

## Deadlock

### General Definition

- A set of processes  $S$  is *deadlocked* if each process in  $S$  is waiting for an event that can be caused only by a process in  $S$ .

### Resource Control

- Process waits for one or more resources held by others
- Necessary condition for deadlock:
  - **Mutual exclusion**
  - **Hold-and-wait**
  - **No preemption**
  - **Circular wait**

## Principles of dealing with deadlock

- Deadlock *prevention*
- Deadlock *avoidance*
- Deadlock *detection* and *recovery*
- Ignore (hope for the best)

## Deadlock Prevention

### Idea

- To introduce *structural restrictions* that eliminates deadlock risk

### Methods

- **Mutual exclusion**  
Enable simultaneous use, e.g. by spooling [not general]
- **Hold-and-wait**  
Reserve all resources at once [low utilization, risk of starvation]
- **No-preemption**  
Allow preemption, e.g. of CPU and memory [not general]
- **Circular wait**  
Assign ranks to resource types:  
A process may only request resources having **strictly higher** rank than already allocated ones.

## Deadlock Avoidance

### Idea

- To use *behavioural information* to dynamically avoid deadlock.

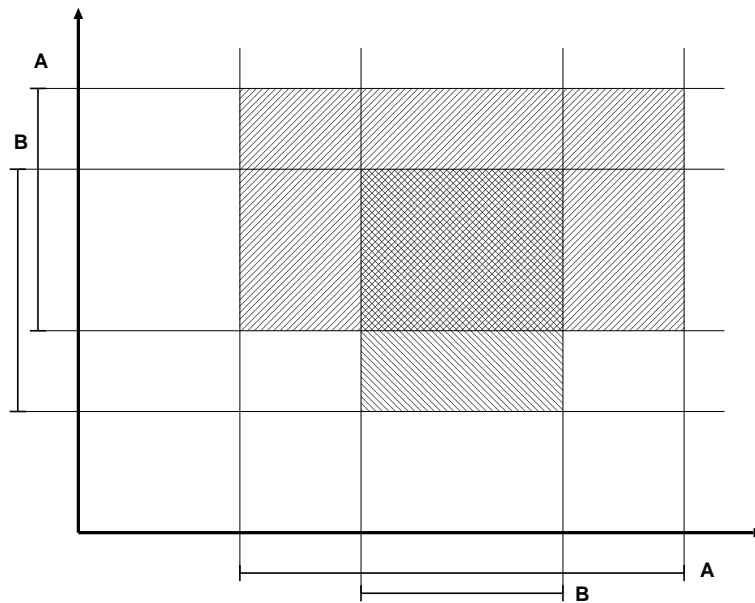
### Prerequisites

- Behavioural information must be available for all processes
- Examples:
  - Max resource claim for each resource type
  - Resource usage pattern

### Method

- A **safe** state is a state from which there exists a way to terminate all processes (according to usage information).
- **Banker's Algorithm** A resource request is granted only if the resulting state remains safe.

## Safe/unsafe States



## Deadlock Detection

### Idea

- To detect deadlocks and handle them by automatic recovery

### Deadlock Detection

- Maintain global allocation state and perform deadlock detection:
  - Regularly
  - When some process seems not to make progress
- Assume deadlock if no progress for a while

### Recovery

- Select one or more victims based on *cost factors*
- Kill victim or *roll-back* to *check-point*
- Risk of starvation