Deadlock

Deadlock avoidance techniques

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Deadlock avoidance

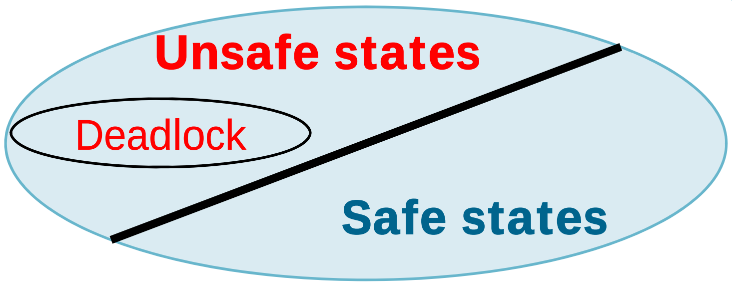
- Deadlock avoidance techniques force the processes to provide (a priori) additional information about requests that they will perform in the course of their execution
  - Each process must indicate how many resources of all types it will need to terminate its task
  - This information allow the process scheduling order so that that there is no deadlock
    - If the execution of a process can cause deadlock, the request causes the process to wait

Deadlock avoidance

- The main algorithms
  - differ in the amount and type of information required
    - The simplest model imposes to all processes declaring the maximum number of resources of each type that the process will need
  - generally reduce the use of resources and the efficiency of the system
  - are based on the concept of **safe state** and **safe sequence**

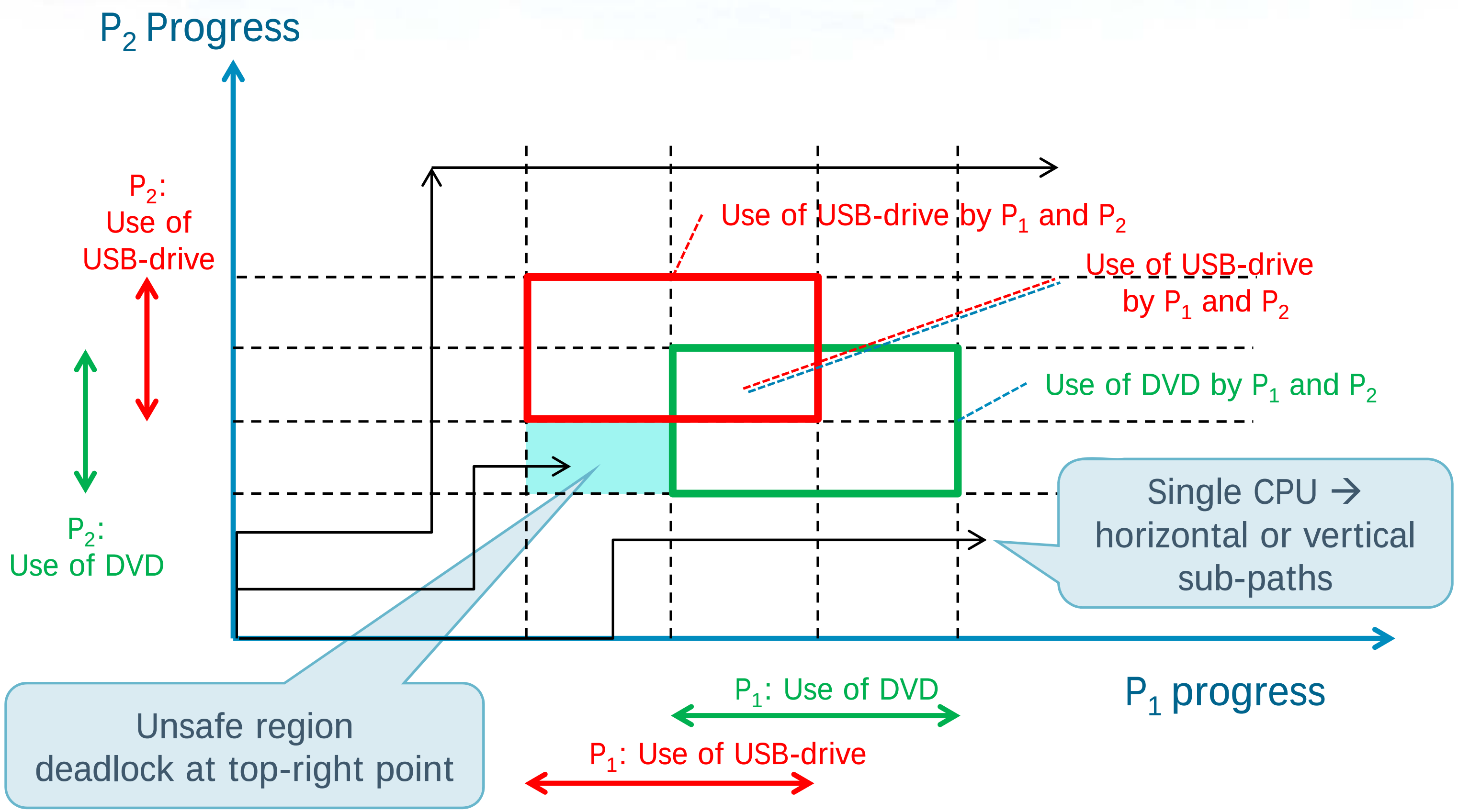
Safe state

Safe state	The system is able to • Allocate the required resources to all processes • Prevent the occurrence of a deadlock • Find a safe sequence
Safe sequence	A sequence of process scheduling $\{P_1, P_2, \ldots, P_n\}$ such that for each requests that could performed by any P_i , it can be satisfied by using the currently available resources and the other resources released by P_j processes with $j < i$



Otherwise, a state is said **unsafe**. An unsafe state is not necessarily a deadlock state. It leads to a deadlock state in case of standard behavior.

Joint progress of two processes

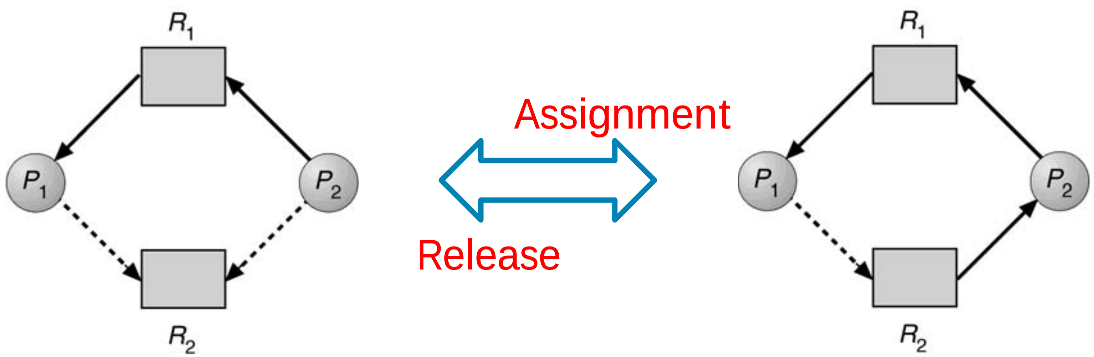


Strategies

- To avoid a deadlock, one must ensure that the system remains always in a safe state
  - Initially the system is in a safe state
  - Each new resource request
    - will be granted immediately if this allows leaving the system in a safe state
    - Otherwise, it will be delayed; the process that performed the request will wait
- There are two classes of strategies
  - For resources having unitary instances
  - For resources having multiple instances

Algorithm for resources with a single instance

- Based on the determination of cycles, using the claim-for graph
  - All requests must be a priori declared
  - they are represented by claim edges - - - ->
- At a time a request is performed
  - the corresponding claim edge is transformed into an assignment edge



Algorithm for resources with a single instance

- On the graph thus obtained the algorithm verifies the presence of cycles (excluding dotted edges), which do not occur if the state is still safe
  - If the graph has no cycles the conversion to assignment edge is confirmed, otherwise it is postponed
- When a resource is releases
  - the assignment edge returns to be a claim edge (to predict subsequent requests)

Algorithm for resources with multiple instances

- Verify the state of the system to understand if the available resources are sufficient to complete all processes
  - based on the number of resources available to the system, number of resources allocated and max number of resource that the process may need
- Each process
  - must declare in advance its maximum number of resources it may need
  - requesting a resource it can be blocked for a limited amount of time
  - must guarantee to return an allocated resource in a finite amount of time

Algorithm for resources with multiple instances

- Banker's Algorithm (Dijkstra, [1965])
  - Verifies that the current state is safe
  - Verifies that the new request can be immediately granted allowing to system to remain in a safe state
    - Simulates assigning the resource, and controls that a sequence of assignments exist that allow the system to satisfy all requests, possibly delaying the delivery of the resources for some of requests.
- The algorithm uses the data structures listed in the following slide

Algoritmo per istanze multiple

Given a set of:

- **n processes**
- **m resources**

Name	Dim.	Content and meaning
completed	[n]	completed[r] initially false
allocated	[n][m]	allocated[r][c]=k P_r owns k instances of R_c
max_res.	[n][m]	max_resources[r][c]=k P_r can ask for max_resources k instances of R_c
need	[n][m]	need[r][c]=k P_r needs k additional k instances of R_c ∀i∀j need[i][j]=max_resources[i][j]-allocated][j]
available	[m]	available]=k k resources R_c are available

Example

- By applying the banker algorithm, the underlying system is in a safe state?
  - Safe sequence: P_1, P_3, P_4, P_0, P_2

P	completed	Allocated	Max_res	need	Available
		R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2
P_0	F	0 1 0	7 5 3		3 3 2
P_1	F	2 0 0	3 2 2		
P_2	F	3 0 2	9 0 2		
P_3	F	2 1 1	2 2 2		
P_4	F	0 0 2	4 3 3		

Example

- Can the request of P_1 (1, 0, 2) be satisfied?
  - System state evolution ...

P	completed	Allocated	Max_res	need	Available
		R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2
P_0	F	0 1 0	7 5 3	7 4 3	3 3 2
P_1	F	2 0 0	3 2 2	1 2 2	
P_2	F	3 0 2	9 0 2	6 0 0	
P_3	F	2 1 1	2 2 2	0 1 1	
P_4	F	0 0 2	4 3 3	4 3 1	

Example

- The new state is safe or not?
  - Safe sequence: P_1, P_3, P_4, P_0, P_2

P	completed	Allocated	Max_res	need	Available
		R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2
P_0	F	0 1 0	7 5 3	7 4 3	2 3 0
P_1	F	3 0 2	3 2 2	0 2 0	
P_2	F	3 0 2	9 0 2	6 0 0	
P_3	F	2 1 1	2 2 2	0 1 1	
P_4	F	0 0 2	4 3 3	4 3 1	

Example

- Can the request of P_4 (3, 3, 0) be satisfied?
  - No ...
- Can the request of P_0 (0, 3, 0) be satisfied?
  - No ...

P	completed	Allocated	Max_res	need	Available
		R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2
P_0	F	0 1 0	7 5 3	7 4 3	2 3 0
P_1	F	3 0 2	3 2 2	0 2 0	
P_2	F	3 0 2	9 0 2	6 0 0	
P_3	F	2 1 1	2 2 2	0 1 1	
P_4	F	0 0 2	4 3 3	4 3 1	

Banker's algorithm

- Verify a set of requests performed by P_i

```
if
  ∀j requests[i][j] <= need [i][j]
  and
  ∀j requests[i][j] <= available[j]
  then
    ∀j available[j]      -= requests[i][j]
    ∀j allocation[i][j] += requests[i][j]
    ∀j need[i][j]        -= requests[i][j]

if the resulting state is safe then
  the assignment is confirmed,
else
the previous state is restored
```

Banker’s algorithm

- Verify whether a state is safe or unsafe

```
1.
∀i∀j need[i][j]= max_resource[i][j] - allocated[i][j]
∀i completed[i]=false
2.
Find a process Pi such that
Completed[i]=false and ∀j need[i][j] <= available[j]
If no such i is found goto step 4
3.
∀j available[j] += allocated[i][j]
completed[i]=true
goto step 2
4.
if ∀i completed[i]=true then
  system is in a safe state
```

Exercise

- Can the request of P_1 (1, 0, 1) be satisfied?
  - Yes …
- Can the request of P_2 (1, 0, 1) be satisfied?
  - No …

P	completed	Allocated	Max_res	need	Available
		R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2	R_0 R_1 R_2
P_0	F	1 0 0	3 2 2		1 1 2
P_1	F	5 1 1	6 1 3		
P_2	F	2 1 1	3 1 4		
P_3	F	0 0 2	4 2 2		

Exercise

- Are the following states safe or unsafe?

(single resource problems)

P	F	A	M	N	D
P_0	F	3	9		3
P_1	F	2	4		
P_2	F	2	7		

... safe state

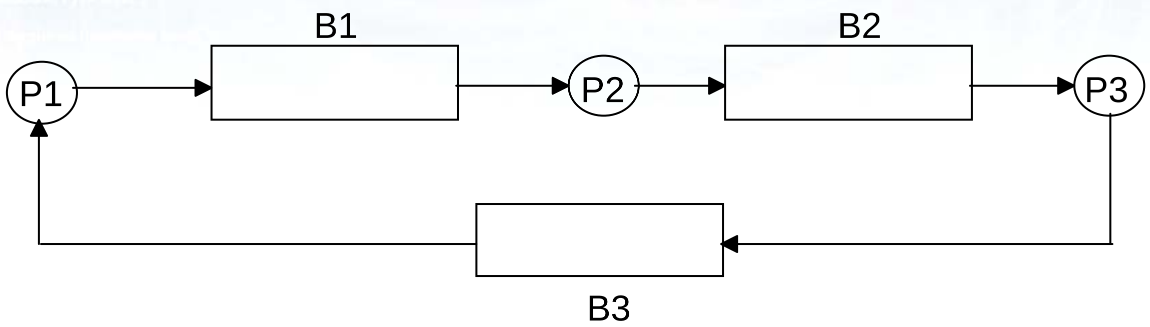
P	F	A	M	N	D
P_0	F	4	9		2
P_1	F	2	4		
P_2	F	2	7		

... unsafe state

Banker's algorithm

- Complexity is
  - $O(m \cdot n^2) = O(|R| \cdot |P|^2)$
- It is also based on unrealistic assumptions
  - Processes must specify their demands in advance
    - The necessary resources are not always known
    - Also it is not known when a resource will be used
  - Assumes that the number of resources is constant
    - Resources may increase or decrease due to transient or continuous failures
  - It requires a fixed population of processes
    - The number of active processes in the system increases and decreases dynamically

Circular Wait using IPC



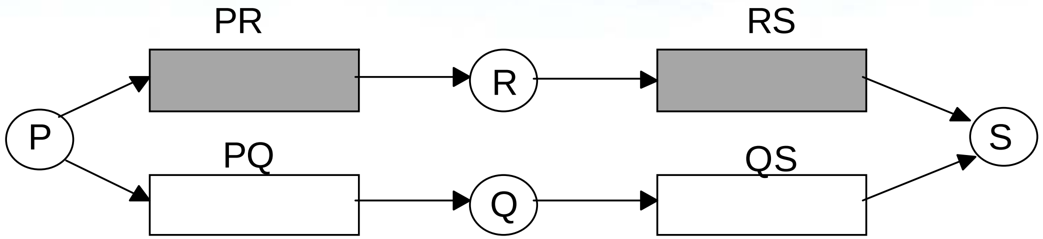
P1	P2	P3
...	...	...
send (B1,m)	send (B2,m)	send (B3,m)
...	...	...
send (B1,m)	send (B2,m)	send (B3,m)
...	...	...
receive (B3,m)	receive (B1,m)	receive (B2,m)

time

m = message
B_i = i-th communication buffer

Deadlock using IPC

Multiple communication paths



P	Q	R	S
....	....	....	
send (PR,m)	....	send (RS,m)	....
....	....	....	....
send (PR,m)	receive (PQ,m)	send (RS,m)	receive (QS,m)
....			
send (PQ,m)	send (QS,m)	receive (PR,m)	receive (RS,m)