Deadlock

CSE 410 - Computer Systems
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Readings and References

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

• Other References
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

```
...  
lockOne->Acquire();
...
...
lockTwo->Acquire();
```

```
...  
lockTwo->Acquire();
lockOne->Acquire();
```

DEADLOCK!
Simple Traffic Gridlock Example
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
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 a priori is hard
The Banker’s Algorithm

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

Resource allocation state space

deadlock
unsafe
safe
Deadlock Detection

- Build a *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

![Wait-for graph example]

- A waits for B
- B waits for D
- D waits for A

deadlock!
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 *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”