ECE437/CS481

M05A: DEADLOCKS

CHAPTER 7

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Deadlock Problem

- Deadlock problem
  - A set of blocked processes, each of which holds a resource and waits to acquire another resource held by another process.
- Example of deadlock
  - System has 2 disk drives; P1 and P2 each hold one disk drive and each needs another one.
  - Semaphores A and B, initialized to 1

P_0	P_1
wait (A);	wait(B)
wait (B);	wait(A)

- Deadlock problem
  - A set of blocked processes, each of which holds a resource and waits to acquire another resource held by another process.
- Example of deadlock
  - Space is available for allocation of 200K bytes, and the following sequence of events occur.
  - Deadlock occurs if both processes progress to their second requests.

P_0	P_1
Request 80K bytes;	Request 70K bytes;
......	......
Request 60K bytes;	Request 80K bytes;

Deadlock & Starvation

Deadlock	Starvation
A deadlock occurs when a set of processes in a system is blocked waiting on requirements that can **NEVER** be satisfied. 	Starvation occurs when a process waits for a resource that continually available but is never assigned to that process because of priority or a flaw in the design of the scheduler.

❑ Difference:

- ➢ In starvation, it's not certain that a process will ever get the requested resource, whereas a deadlock process is permanently blocked.
- ➢ In starvation, the resource under contention is in continuous use, whereas this is not true in a deadlock.

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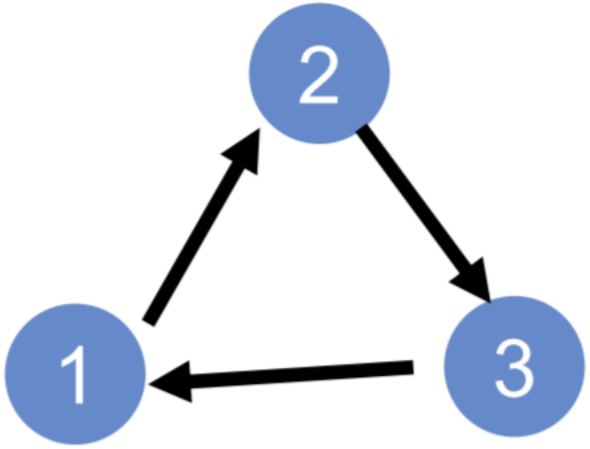
Deadlock Characterization

- Four conditions are necessary for deadlocks to occur:
  - **Mutual exclusive**
    - ✓ at least 1 resource is held in a non-sharable mode. Other requesting processes must wait until the resource is released
  - **Wait while hold**
    - ✓ processes hold previously acquired resources while waiting for additional resources
  - **No preemption**
    - ✓ A resource cannot be preempted from a process without aborting the process
  - **Circular wait**
    - ✓ ∃ a set of processes {P1, P2, … PN}, such that P1 is waiting for P2, P2 for P3, …. and PN for P1

Deadlock Detection based on WFG

- Create a Wait-For Graph (WFG):
  - **Node:** process
  - **Edge with direction:** the blocking/waiting relation between processes, e.g., e(pi,pj) means that pi needs a resource currently held by pj, or pi is waiting for pj.
  - **Cycle:** indication of deadlock



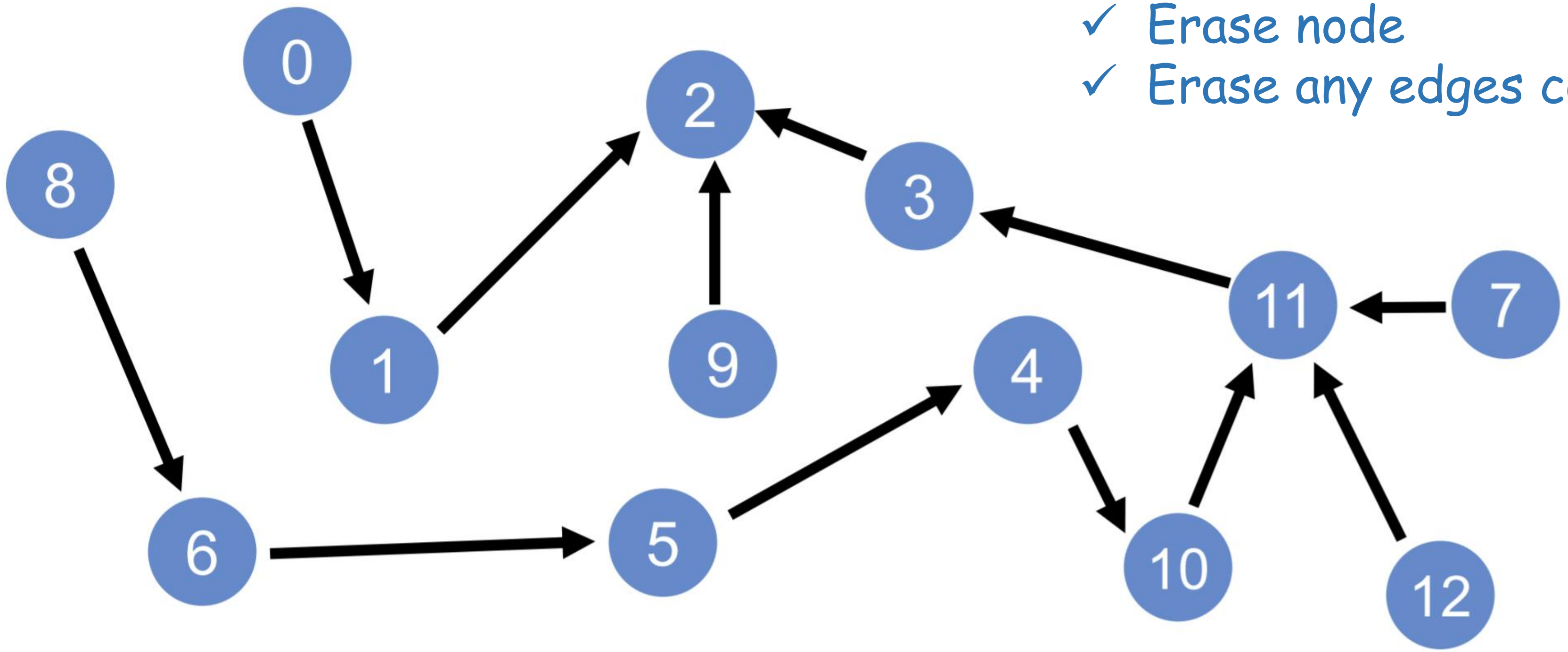
Deadlock Detection based on WFG

- Testing for cycle in WFG:
  - Find a node with no outgoing edges
    - ✓ Erase node
    - ✓ Erase any edges coming into it
  - Intuition: this was a process waiting on nothing. It will eventually finish, and anyone waiting on it will no longer be waiting.
  - Results:
    - ✓ Erase whole graph ↔ graph has no cycles
    - ✓ Graph remains ↔ deadlock

Graph reduction algorithm

Deadlock Detection based on WFG

❑ Graph Reduction in WFG: Example 1

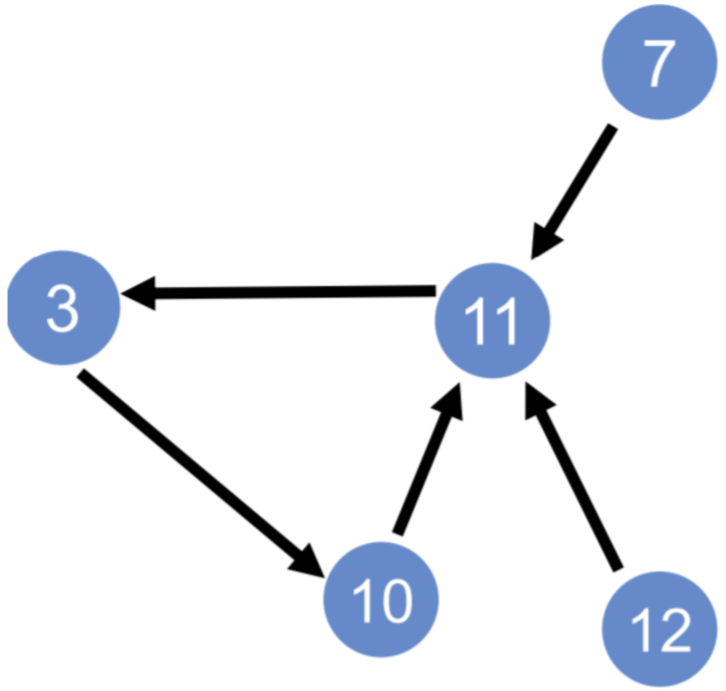


- ➢ Find a node with no outgoing edges
  - ✓ Erase node
  - ✓ Erase any edges coming into it

✓ Graph can be fully reduced, hence there was no deadlock at the time the graph was drawn. (Obviously, things could change later!)

Deadlock Detection based on WFG

❑ Graph Reduction in WFG: Example 2



- ➢ Find a node with no outgoing edges
  - ✓ Erase node
  - ✓ Erase any edges coming into it

✓ No node with no outgoing edges… Irreducible graph, contains a cycle ↔ deadlock.

Deadlock Detection based on RAG

❑ Create a Resource Allocation Graph (RAG):

➢ Two types of Nodes

node circles:

$P = \{P_1, P_2, \ldots, P_n\}$

- the set consisting of all the processes in the system

node squares:

$R = \{R_1, R_2, \ldots, R_m\}$

- the set consisting of all resource types in the system
- (dots within a square --- resource instances)

➢ Two types of edges

request edge:

directed edge $P_i \rightarrow R_j$

- ❖ edge from a process node to a resource node

assignment edge (granting edge):

directed edge $R_j \rightarrow P_i$

- ❖ edge from a resource instance to a process node

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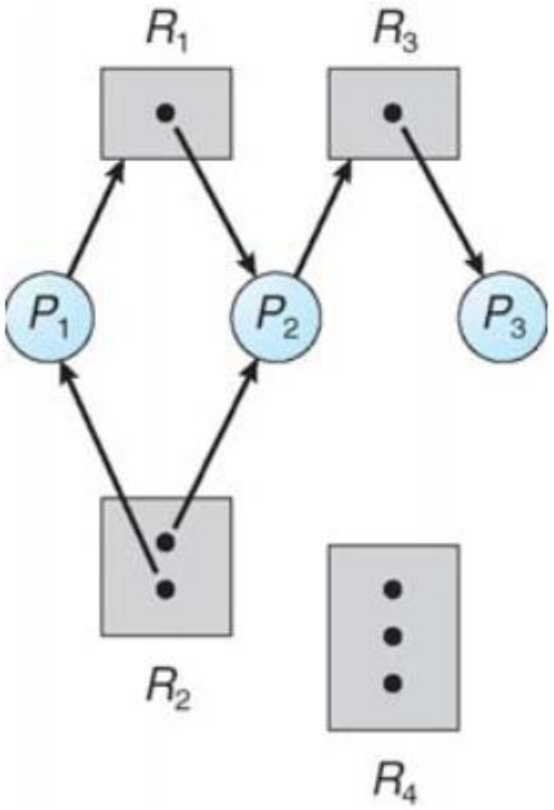
Deadlock Detection based on RAG

❑ RAG

- If each resource type has exactly one instance
  - ✓ a cycle in the graph is both a necessary and a sufficient condition for the existence of deadlock
- If each resource type has several instances
  - ✓ a cycle in a graph is a necessary but not a sufficient condition for the existence of deadlock

P_1 hold R_2 request R_1 P_2 hold R_1 & R_2 request R_3 P_3 hold R_3	R_1 --- m=1 R_2 --- m=1 R_3 --- m=2 R_4 --- m=3



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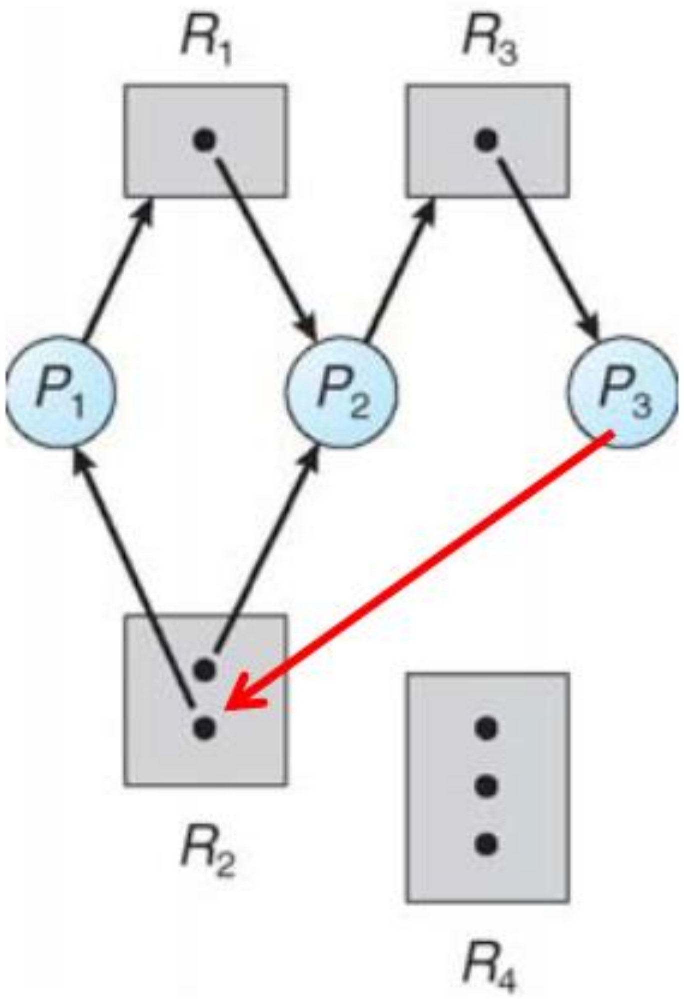
Deadlock Detection based on RAG

- RAG: a circle incurs a deadlock

P_1 hold R_2	R_1 --- m=1
request R_1	R_2 --- m=1
P_2 hold R_1 & R_2	R_3 --- m=2
request R_3	R_4 --- m=3
P_3 hold R_3	

P_3 request R_2

Deadlock!



❑ RAG: a circle does not incur a deadlock

P_1 hold R_2 request R_1 P_2 hold R_1 R_3 hold R_1 request R_2 P_4 hold R_2	R_1 --- m=2 R_2 --- m=2

With a cycle,

But no deadlock!