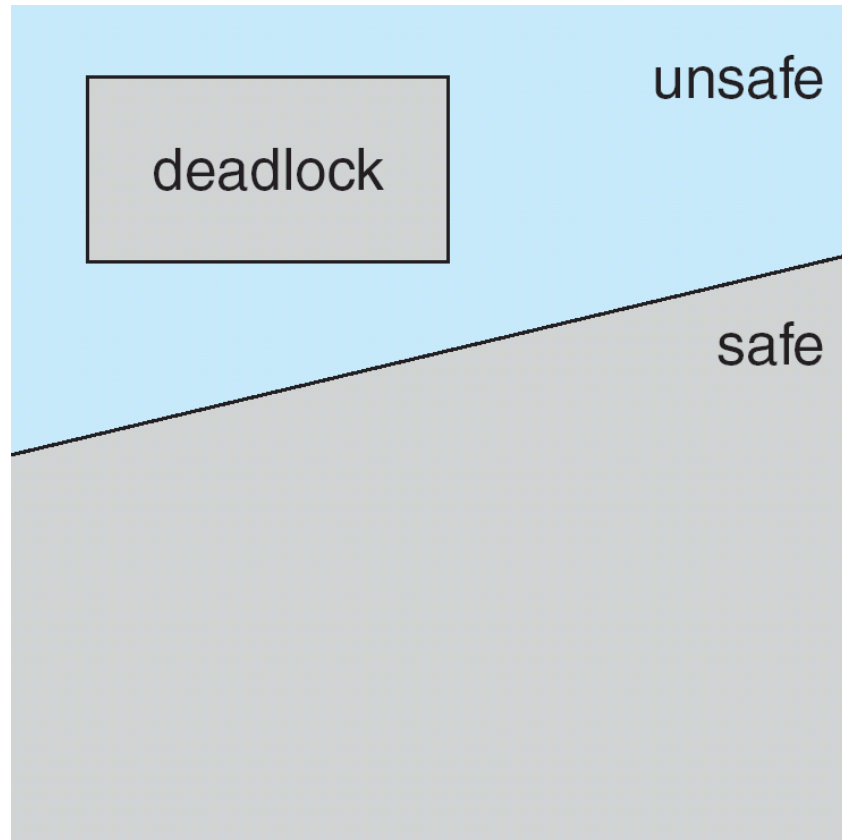
Basic Facts

- If a system is in safe state \Rightarrow no deadlocks
- If a system is in unsafe state \Rightarrow possibility of deadlock
- Avoidance \Rightarrow ensure that a system will never enter an unsafe state.





Safe, Unsafe, Deadlock State





Avoidance Algorithms

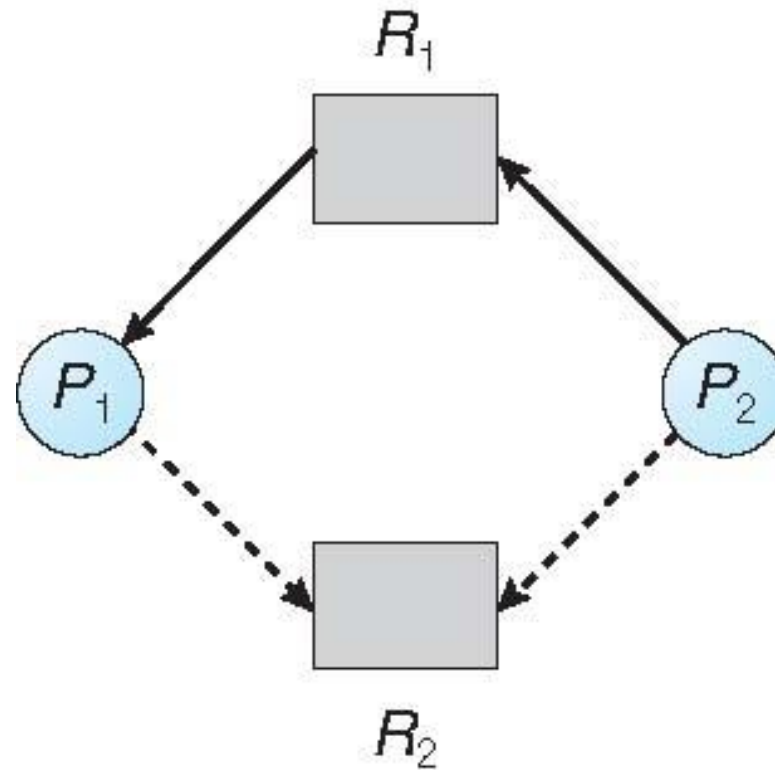
- Single instance of a resource type
 - Use a resource-allocation graph

- Multiple instances of a resource type
 - Use the banker's algorithm





Resource-Allocation Graph

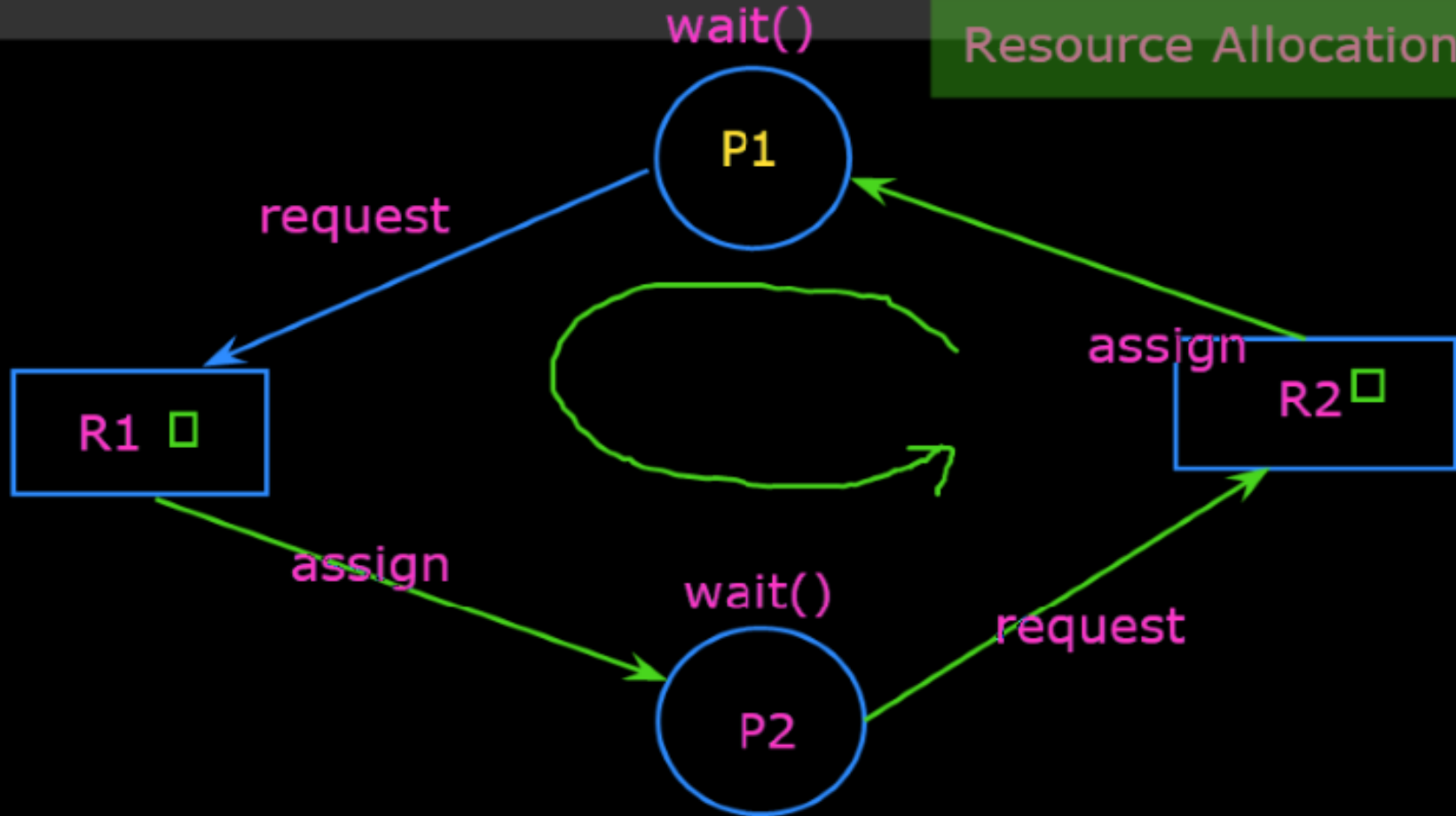




Resource-Allocation Graph Algorithm

- Suppose that process P_i requests a resource R_j
- The request can be granted only if converting the request edge to an assignment edge does not result in the formation of a cycle in the resource allocation graph





	Allocate		Request		Availability	
	R1	R2	R1	R2	R1	R2
P1	0	1	1	0	0	0
P2	1	0	0	1		

Deadlock



Banker's Algorithm

- Multiple instances
- Each process must a priori claim maximum use
- When a process requests a resource it may have to wait
- When a process gets all its resources it must return them in a finite amount of time





Data Structures for the Banker's Algorithm

Let n = number of processes, and m = number of resources types.

- **Available:** Vector of length m . If available $[j] = k$, there are k instances of resource type R_j available
- **Max:** $n \times m$ matrix. If $Max[i,j] = k$, then process P_i may request at most k instances of resource type R_j
- **Allocation:** $n \times m$ matrix. If $Allocation[i,j] = k$ then P_i is currently allocated k instances of R_j
- **Need:** $n \times m$ matrix. If $Need[i,j] = k$, then P_i may need k more instances of R_j to complete its task

$$Need[i,j] = Max[i,j] - Allocation[i,j]$$





Safety Algorithm

1. Let **Work** and **Finish** be vectors of length m and n , respectively. Initialize:

Work = Available

Finish [i] = **false** for $i = 0, 1, \dots, n-1$

2. Find an i such that both:

(a) **Finish** [i] = **false**

(b) **Need** _{i} ≤ **Work**

If no such i exists, go to step 4

3. **Work = Work + Allocation** _{i}
Finish [i] = **true**
go to step 2

4. If **Finish** [i] == **true** for all i , then the system is in a safe state





Resource-Request Algorithm for Process P_i

$Request_i$ = request vector for process P_i . If **$Request_i[j] = k$** then process P_i wants k instances of resource type R_j

1. If **$Request_i \leq Need_i$** , go to step 2. Otherwise, raise error condition, since process has exceeded its maximum claim
2. If **$Request_i \leq Available$** , go to step 3. Otherwise P_i must wait, since resources are not available
3. Pretend to allocate requested resources to P_i by modifying the state as follows:

$$Available = Available - Request_i;$$

$$Allocation_i = Allocation_i + Request_i;$$

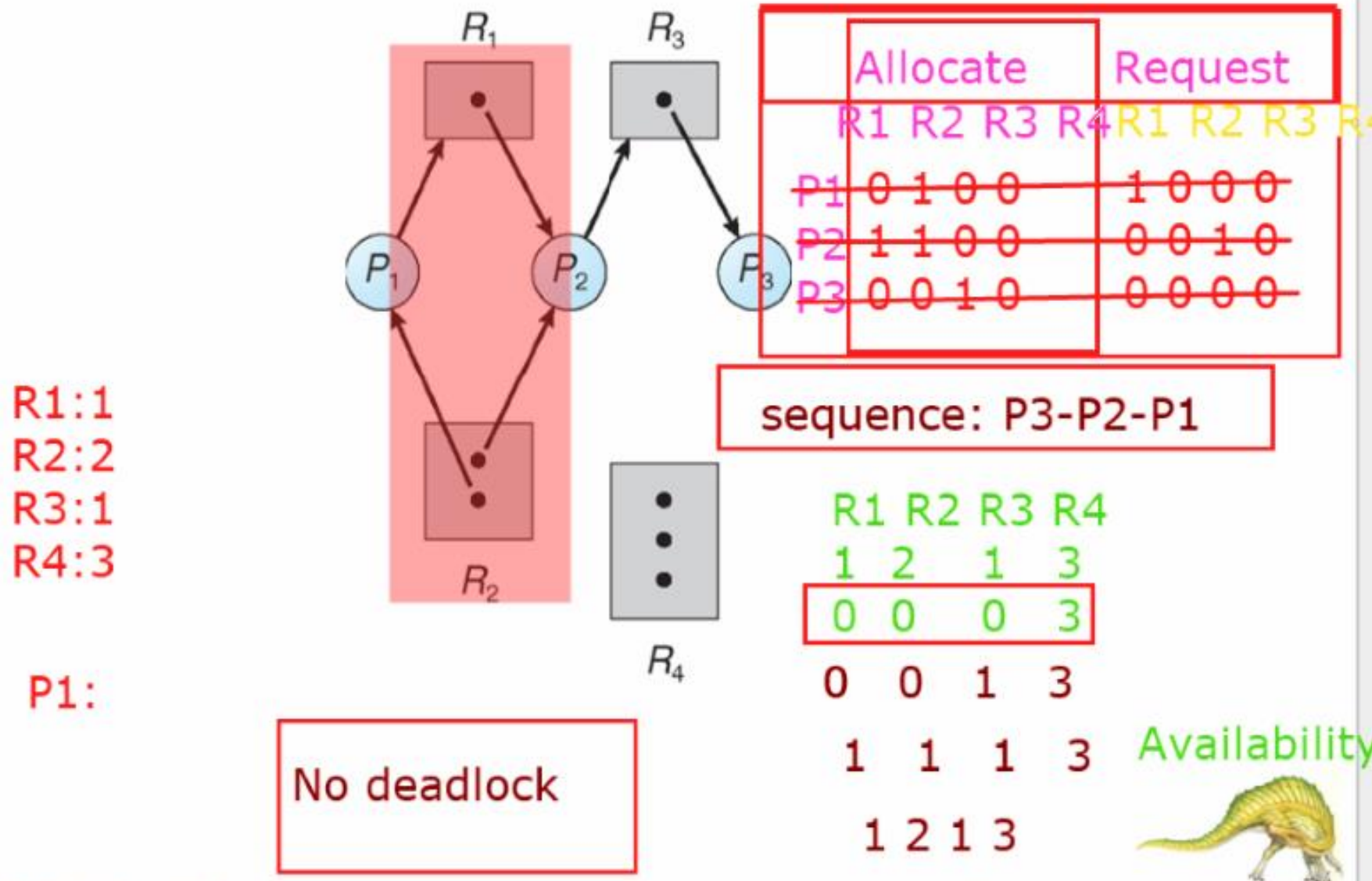
$$Need_i = Need_i - Request_i;$$

- If safe \Rightarrow the resources are allocated to P_i
- If unsafe $\Rightarrow P_i$ must wait, and the old resource-allocation state is restored





Example of a Resource Allocation Graph





Example of Banker's Algorithm

- 5 processes P_0 through P_4 ;

3 resource types:

A (10 instances), B (5 instances), and C (7 instances)

- Snapshot at time T_0 :

	<u>Allocation</u>	<u>Max</u>	<u>Available</u>
	$A \ B \ C$	$A \ B \ C$	$A \ B \ C$
P_0	0 1 0	7 5 3	3 3 2
P_1	2 0 0	3 2 2	
P_2	3 0 2	9 0 2	
P_3	2 1 1	2 2 2	
P_4	0 0 2	4 3 3	





Example (Cont.)

- The content of the matrix **Need** is defined to be **Max – Allocation**

	<u>Need</u>		
	A	B	C
P_0	7	4	3
P_1	1	2	2
P_2	6	0	0
P_3	0	1	1
P_4	4	3	1

- The system is in a safe state since the sequence $\langle P_1, P_3, P_4, P_2, P_0 \rangle$ satisfies safety criteria





Example: P_1 Request (1,0,2)

- Check that Request \leq Available (that is, $(1,0,2) \leq (3,3,2) \Rightarrow$ true

	<u>Allocation</u>	<u>Need</u>	<u>Available</u>
	A B C	A B C	A B C
P_0	0 1 0	7 4 3	2 3 0
P_1	3 0 2	0 2 0	
P_2	3 0 2	6 0 0	
P_3	2 1 1	0 1 1	
P_4	0 0 2	4 3 1	

- Executing safety algorithm shows that sequence $\langle P_1, P_3, P_4, P_0, P_2 \rangle$ satisfies safety requirement
- Can request for (3,3,0) by P_4 be granted?
- Can request for (0,2,0) by P_0 be granted?





Deadlock Detection

- Allow system to enter deadlock state
- Detection algorithm
- Recovery scheme





Recovery from Deadlock: Process Termination

- Abort all deadlocked processes
- Abort one process at a time until the deadlock cycle is eliminated
- In which order should we choose to abort?
 1. Priority of the process
 2. How long process has computed, and how much longer to completion
 3. Resources the process has used
 4. Resources process needs to complete
 5. How many processes will need to be terminated
 6. Is process interactive or batch?





Recovery from Deadlock: Resource Preemption

- **Selecting a victim** – minimize cost
- **Rollback** – return to some safe state, restart process for that state
- **Starvation** – same process may always be picked as victim, include number of rollback in cost factor



End of Chapter 7

