CSE 120: Principles of Operating Systems

Lecture 6
Deadlock
January 30, 2006

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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

<table>
<thead>
<tr>
<th></th>
<th>Claim</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₁</td>
<td>P₂</td>
</tr>
<tr>
<td>R₁</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>R₂</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>R₃</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

This is a safe state

• Which process can run to completion? P₂
• After P₂ completes, its resources are returned
• Next select P₁, then P₃, then P₄
Example of an Unsafe State

Current state

<table>
<thead>
<tr>
<th>Claim</th>
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</thead>
<tbody>
<tr>
<td>P₁</td>
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<td>3</td>
</tr>
<tr>
<td>R₂</td>
<td>2</td>
</tr>
<tr>
<td>R₃</td>
<td>2</td>
</tr>
</tbody>
</table>

This is an unsafe state

- Can any process definitely run to completion? No!
- P₁ may block asking for R₁; same for P₂, P₃, and P₄
- 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-a-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