CSCI315 – Operating Systems Design

Department of Computer Science
Bucknell University

Handling Deadlocks
Banker's Algorithm

Ch 8.4-8.5

This set of notes is based on notes from the textbook authors, as well as L. Felipe Perrone, Joshua Stough, and other instructors.
Xiannong Meng, Fall 2021.

Methods for Handling Deadlocks

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

Deadlock Prevention

- If we want to prevent the deadlocks from happening, we just need to break (or prevent) any one of the four necessary conditions.
    - Mutual exclusion
    - Hold and wait
    - Non-preemption
    - Circular wait

Safe States

- Sequence **$<P_1, P_2, \ldots, P_n>$** is ***safe*** if for each P_i, the resources that P_i can still request can be satisfied by currently available resources plus the resources held by all the P_j, with $j < i$.
  - 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.

- The system is in a ***safe state*** if there exists a safe sequence for all processes.
- When a process requests an available resource, the system must decide if immediate allocation leaves the system in a **safe state**.

Safe Sequence and State Example

Table: Resource allocation

	Maximum Needs	Allocated
P0	10	5
P1	4	2
P2	5	2

total allocated is 9

Table: Total resources

	Total Count
R	12

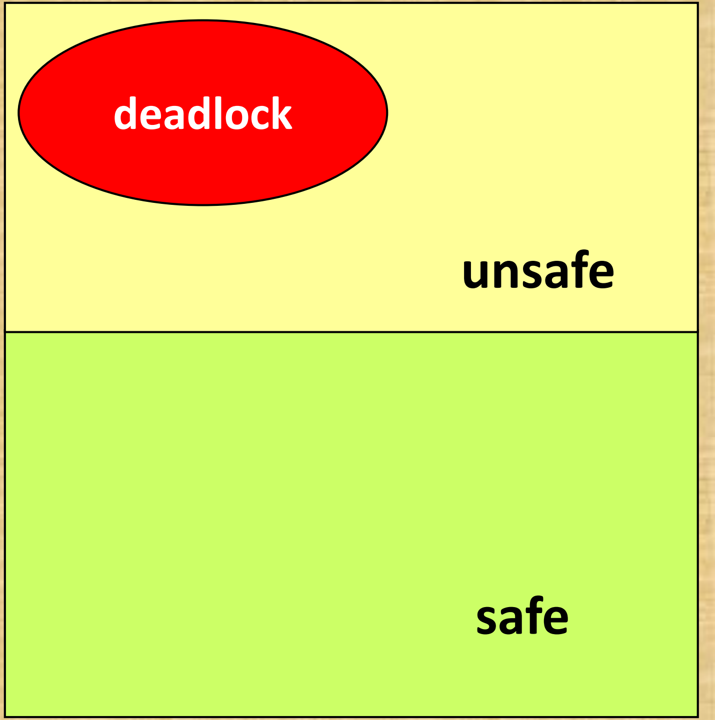
3 remaining

Safe sequence 1: [<p1,2>, <p0, 5>, <p2,3>]
Safe sequence 2: [<p2,3>, <p0, 5>, <p1,2>]
More safe sequences?

Basic Facts

- If a system is in a safe state there can be no deadlock.
- If a system is in unsafe state, there exists the **possibility** of deadlock.
- **Avoidance** strategies ensure that a system will never enter an unsafe state.

Safe, Unsafe, and Deadlock States

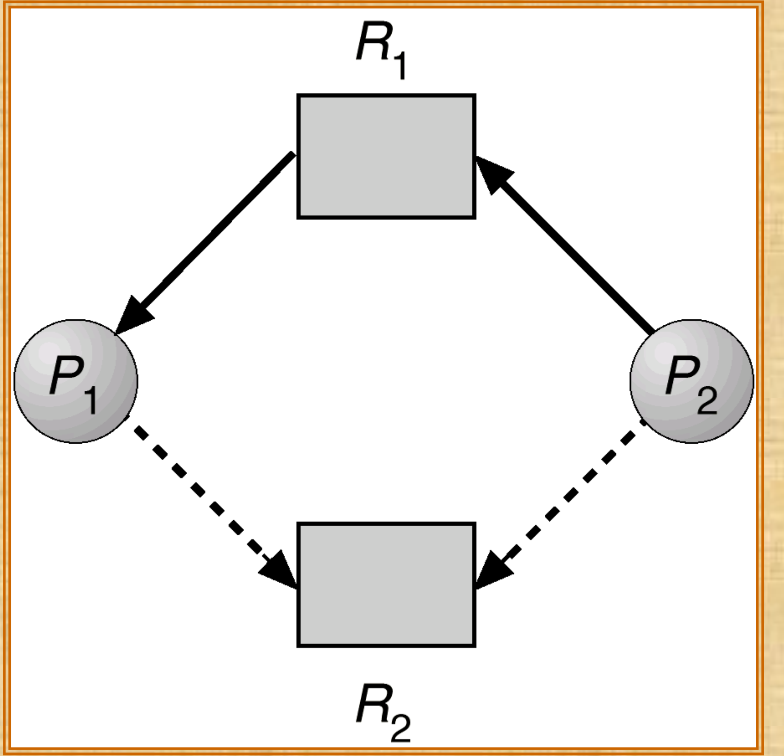


Resource-Allocation Graph Algorithm

Goal: prevent the system from entering an unsafe state.

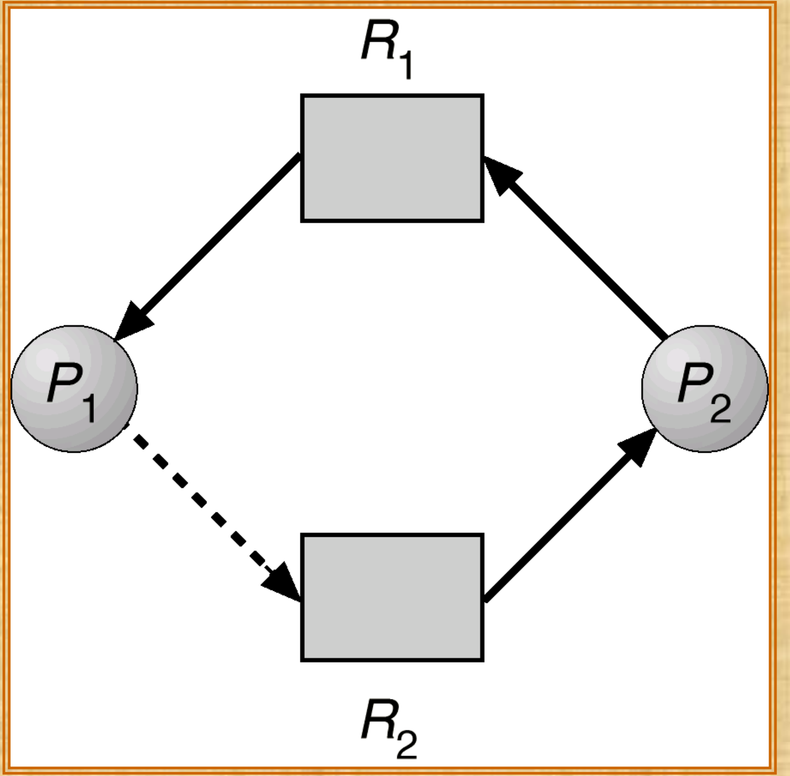
- *Claim edge* $P_i \rightarrow R_j$ indicates that process P_j may request resource R_j; represented by a dashed line.
- Claim edge converts to request edge when a process requests a resource.
- When a resource is released by a process, assignment edge reconverts to a claim edge.
- Resources must be claimed ***a priori*** in the system.
- If there is no cycle as the result of allocation, the system is safe.

Resource-Allocation Graph for Deadlock Avoidance



Both P1 and P2 may request R2

Unsafe State In Resource-Allocation Graph



R2 now is allocated to P2.

Banker’s Algorithm by Dijkstra

- Applicable when there are multiple instances of each resource type.
- In a bank, the cash must never be allocated in a way such that it cannot satisfy the need of **all its customers**.
- Each process must state a priori the maximum number of instances of each kind of resource that it will ever need.
- 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.

Banker's Algorithm: Data Structures

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 x m* matrix. If *Max* [*i,j*] = *k*, then process P_i may request at most *k* instances of resource type R_j.
- ***Allocation:*** *n* x *m* matrix. If Allocation[*i,j*] = *k* then P_i is currently allocated *k* instances of $R_{j.}$
- ***Need:*** *n* x *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* = 0,1,2,3, …, *n-1.*

2. Find an *i* such that both:

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

   (b) $Need_i \leq Work$

   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, otherwise in an unsafe state.

Resource-Request Algorithm for Process P_i

Request = 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*. (run safety algorithm)*
- *If unsafe* $\Rightarrow$ P_i *must wait, and the old resource-allocation state is restored*

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). $[\text{sum}(\text{allocated}_i)+\text{available}_i == R_i]$
- Snapshot at time T_0:

	Allocation			*Max*			*Available*		
	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. Define **Need = Max – Allocation**.

Need

	A	B	C
P0	7	4	3
P1	1	2	2
P2	6	0	0
P3	0	1	1
P4	4	3	1

=

Max

A	B	C
7	5	3
3	2	2
9	0	2
2	2	2
4	3	3

-

Allocation

A	B	C
0	1	0
2	0	0
3	0	2
2	1	1
0	0	2

Available

A	B	C
3	3	2

The system is in a safe state since the sequence < P_1, P_3, P_4, P_2, P_0> satisfies the safety criteria.

Example P_1 Request (1,0,2) (Cont.)

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

	Allocation	*Need*	*Available*
	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 1	6 0 0	
P_3	2 1 1	0 1 1	
P_4	0 0 2	4 3 1	

Allocation(P1) = (2,0,0) + (1,0,2) = (3,0,2)

- Executing safety algorithm shows that sequence <P1, P3, P4, P0, P2> satisfies safety requirement.
- Can request for (3,3,0) by P4 be granted?
- Can request for (0,2,0) by P0 be granted?