Readings and References

- Reading
  - Chapter 8, *Operating System Concepts*, Silberschatz, Galvin, and Gagne

- Other References

System Model

- There are tasks and resources
- A task follows these steps to utilize a resource
  - Acquire the resource
    - If the resource is unavailable, block
  - Use the resource
  - Release the resource

Necessary Conditions for Deadlock

- Mutual Exclusion
  - The resource can’t be shared
- Hold and Wait
  - Task holds one resource while waiting for another
- No Preemption
  - If a task has a resource, it cannot be forced to give it up
- Circular Wait
  - A waits for B, B for C, C for D, D for A

Simple Traffic Gridlock Example

Deadlock

- Circular waiting for resources
  - Task A wants what task B has
  - Task B wants what task A has
- No progress possible!
  - Neither can make progress without the other’s resource
  - Neither will relinquish its own resource

```c
... lockOne->Acquire(); ...
... lockTwo->Acquire();
lockOne->Acquire();
DEADLOCK!
```
Is Gridlock Example Deadlock?

- **Mutual Exclusion**
  - space-time can only hold one car at a time
- **Hold and wait**
  - I’m here, and I want to turn left, so watch out
- **No preemption**
  - cannons are not allowed in cars at this time
- **Circular wait**
  - blue waiting for red’s space and vice versa

Dealing with Deadlock

- **Deadlock Prevention**
  - Ensure statically that deadlock is impossible
- **Deadlock Avoidance**
  - Ensure dynamically that deadlock is impossible
- **Deadlock Detection and Recovery**
  - Allow deadlock to occur, but notice when it does and try to recover
- **Ignore the Problem**

Deadlock Prevention

- There are four necessary conditions for deadlock
- Take any one of them away and deadlock is impossible
- Let’s attack deadlock by
  - examining each of the conditions
  - considering what would happen if we threw it out

Condition: Mutual Exclusion

- Usually can't eliminate this condition
  - some resources are intrinsically non-sharable
- Examples include printer, write access to a file or record, entry into a section of code
- However, you can often mitigate this by adding a layer of abstraction
  - For example, use a print spooler, not direct connection to the printer

Condition: Hold and Wait

- Eliminate partial acquisition of resources
- Task must acquire all the resources it needs before it does anything
  - if it can’t get them all, then it gets none
- Resource utilization may be low
  - If you need P for a long time and Q only at the end, you still have to hold Q’s lock the whole time
- Starvation prone
  - May have to wait indefinitely before popular resources are all available at the same time

Condition: No Preemption

- Allow preemption
  - If a process asks for a resource not currently available, block it and take away all of its other resources
  - Add the preempted resources to the list of resources the process is waiting for
- This strategy works for some resources:
  - CPU state (contents of registers can be spilled to memory)
  - memory (can be spilled to disk)
- But not for others:
  - printer - rip off the existing printout and tape it on later?
Condition: Circular Wait

- To attack the circular wait condition:
  › Assign each resource a priority
  › Make processes acquire resources in priority order
- Two processes need the printer and the scanner, both must acquire the printer (higher priority) before the scanner
- This is the most common form of deadlock prevention
- The only problem: sometimes forced to relinquish a resource that you thought you had locked up

Deadlock Avoidance

- Deadlock prevention is often too strict
  › low device utilization
  › reduced system throughput
- If the OS had more information, it could do more sophisticated things to avoid deadlock and keep the system in a safe state
  › “If” is a little word, but it packs a big punch
  › predicting all needed resources \textit{a priori} is hard

The Banker’s Algorithm

- Idea: know what each process \textit{might} ask for
- Only make allocations that leave the system in a \textit{safe} state
- Inefficient

Deadlock Detection

- Build a \textit{wait-for} graph and periodically look for cycles, to find the circular wait condition
- The wait-for graph contains:
  › nodes, corresponding to tasks
  › directed edges, corresponding to a resource held by one task and desired by the other

Deadlock Recovery

- Once you’ve discovered deadlock, what next?
- Terminate one of the tasks to stop circular wait?
  › Task will likely have to start over from scratch
  › Which task should you choose?
- Take a resource away from a task?
  › Again, which task should you choose?
  › How can you \textit{roll back} the task to the state before it had the coveted resource?
  › Make sure you don’t keep on preempting from the same task: avoid starvation

Ignoring Deadlock

- Not a bad policy for operating systems
- The mechanisms outlined previously for handling deadlock may be expensive
  › if the alternative is to have a forced reboot once a year, that might be acceptable
- However, for thread deadlocks, your users may not be quite so tolerant
  › “the program only locks up once in a while”