MODELS OF DEADLOCKS

The models of deadlocks are explained based on their hierarchy. The diagrams illustrate the working of the deadlock models. P_a, P_b, P_c, P_d are passive processes that had already acquired the resources. P_e is active process that is requesting the resource.

Single Resource Model

- A process can have at most one outstanding request for only one unit of a resource.
- The maximum out-degree of a node in a WFG for the single resource model can be 1, the presence of a cycle in the WFG shall indicate that there is a deadlock.

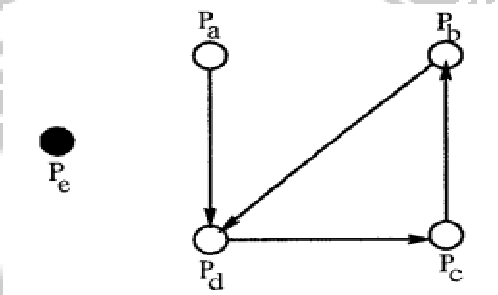

Fig: Deadlock in single resource model

AND Model

- In the AND model, a passive process becomes active (i.e., its activation condition is fulfilled) only after a message from each process in its dependent set has arrived.
- In the AND model, a process can request more than one resource simultaneously and the request is satisfied only after all the requested resources are granted to the process.
- The requested resources may exist at different locations.
- The out degree of a node in the WFG for AND model can be more than 1.
- The presence of a cycle in the WFG indicates a deadlock in the AND model.
- Each node of the WFG in such a model is called an AND node.
- In the AND model, if a cycle is detected in the WFG, it implies a deadlock but not vice versa. That is, a process may not be a part of a cycle, it can still be deadlocked.

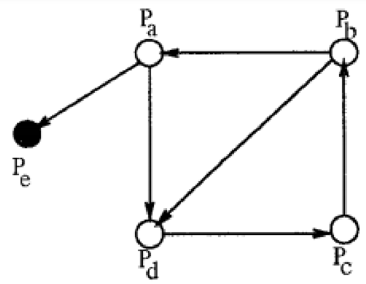

Fig : Deadlock in AND model

OR Model

- A process can make a request for numerous resources simultaneously and the request is satisfied if any one of the requested resources is granted.
- Presence of a cycle in the WFG of an OR model does not imply a deadlock in the OR model.
- In the OR model, the presence of a knot indicates a deadlock.

Deadlock in OR model: a process Pi is blocked if it has a pending OR request to be satisfied.

- With every blocked process, there is an associated set of processes called **dependent set.**
- A process shall move from an idle to an active state on receiving a grant message from any of the processes in its dependent set.
- A process is permanently blocked if it never receives a grant message from any of the Processes in its dependent set.
- A set of processes S is deadlocked if all the processes in S are permanently blocked.
- In short, a processis deadlocked or permanently blocked, if the following conditions are met:

  1. Each of the process is the set S is blocked.
  2. The dependent set for each process in S is a subset of S.
  3. No grant message is in transit between any two processes in set S.

- A blocked process P is the set S becomes active only after receiving a grant message from a process in its dependent set, which is a subset of S.

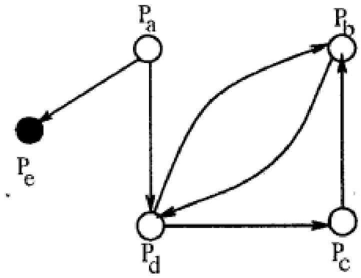

Fig: OR Model

$\binom{p}{q}$ Model (p out of q model)

- This is a variation of AND-OR model.
- This allows a request to obtain any k available resources from a pool of n resources. Both the models are the same in expressive power.
- This favours more compact formation of a request.
- Every request in this model can be expressed in the AND-OR model and vice-versa.
- Note that AND requests for p resources can be stated as $\binom{p}{q}$ and OR requests for p resources can be stated as $\binom{p}{1}$.

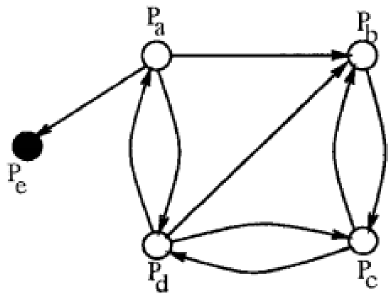

Fig: p out of q Model

Unrestricted model

- No assumptions are made regarding the underlying structure of resource requests.
- In this model, only one assumption that the deadlock is stable is made and hence it is the most general model.
- This model helps separate concerns: Concerns about properties of the problem (stability and deadlock) are separated from underlying distributed systems computations (e.g., message passing versus synchronous communication).