Deadlock

How to Prevent It

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Deadlock

What is deadlock?

How do we prevent it?

Reference:

William Stallings, *Operating Systems and Design Principles*, 4th Edition, 2001, Chapter 6

What is deadlock?

- A set of processes or threads is in deadlock if:
- Each process is waiting for something that can only be offered by another process in the set.
- The set of processes is stuck
- To the user, they appear to have hung

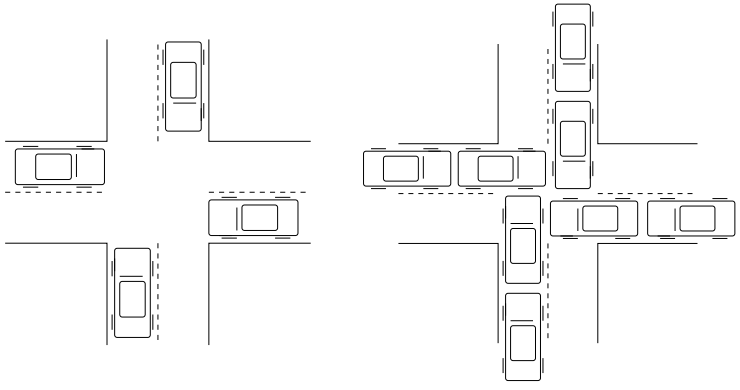
Concurrent Systems

- A *concurrent system* is one where more than one process or thread is executing at the same time
  - I.e., is running or is ready to run
- Examples:
  - operating system
  - multiprocessing application (e.g., Apache 1.3.x)
  - multithreaded application (e.g., Apache 2.x.x)
- Deadlock can occur in a concurrent system

Starvation

- *Starvation* is a second danger for concurrent systems besides deadlock
- Involves a process not getting access to a resource because other processes are unfairly granted access
- We do not discuss starvation further here.

Gridlock — 2



Gridlock on physical road

- Deadlock is like gridlock at an intersection
- Cars cannot move forward, because the space in front is occupied by another car
- Cannot move back
- Very similar to deadlock in OS

Requirements for Deadlock

- Mutual exclusion
  - only one process can use a resource at one time
  - result of locking access to the resource
- Hold and Wait
  - Processes in the set holding resources given earlier can request new resources
- No Preemption
  - Resources given to process cannot be taken away forcibly by OS or other process
  - the process needs to surrender the resource itself
- Circular Wait
  - Each process is waiting for a resource held by another process in the set (the actual deadlock)

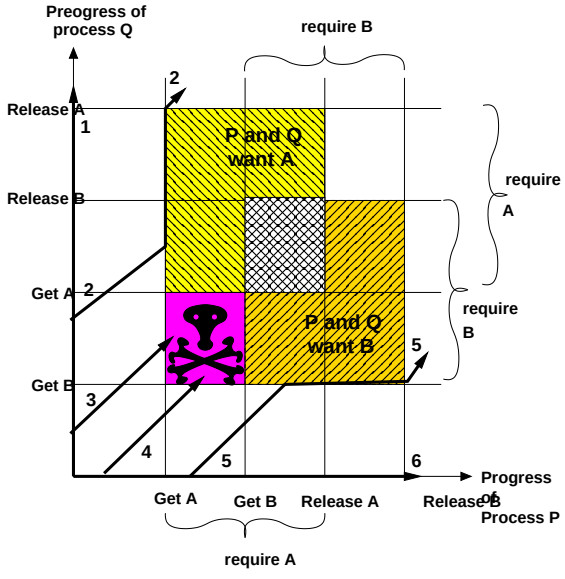
Deadlock Avoidance

- The first three conditions are necessary for deadlock to occur
- The fourth condition can result because the first three are true
- A set of processes can reach an *unsafe* state where deadlock is possible
- *Deadlock avoidance* involves detecting unsafe states and not allocating resources that would cause an unsafe state
  - We do not investigate deadlock avoidance here.
- Need balance cost of deadlock against cost of preventing it

Two processes that can deadlock

```
Process P          Process Q
. . .              . . .
Get A              Get B
. . .              . . .
Get B              Get A
. . .              . . .
Release A          Release B
. . .              . . .
Release B          Release A
. . .              . . .
```


Deadlock Example — 2



1. Only Q executes.
6. Only P executes.
2. Q gets B, then A. P blocks waiting for A, resumes after Q releases A
5. P gets A, then B. Q blocks waiting for B, resumes after P releases B

Deadlock Example — 3

- Path 1: only Q executes, no deadlock
- Path 6: only P executes, no deadlock
- Path 2: Q gets B, then A. P executes, blocks waiting for A, resumes after Q releases A. No deadlock.
- Path 5: P gets A, then B. Q executes, blocks waiting for B, resumes after P releases B. No deadlock.

Deadlock Example — 4

- No problem if only P or Q executing
- No problem if Q gets B then A, P executes, but blocks waiting for A. Q releases A and B. P can then run OK
- No problem if either process gets both resources before the other starts.

Deadlock Example — 5

- But if:
- Q gets B, then P gets A (Path 3), or
- P gets A, then Q gets B (Path 4)
- Deadlock must happen since both will block waiting for the other.

How to prevent deadlock?

- Two main methods:
  - Indirect method: prevent one of the first three conditions
- Direct method:
  - Prevent the last condition.
- All methods of prevention may have some cost in
  - execution time, or
  - more limited access to resources
  - design and programming time

Indirect: preventing mutual exclusion

- This condition depends on the nature of the resource.
- If resource must be locked, then the OS must support mutual exclusion.
  - If concurrent processes share data, there is a danger of data corruption
  - i.e., two or more threads both write to same file at the same time

Indirect: prevent hold & wait — 1

- Process does not proceed until allocated all resources it will ever need.
- Wasteful, since:
  - process may wait much longer for all resources rather than enough to start with.
  - Resources locked while not being used.

Indirect: prevent hold & wait — 2

- Another way to prevent hold and wait:
- Process holds only one resource at one time
- Example: modify P as shown
- Note no deadlock possible even if do not change Q

Indirect: prevent hold & wait — 3

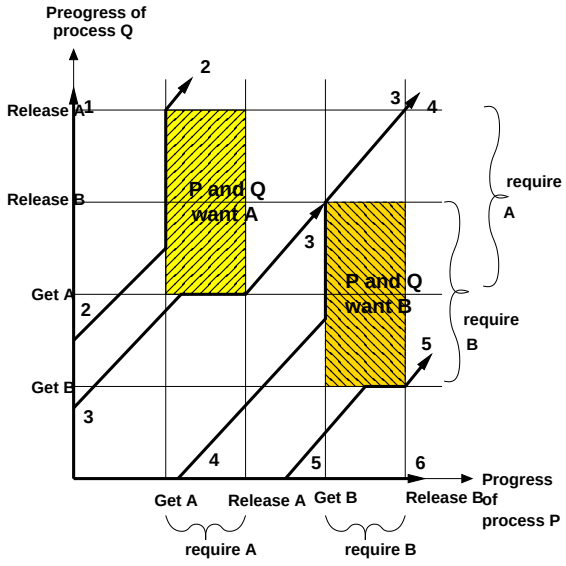
- Another strategy is for a thread or process to test if additional resources are available before waiting for them
- If any resource is not available,
  - then release all resources,
  - yield the `CPU` and then try again
    - yield = give up, i.e, thread voluntarily goes to the end of the scheduler queue for threads of its own priority
    - means another thread gets the `CPU` instead
- See `backoff.c` from *Programming with POSIX Threads*, pp. 67–69

Indirect: prevent hold & wait 3

```
Process P
. . .
Get A
. . .
Release A
. . .
Get B
. . .
Release B
. . .
```

```
Process Q
. . .
Get B
. . .
Get A
. . .
Release B
. . .
Release A
. . .
```

Indirect: prevent hold & wait 4



- some paths result in P or Q being *temporarily* blocked
- but the other process can always complete
- no chance of deadlock

Indirect: allow preemption

- OS or concurrent application could order a hierarchy of processes
- Highest priority could always get resources used by a lower priority process.
- Drawback: must be able to resume the preempted task at the point where the resource was taken away.

Direct: prevent circular wait

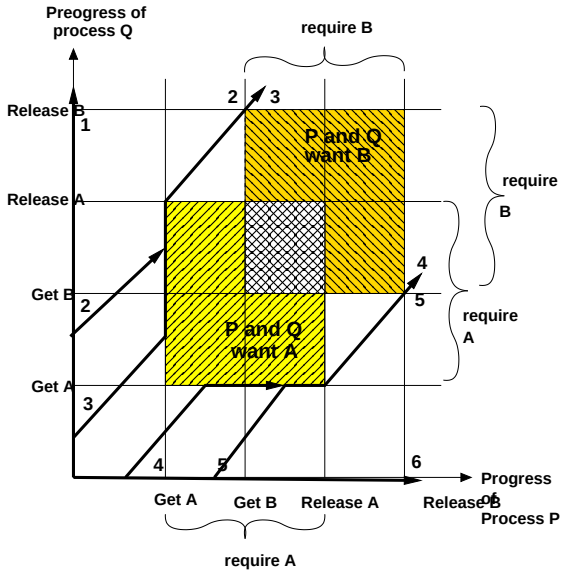
- Define an order in which resources are always requested
- For example, in previous example, if always allocate A then B, no deadlock can occur.
- This method is a part of strategy used in Linux and Windows operating system design

Direct: prevent circular wait — 2

```
Process P
. . .
Get A
. . .
Get B
. . .
Release A
. . .
Release B
. . .
```

```
Process Q
. . .
Get A
. . .
Get B
. . .
Release A
. . .
Release B
. . .
```

Direct: prevent circular wait — 3



- some paths result in P or Q being *temporarily* blocked
- but the other process can always complete
- again, no possibility of deadlock

Conclusion

- Deadlock is very undesirable
- Occurs within a set of processes or threads
- The processes “lock up”, each process waiting for the other.
- 4 conditions *all* required for deadlock
- deadlock avoidance detects and avoids *unsafe* states
- Prevention involves removing/preventing *one* or more of these conditions