Operating Systems

Autumn 2024

Resource allocation graph

Managing deadlocks

- Deadlock detection algorithms find instances of deadlock and try to recover
- Admit the possibility of deadlock occurring and periodically check for it

System Modeling

- Set of resource types: R_1, R_2, . . . , R_m
  - There are multiple resource of each type: e.g., 3 NICs, 4 disks
- Set of processes (or threads): P_1, P_2, . . . , P_n

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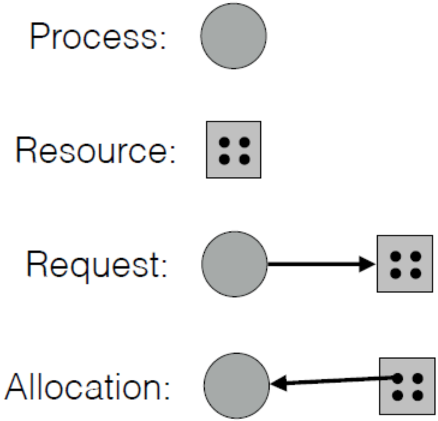
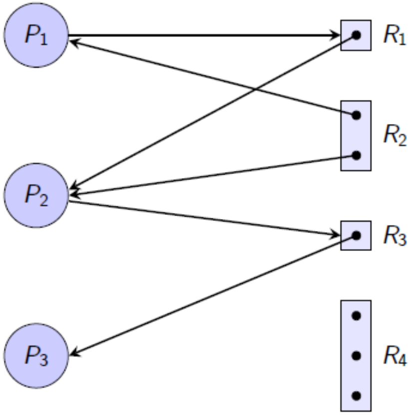
  - There are multiple resource of each type: e.g., 3 NICs, 4 disks
- Set of processes (or threads): $P_1, P_2, \ldots, P_n$
- Each process can:
  - Request a resource of a given type and block/wait until one resource instance of that type becomes available
  - Use a resource
  - Release a resource

Resource-allocation graph



Example Graph



Cycle and deadlock

- Theorem [Holt]:
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  - If cycles do exist then a deadlock is possible

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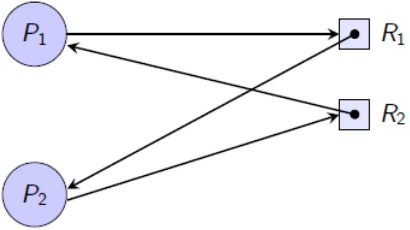
- Theorem [Holt]:
  If the resource allocation graph contains no (directed) cycle, then there is no deadlock in the system
  - If cycles do exist then a deadlock is possible
- If there is only one resource instance (black dot) per resource type then we have a stronger theorem:
  The existence of a cycle is a necessary and sufficient condition for the existence of a deadlock

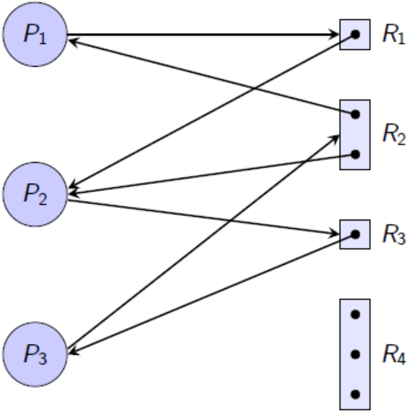
Cycle and deadlock: our 2-lock example

Clearly, there is a cycle



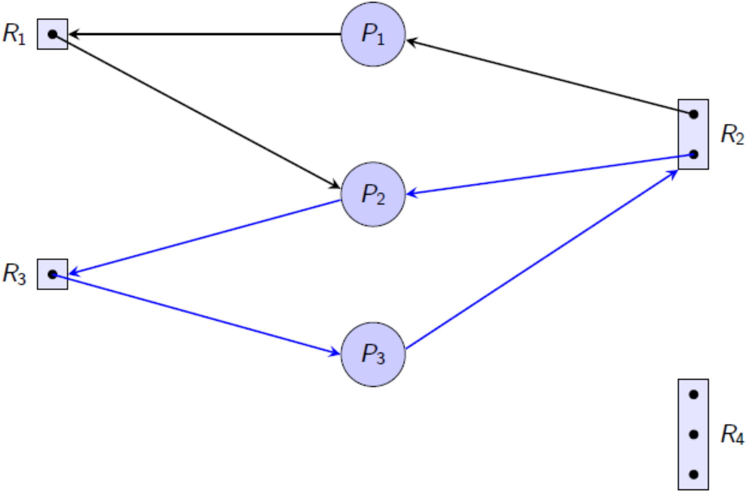
Another Example

Can you see the cycle(s)?



Moving vertices around

Can you see the cycle(s) now?



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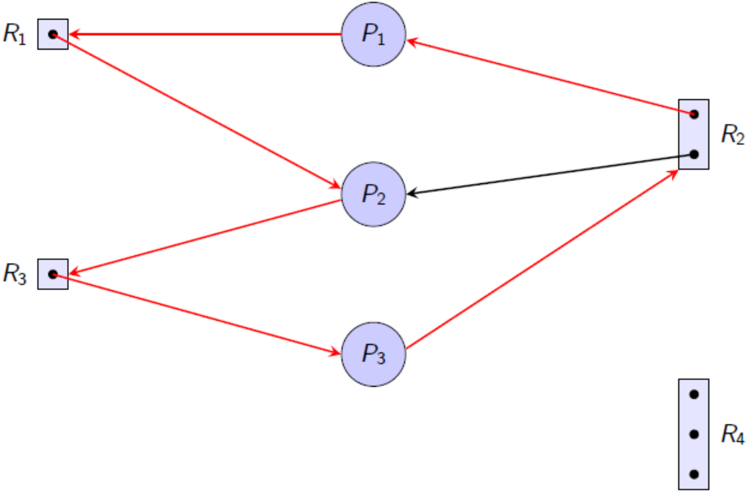
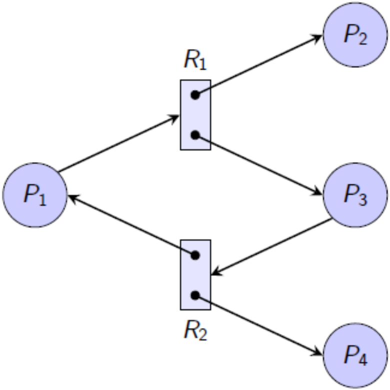


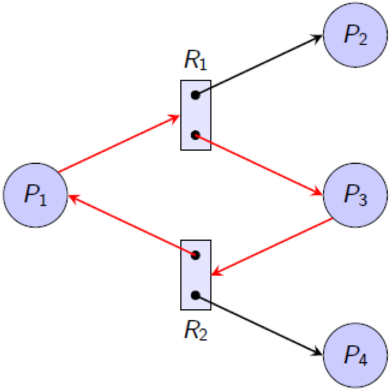
Example: Cycle and No Deadlock

There is a cycle . . .



Example: Cycle and No Deadlock

There is a cycle . . . but there is no deadlock

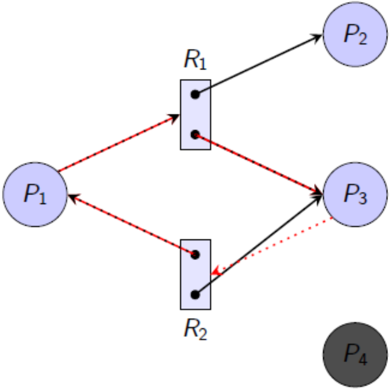


Example: Cycle and No Deadlock

When P_4 terminates it will release the instance of R_2 it locked, and that resource will be locked by P_3.

P_3 will then be able to complete.

(Another option is that P_2 completes first.)



Deadlock detection

- A cycle in the resource allocation graph
  - Is a necessary condition for a deadlock
  - But not a sufficient condition
- many algorithms for detecting cycles in directed graphs

Cheeky interview answer

- Interviewer: Explain how deadlock works and we'll hire you !
- Candidate: Hire me and I'll explain it to you . . .