Deadlock

CSE 410, Spring 2009

Computer Systems

http://www.cs.washington.edu/410

Readings and References

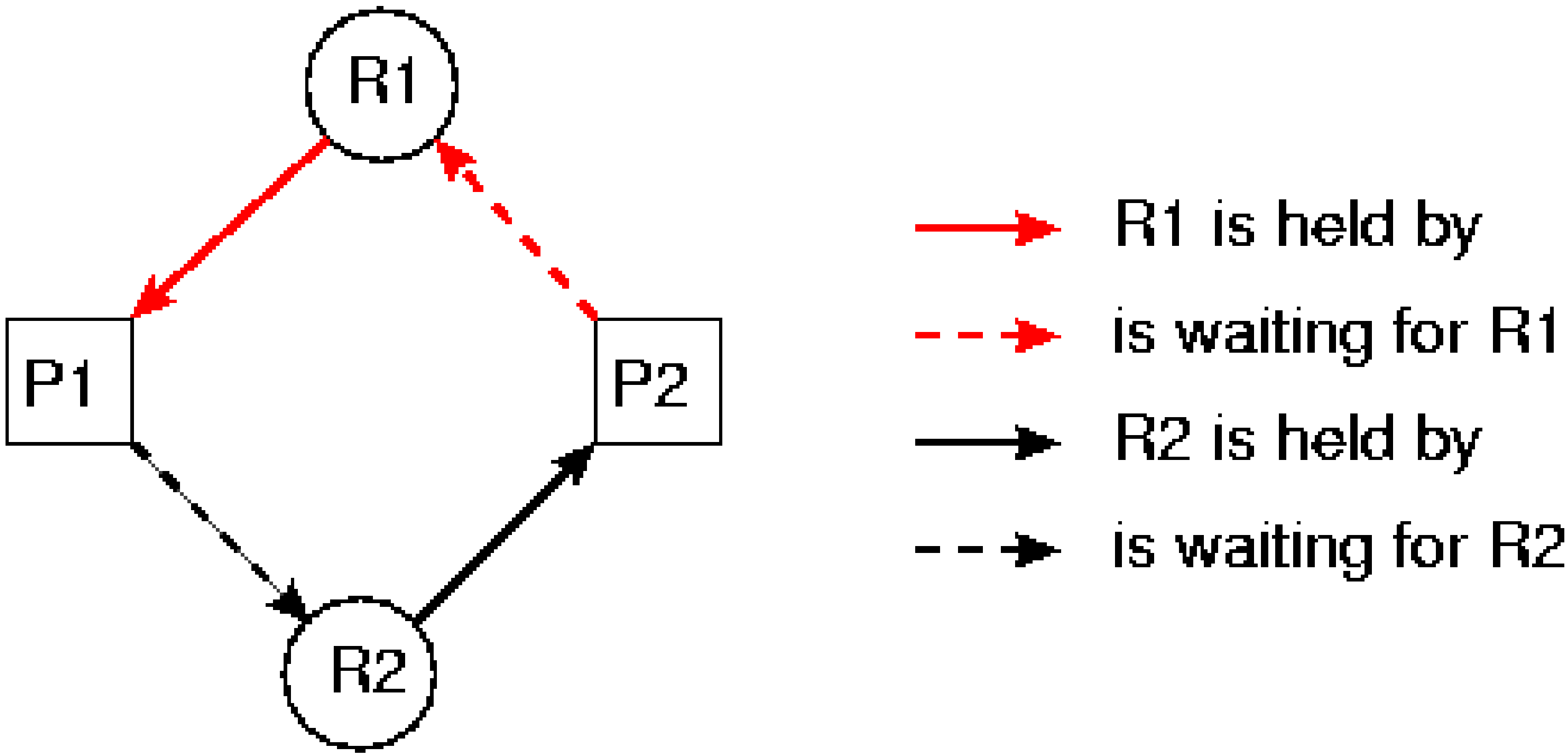
- Reading
  - » Chapter 7, *Operating System Concepts*, Silberschatz, Galvin, and Gagne

(Is Google the greatest, or what?)

Definition

- A thread is deadlocked when it's waiting for an event that can never occur
  - » I'm waiting for you to clear the intersection, so I can proceed
    - but you can't move until he moves, and he can't move until she moves, and she can't move until I move
  - » thread A is in critical section 1, waiting for access to critical section 2; thread B is in critical section 2, waiting for access to critical section 1
  - » I'm trying to book a vacation package to Tahiti – air transportation, ground transportation, hotel, side-trips. It's all-or-nothing – one high-level transaction – with the four databases locked in that order. You're trying to do the same thing in the opposite order.

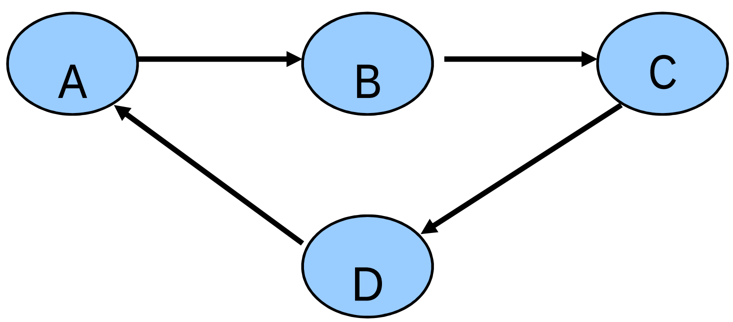
Resource graph



- A deadlock exists if there is an *irreducible cycle* in the resource graph (such as the one above)

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



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
  - » Let the operator untangle it, that's what they're paid for

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, write to a queue of jobs for a shared resource instead of locking the resource to write

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
- Issue: 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
- Issue: 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

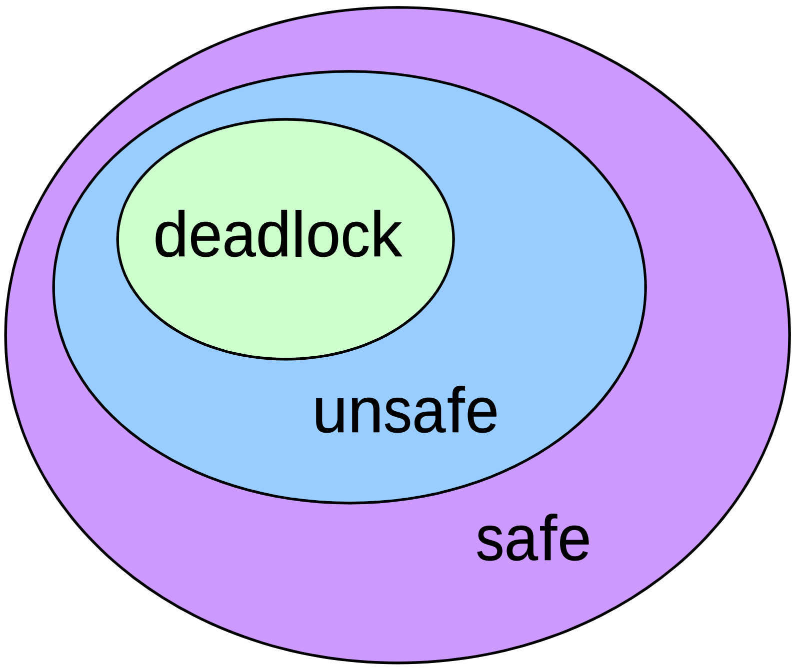
- To attack the circular wait condition:
  - » Assign each resource a priority
  - » Make processes acquire resources in priority order
- Two processes need the printer and the scanner, both must acquire the printer (higher priority) before the scanner
- This is a common form of deadlock prevention
- A problem: sometimes forced to relinquish a resource that you thought you had locked up
- A problem: sometimes (often?) impossible to assign a global, total order on resources/priorities

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 Detection

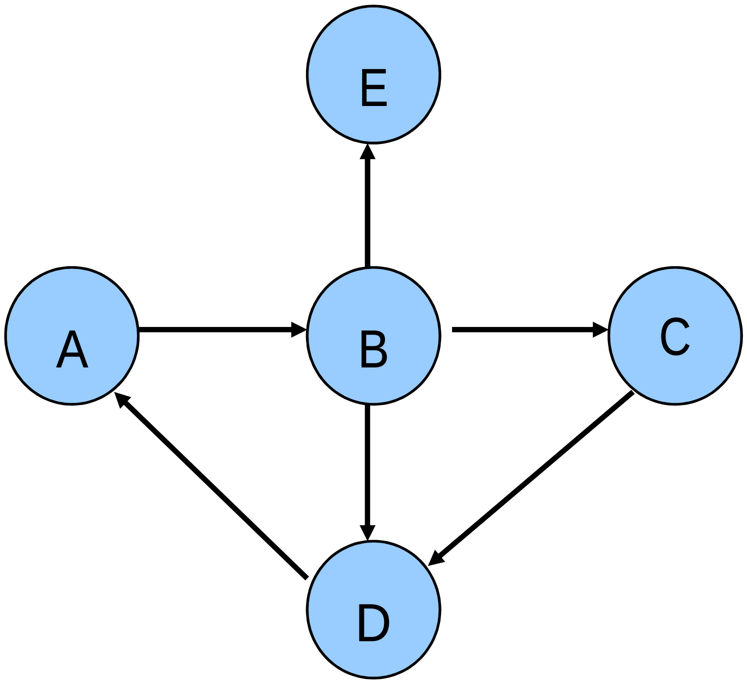
- Build a *wait-for* graph and periodically look for cycles, to find the circular wait condition
- The wait-for graph contains:
  - » nodes, corresponding to tasks
  - » directed edges, corresponding to a resource held by one task and desired by the other

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 always 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"