CSE 120: Principles of Operating Systems

Lecture 6

Deadlock

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Before We Begin …

Read Chapter 7 (on Deadlocks)

Homework Assignment #3

- Due Tuesday, February 7, midnight

Programming Assignment #3

- Due Saturday, February 11, midnight

Midterm Exam

- February 13
- Will cover all material up to that point

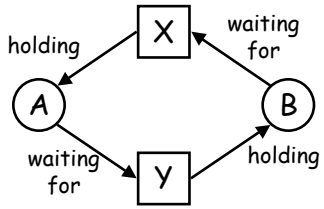
What is Deadlock?

The state of a set of permanently blocked processes

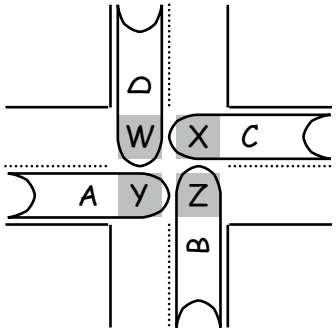
- Unblocking of one relies on progress of another
- But none can make progress!

Example

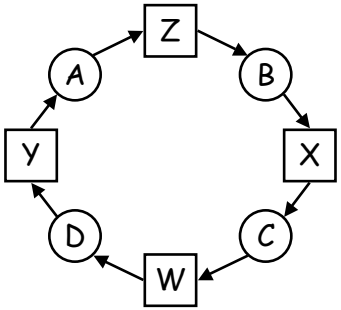
- Processes A and B
- Resources X and Y
- A holding X, waiting for Y
- B holding Y, waiting for X
- Each is waiting for the other; will wait forever



Traffic Jam as Example of Deadlock



Cars deadlocked in an intersection

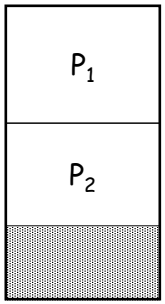


Resource Allocation Graph

More Examples of Deadlock

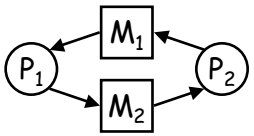
Memory (a reusable resource)

- total memory = 200KB
- P1 requests 80KB
- P2 requests 70KB
- P1 requests 60KB (wait)
- P2 requests 80KB (wait)



Messages (a consumable resource)

- P1: receive M2 from P2
- P2: receive M1 from P1



Conditions for Deadlock

Mutual Exclusion

- Only one process may use a resource at a time

Hold-and-Wait

- Process holds resources while waiting for others

No Preemption

- Can't take a resource away from a process

Circular Wait

- The waiting processes form a cycle

How to Attack the Deadlock Problem

Deadlock *Prevention*

- Make deadlock impossible by removing a condition

Deadlock *Avoidance*

- Avoid getting into situations that lead to deadlock

Deadlock *Detection*

- Don't try to stop deadlocks
- Rather, if they happen, detect and resolve

Deadlock Prevention

Simply prevent any one of the conditions for deadlock

Mutual exclusion

- Relax where sharing is possible

Hold-and-wait

- Get all resources simultaneously (wait until all free)

No preemption

- Allow resources to be taken away

Circular wait

- Order all the resources, force ordered acquisition

How Can We Prevent a Traffic Jam?

What are the processes?

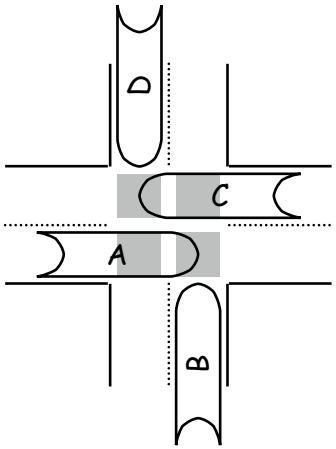
What are the resources?

How does deadlock occur?

How to prevent deadlock?

- Add a traffic light

Which condition is being prevented?



Deadlock Avoidance

Avoid situations that lead to deadlock

- *Selective* prevention
- Remove condition only when deadlock a possibility

Works with *incremental* resource requests

- Resources are asked for in increments
- Do not grant request that can lead to a deadlock

Requires knowledge of maximum resource requirements

Banker's Algorithm: Concepts

System has a fixed number of processes and resources

- Each process has zero or more resources allocated

System state: either safe or unsafe

- Depends on allocation of resources to processes

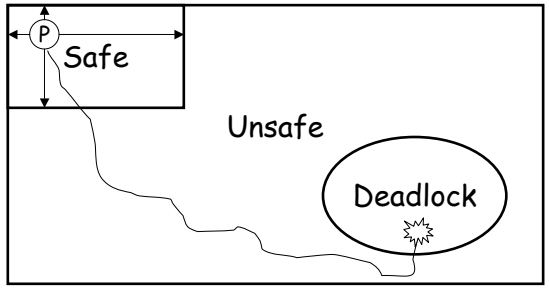
Safe state: deadlock is absolutely avoidable

- Can avoid deadlock by certain order of execution

Unsafe state: deadlock is possible (but not certain)

- May not be able to avoid deadlock

Safe, Unsafe, and Deadlock States



Banker's Algorithm

Given

- process/resource claim matrix
- process/resource allocation matrix
- resource availability vector

Is there a sequence of process executions such that

- a process can run to completion, return resources
- resources can then be used by another to complete
- eventually, all the processes complete?

Example of a Safe State

Current state

	Claim				Allocation					
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	Avail	Total
R_1	3	6	3	4	1	6	2	0	0	9
R_2	2	1	1	2	0	1	1	0	1	3
R_3	2	3	4	2	0	2	1	2	1	6

This is a safe state

- Which process can run to completion? P_2
- After P_2 completes, its resources are returned
- Next select P_1, then P_3, then P_4

Example of an Unsafe State

Current state

	Claim				Allocation					
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	Avail	Total
R_1	3	6	3	4	2	5	2	0	0	9
R_2	2	1	1	2	0	1	1	0	1	3
R_3	2	3	4	2	1	1	1	2	1	6

This is an unsafe state

- Can any process definitely run to completion? No!
- P_1 may block asking for R_1; same for P_2, P_3, and P_4
- Possible deadlock does not mean certain deadlock

How Do We Avoid a Traffic Jam?

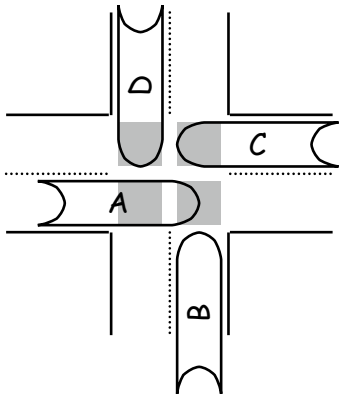
What are the incremental resources?

What is a safe state?

How to avoid deadlock?

- Allow at most 3 cars into intersection

Which condition is being prevented?



Deadlock Detection and Recovery

Don't do anything special to prevent or avoid deadlocks

- If they happen, they happen
- Periodically, try to detect if a deadlock occurred
- Do something (or even nothing) about it

Reasoning

- Deadlocks rarely happen
- Cost of prevention or avoidance is not worth it
- Deal with them in special way (may be very costly)

Most general purpose OS's take this approach!

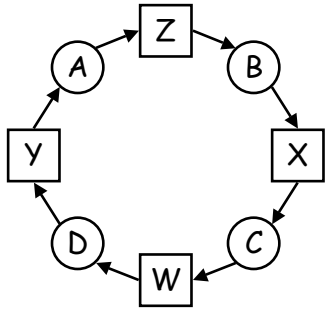
Detecting Deadlocks

Construct resource allocation "wait-for" graph

- if cycle, deadlock

Requires

- identifying all resources
- tracking their use
- periodically running detection algorithm



Recovery from Deadlock

Abort all deadlocked processes

- Will remove deadlock, but drastic and costly

Abort deadlocked processes one-at-at-time

- Do until deadlock goes away (need to detect)
- What order should processes be aborted?

What happens to resources in inconsistent states

- such as files that are partially written?
- or interrupted message (e.g., file) transfers?

Classical Synchronization Problems

The Producer/Consumer (Bounded Buffer) Problem

The Dining Philosophers Problem

The Readers/Writers Problem

Study these problems and their solutions!

The Dining Philosophers Problem

Five philosophers

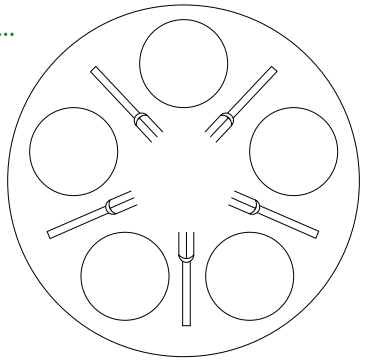
- Think, eat, think, eat, …

To eat

- Pick up two forks, one at a time
- Eat
- Put down forks

Mutual exclusion

- Avoid deadlock or starvation



Implementing Dining Philosophers

Identify critical section(s)

How to achieve mutual exclusion?

How to avoid deadlock?

How to avoid starvation?

How to generalize to n philosophers?

```
DoPhilosopher (int i)
  while (TRUE) {
    Think ();
    PickupFork (i);
    PickupFork ((i+1)%5);
    Eat ();
    PutdownFork ((i+1)%5);
    PutdownFork (i);
}
```


The Readers-Writers Problem

Multiple readers: processes that only read a file

Multiple writers: processes that modify a file

Rules

- Allow multiple simultaneous readers
- A writer gets exclusive access
- Avoid starvation
  - Once a writer arrives, wait until current readers leave and do not allow any new readers