Deadlocks: Characterisation & Prevention

Summer 2011
Cornell University
Today

• What are the deadlocks and how are they created?
• System Model
• Deadlock examples
• Deadlock
• Four conditions for deadlock
• Resource allocation graph
• Deadlock prevention
System Model

- There are **non-shared** computer resources
  - Maybe more than one instance
  - Printers, Semaphores, Tape drives, CPU
- Processes need **access** to these resources
  - **Acquire** resource
    - If resource is available, access is granted
    - If not available, the process is blocked
  - **Use** resource
  - **Release** resource
- Undesirable scenario:
  - Process A acquires resource 1, and is waiting for resource 2
  - Process B acquires resource 2, and is waiting for resource 1
  - Deadlock!
Deadlock
Deadlock
Example 1: Semaphores

semaphore: mutex1 = 1 /* protects file */
           mutex2 = 1 /* protects printer */

Process A code:
{
    /* initial compute */
    P(mutex1)
    P(mutex2)

    /* use file & printer*/
    V(mutex2)
    V(mutex1)
}

Process B code:
{
    /* initial compute */
    P(mutex2)
    P(mutex1)

    /* use file & printer */
    V(mutex1)
    V(mutex2)
}
Example 2: Dining Philosophers

class Philosopher:
    chopsticks[N] = [Semaphore(1),…]
    def __init__(mynum):
        self.id = mynum
    def eat():
        right = (self.id+1) % N
        left = (self.id-1+N) % N
        while True:
            P(left)
            P(right)
            # eat
            V(right)
            V(left)
Deadlock

• A set of processes is in a deadlock state when every process in the set is waiting for an event that can be caused only by another process in the set.

• Events: resource acquisition and resource release

• Resources: physical or logical
Four Conditions for Deadlock

- Necessary conditions for deadlock to exist:
  - Mutual Exclusion
    - At least one resource must be held in non-sharable mode
  - Hold and wait
    - There exists a process holding a resource, and waiting for another
  - No preemption
    - Resources cannot be preempted
  - Circular wait
    - There exists a set of processes \{P_1, P_2, \ldots, P_N\}, such that
      - P_1 is waiting for P_2, P_2 for P_3, \ldots and P_N for P_1
  - \textit{All} four conditions must hold for deadlock to occur
Resource-Allocation Graph

- It helps us **depict** which **resources** have been assigned to which **processes** and which processes have requested which resources.

- Directed graph

- Vertices
  - P: set of processes
  - R: set of resources

- Edges
  - $P_i \rightarrow R_j$: request edge
  - $R_j \rightarrow P_i$: assignment edge
Resource-Allocation Graph

- If there is a deadlock, then there is a cycle.
- If there is a cycle, then:
  - If the involved resources have one instance each, then there is deadlock
  - Else a deadlock may not exist
Handling Deadlocks

- A system never enters a deadlock state.
  - Prevention, or
  - Avoidance
- A system may enter a deadlock state.
  - Detect deadlock
  - Recover from deadlock
- Ignore deadlock problem
Deadlock Prevention

- Prevention: **Negate one of necessary conditions**
- Mutual exclusion:
  - Make resources sharable
  - Not always possible (printers?)
- Hold and wait
  - Do not hold resources when waiting for another
  - Request all resources before beginning execution
  - Processes do not know what all they will need
  - Starvation (if waiting on many popular resources)
  - Low utilization (Need resource only for a bit)
  - Alternative: Release all resources before requesting anything new
    - Still has the last two problems
Deadlock Prevention

- No preemption:
  - Make resources preemptable (2 approaches)
    - Preempt requesting processes’ resources if all not available
    - Preempt resources of waiting processes to satisfy request
  - Good when easy to save and restore state of resource
    - CPU registers, memory virtualization

- Circular wait: (2 approaches)
  - Single lock for entire system? (Problems)
  - Impose **partial ordering** on resources, request them in order
Today

- What are the deadlocks and how are they created?
- System Model
- Deadlock examples
- Deadlock
- Four conditions for deadlock
- Resource allocation graph
- Deadlock prevention