<u>Paper Name : Operating System</u>

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Resource Allocation Graph -

The resource allocation graph is the pictorial representation of the state of a system. As its name suggests, the resource allocation graph is the complete information about all the processes which are holding some resources or waiting for some resources.

It also contains the information about all the instances of all the resources whether they are available or being used by the processes.

It contains a set of vertices *V* and a set of edges *E*.

V is partitioned into two types:

- $P = \{P_1, P_2, \ldots, P_n\}$, the set consisting of all the processes in the system
- $R = \{R_1, R_2, \ldots, R_m\}$, the set consisting of all resource types in the system

Types of edges:

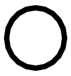
1. Assign Edge –
   - If a resource is already assigned to a process then it is called assign edge.
   - directed edge $R_j \rightarrow P_i$

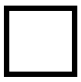
2. Request Edge –
   - It means in future the process might want some resource to complete the execution, that is called request edge.
   - directed edge $P_i \rightarrow R_j$

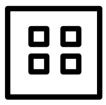
So, if a process is using a resource, an arrow is drawn from the resource node to the process node. If a process is requesting a resource, an arrow is drawn from the process node to the resource node

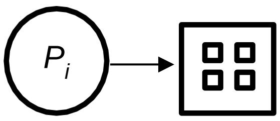
- If graph contains no cycles $\Rightarrow$ no deadlock

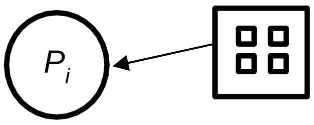
- If graph contains a cycle ⇒
  - ❖ If each resource in the cycle provides only one instance, then the processes will be in deadlock. So cycle in single-instance resource type is a sufficient condition for deadlock.
  - ❖ In multi-instance resource type, cycle is not a sufficient condition for deadlock.

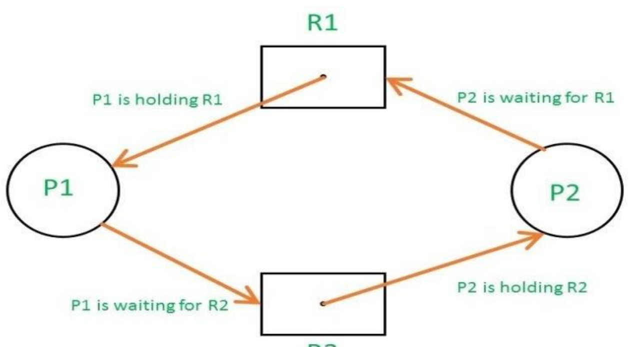
Process 

Resource 

Resource type with 4 instances 

P_i requests instance of R_j 

P_i is holding an instance of R_j 



SINGLE INSTANCE RESOURCE TYPE WITH DEADLOCK

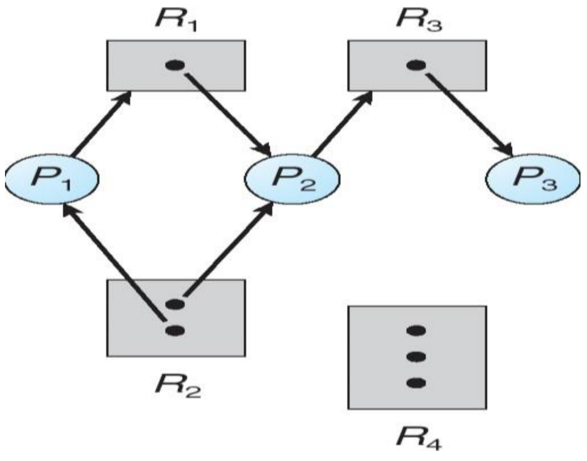


Fig : Example of resource allocation graph

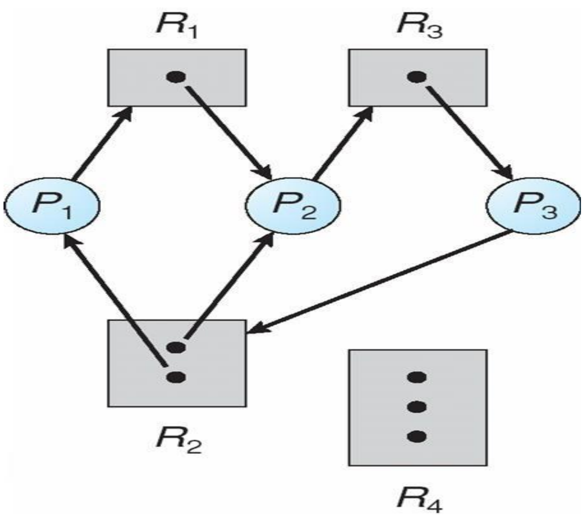


Fig : Example of resource allocation graph with a deadlock

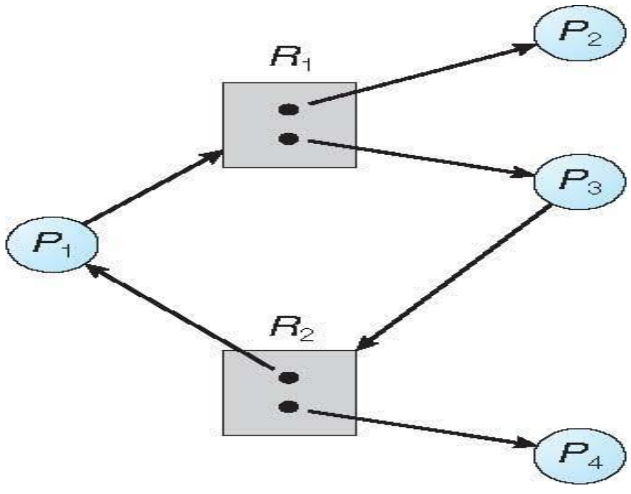


Fig : Example of resource allocation graph with a cycle but no deadlock

Deadlock Prevention -

We can prevent deadlock by eliminating any of the above four conditions.

1. **Eliminate Mutual Exclusion**
   The mutual-exclusion condition must hold for non-shareable resources. For example, a printer cannot be simultaneously shared by several processes. Sharable resources, in contrast, do not require mutually exclusive access and thus cannot be involved in a deadlock. Read-only files are a good example of a sharable resource. If several processes attempt to open a read-only file at the same time, they can be granted simultaneous access to the file. A process never needs to wait for a sharable resource.

In general, however, we cannot prevent deadlocks by denying the mutual-exclusion condition, because some resources are intrinsically non-shareable.
If access to a resource requires mutual exclusion, then mutual exclusion must be supported by the operating system. Some resources such as files may allow multiple accesses for reads but only exclusive access for writes. Even in this case, deadlock can occur if more than one process requires write permission.

2. **Eliminate Hold and wait -**
   To ensure that the hold-and-wait condition never occurs in the system, we must guarantee that, whenever a process requests a resource, it does not hold any other resources.
   a. Allocate all required resources to the process before the start of its execution, this way hold and wait condition is eliminated but it will lead to low device utilization. For example, if a process requires printer at a later time and we have allocated printer before the start of its execution printer will remain blocked till it has completed its execution.
   b. An alternative protocol allows a process to request resources only when it has none. A process may request some resources and use them. Before it can request any additional resources, however, it must release all the resources that it is currently allocated.

3. **Eliminate No pre-emption –**
   If the resource can be taken away from the process which is causing deadlock then deadlock can be prevented.

4. **Eliminate Circular Wait -**

To avoid circular wait, resources may be ordered and we can ensure that each process can request resources only in an increasing order of these numbers. The algorithm may itself increase complexity and may also lead to poor resource utilization.

Deadlock Avoidance –

To avoid a deadlock, before allocation a system decides whether it should allocate or not so that it does not enter the deadlock. The request for any resource will be granted if the resulting state of the system doesn't cause deadlock in the system. The state of the system will continuously be checked for safe and unsafe states.

A resource allocation state is defined by the number of available and allocated resources, and the maximum requirements of all processes in the system.

A deadlock avoidance algorithm dynamically examines the resource allocation state from time to time to ensure that no circular wait condition exists.

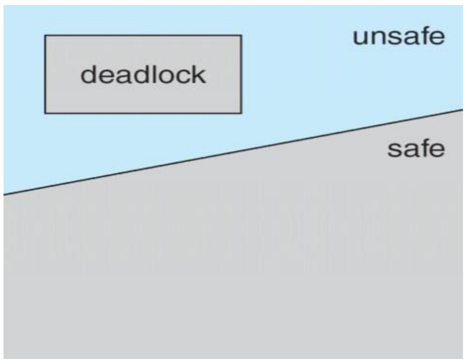
A resource allocation state is safe if the system can allocate all resources requested by all processes (up to their stated maximums) without entering a deadlock state. Otherwise it is a unsafe state.

A system is in a safe state only if there exists a safe sequence. A sequence of processes is a safe sequence for the current allocation state if, for each Pi, the resource requests that Pi can still make can be satisfied by the currently available resources plus the resources held by all Pj, with j < i. In this situation, if the resources that Pi needs are not immediately available, then Pi can wait until all Pj have finished. When they have finished, Pi can obtain all of its needed resources, complete its designated task, return its allocated resources, and terminate. When Pi terminates, Pi+l can obtain its needed resources, and so on. If no such sequence exists, then the system state is said to be unsafe.

A safe state is one in which there is at least one sequence of resource allocations to processes that does not result in a deadlock (i.e. all the processes can be run to completion). An unsafe state is, of course, a state that is not safe.

- If a system is in safe state $\Rightarrow$ no deadlocks
- If a system is in unsafe state $\Rightarrow$ possibility of deadlock

A safe state is not a deadlocked state. Conversely, a deadlocked state is an unsafe state. Not all unsafe states are deadlocks. An unsafe state may lead to a deadlock. As long as the state is safe, the operating system can avoid unsafe (and deadlocked) states. In an unsafe state, the operating system cannot prevent processes from requesting resources in such a way that a deadlock occurs.



Consider there are n processes in the system $P_1, P_2, P_3, \ldots\ldots, P_n$ where-

- Process P_1 requires x_1 units of resource R
- Process P_2 requires x_2 units of resource R
- Process P_3 requires x_3 units of resource R and so on.

In worst case,

The no. of units that each process hold = one less than it's maximum demand

So,

- Process P_1 holds $x_1 - 1$ units of resource R
- Process P_2 holds $x_2 - 1$ units of resource R
- Process P_3 holds $x_3 - 1$ units of resource R and so on.

Now,

- Had there been one more unit of resource R in the system, system could be ensured deadlock free.
- This is because that unit would be allocated to one of the processes and it would get execute and then release its units.

From here, we have-

Maximum Number Of Units That Ensures Deadlock-

Maximum number of units of resource R that ensures deadlock
= $(x_1\text{-}1) + (x_2\text{-}1) + (x_3\text{-}1) + \ldots + (x_n\text{-}1)$
= $(x_1 + x_2 + x_3 + \ldots + x_n) - n$
= $\sum x_i - n$
= Sum of max needs of all n processes – n

Minimum Number Of Units That Ensures No Deadlock-

Minimum number of units of resource R that ensures no deadlock
= One more than maximum number of units of resource R that ensures deadlock
= $(\sum x_i - n) + 1$

a. If a system has 100 identical resources and N processes competing for them. Each process can request atmost 4 units of resources then how many processes can be present at maximum so that no deadlock will occur?

In worst case,
The number of units that each process holds = One less than its maximum demand
So,

- Process P1 holds 3 units of resource R
- Process P2 holds 3 units of resource R
- Process P3 holds 3 units of resource R and so on.
- Process P33 holds 3 units of resource R
- Process P34 holds 1 unit of resource R

Thus,

- Minimum number of processes that ensures deadlock = 34
- Maximum number of processes that ensures no deadlock = 34 – 1 = 33

b. A system is having 3 user processes each requiring 2 units of resource R. Find the minimum number of units of R such that no deadlock will occur-

In worst case,
The number of units that each process holds = One less than its maximum demand
So,
Process P1 holds 1 unit of resource R
Process P2 holds 1 unit of resource R
Process P3 holds 1 unit of resource R
Thus

Maximum no. of units of resource R that ensures deadlock = 1+1+1 = 3
Minimum number of processes that ensures no deadlock = 3 +1 = 4