DEADLOCK

The Deadlock Problem

- Definition:
  - A set of blocked processes each holding some resources and waiting to acquire a resource held by another process in the set
  - None of the processes can proceed or back-off (release resources it owns)
- Examples:
  - Dining philosopher problem
  - System has 2 memory pages (unit of memory allocation); P_1 and P_2 each hold one page and each needs another one
  - Semaphores A and B, initialized to 1

P_1	P_2
wait (A);	*wait(B)*
wait (B);	*wait(A)*

Deadlock Characterization

Deadlock can arise if four conditions hold simultaneously:

- **Mutual exclusion:** only one process at a time can use a resource
- **Hold and wait:** a process holding at least one resource is waiting to acquire additional resources held by other processes
- **No preemption:** a resource can be released only voluntarily by the process holding it, after that process has completed its task
- **Circular wait:** there exists a set $\{P_0, P_1, \ldots, P_n, P_0\}$ of waiting processes such that
  - P_0 is waiting for a resource that is held by P_1,
  - P_1 is waiting for a resource that is held by P_2,
  - …,
  - P_{n-1} is waiting for a resource that is held by P_n,
  - and P_n is waiting for a resource that is held by P_0.

Methods for Handling Deadlocks

- Ignore the problem and pretend that deadlocks would never occur
- Ensure that the system will *never* enter a deadlock state (prevention or avoidance)
- Allow the system to enter a deadlock state and then detect/recover

The Ostrich Algorithm

- Pretend there is no problem
  - unfortunately they can occur
- Reasonable if
  - deadlocks occur very rarely
  - cost of prevention is high
- Your typical OSes take this approach
- It is a trade off between
  - convenience
  - correctness

Deadlock Prevention

Restrain the ways requests can be made to break one of the four necessary conditions for deadlocks.

Attacking the Mutual Exclusion Condition:

- Some devices (such as printer) can be spooled
  - only the printer daemon uses printer resource
  - thus deadlock for printer eliminated
- Not all devices can be spooled

Deadlock Prevention

Attacking the Hold and Wait Condition:

- Require processes to request all resources before starting
- Problems
  - may not know required resources at start of run
  - also ties up resources other processes could be using
- Variation:
  - before a process requests a new resource, it must give up all resources and then request all resources needed

Deadlock Prevention

Attacking the No Preemption Condition:

- Preemption
  - when a process is holding some resources and waiting for others, its resources may be preempted to be used by others
- Problem
  - Many resources may not allow preemption; i.e., preemption will cause process to fail

Attacking the Circular Wait Condition:

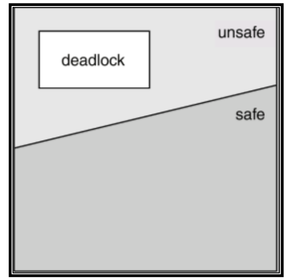
- impose a total order of all resource types; and require that all processes request resources in the same order

Deadlock Avoidance

- When a process requests an available resource, system must decide if immediate allocation leaves the system in a *safe state*
- System is in safe state if there exists a safe sequence of all processes
- Sequence <P_1, P_2, …, P_n> is safe if for each P_i, the resources that P_i can still request can be satisfied by currently available resources + resources held by all the P_j, with $j<i$.
  - If P_i's resource needs are not immediately available, then P_i can wait until all P_j have finished
  - When P_j is finished, P_i can obtain needed resources, execute, return allocated resources, and terminate
  - When P_i terminates, P_{i+1} can obtain its needed resources, and so on

Deadlock Avoidance (cont.)

- If a system is in safe state ⇒ no deadlocks
- If a system is in unsafe state ⇒ possibility of deadlock
- Deadlock avoidance
  - dynamically examines the resource-allocation state
  - ensures that a system will never enter an unsafe state



Banker's Algorithm

- Each process must a priori claim the maximum set of resources that might be needed in its execution
- Safety check
  - repeat
    - pick any process that can finish with existing available resources; finish it and release all its resources
    - until no such process exists
  - all finished → safe; otherwise → unsafe.
- When a resource request is made, the process must wait if:
  - enough available resource is not available for this request
  - granting the request would result in an unsafe system state

Example of Banker's Algorithm

- 5 processes P_0 through P_4
- 3 resource types: *A* (10 instances), *B* (5 instances), and *C* (7 instances)
- Snapshot at time T_0:

	Allocation	*MaxNeeds*	*Available*
	A B C	*A B C*	*A B C*
P_0	0 1 0	7 5 3	3 3 2
P_1	2 0 0	3 2 2	
P_2	3 0 2	9 0 2	
P_3	2 1 1	2 2 2	
P_4	0 0 2	4 3 3	

- Is this a safe state?
- Can request for (1,0,2) by P_1 be granted?

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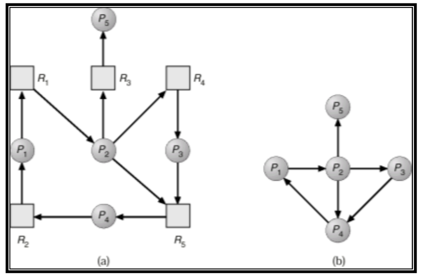
Single Instance of Each Resource Type

- Maintain *wait-for* graph
  - Nodes are processes.
  - $P_i \rightarrow P_j$ if P_i is waiting for P_j.
- Periodically search for a cycle in the graph.



Resource-Allocation Graph   Corresponding wait-for graph

Multiple Instances of Each Resource Type

- When there are several instances of a resource type
  - cycle detection in wait-for graph is not sufficient
- Deadlock detection is very similar to the safety check in the Banker's algorithm
  - just replace the maximum needs with the current requests

Recovery from Deadlock

- Recovery through preemption
  - take a resource from some other process
  - depends on nature of the resource
- Recovery through rollback
  - checkpoint a process state periodically
  - rollback a process to its checkpoint state if it is found deadlocked
- Recovery through killing processes
  - kill one or more of the processes in the deadlock cycle
  - the other processes get its resources
- In which order should we choose process to kill?

Disclaimer

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