Lecture 8

Deadlock & Main Memory I

Lecture Information

Ceng328 *Operating Systems* at April 13, 2010

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Contents

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- In general, deadlocks occur when sharing *reusable* and *nonpreemptable* resources.

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- A system table records whether each resource is free or allocated; for each resource that is allocated, the table also records the process to which it is allocated.
- A process whose resource request has just been denied will normally sit in a tight loop requesting the resource, then sleeping, then trying again.

Deadlocks & System Model III

- One possible way of allowing user management of resources is to associate a semaphore with each resource. Mutexes can be used equally well.

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typedef int semaphore;
semaphore resource_1;

void process_A(void) {
        down(&resource_1);
        use_resource_1( );
        up(&resource_1);
}
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typedef int semaphore;
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void process_A(void) {
        down(&resource_1);
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- A set of processes is in a deadlock state when every process in the set is waiting for an event that can be caused only by another process in the set.

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- Deadlocks can occur in a variety of situations. In a database system, for example, a program may have to lock several records it is using, to avoid race conditions.

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  - If process *A* locks record *R*1 and process *B* locks record *R*2, and then each process tries to lock the other one's record, we also have a deadlock (see Fig. 2).

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- A programmer who is developing multithreaded applications must pay particular attention to this problem.
- Multithreaded programs are good candidates for deadlock because multiple threads can compete for shared resources.

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Necessary Conditions II

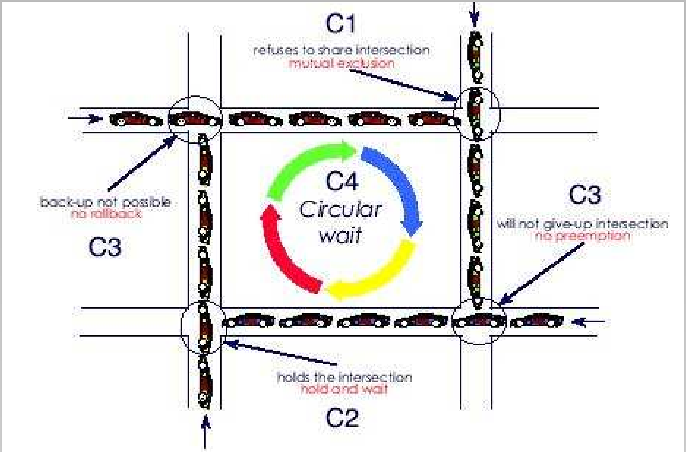

Figure: An example to Deadlock.

We emphasise that **all four conditions must hold for a deadlock** to occur.

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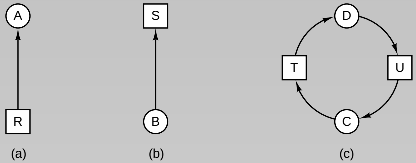
- Pictorially, each process P_i is represented as a circle and each resource type R_j as a rectangle.



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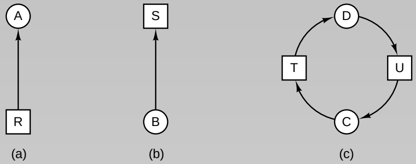

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- An arc from a resource node (square) to a process node (circle) means that the resource has previously been requested by, granted to, and is currently held by that process (see Fig. 4).

Resource-Allocation Graph II

- Since resource type R_j may have more than one instance, each such instance is represented as a dot within the rectangle.

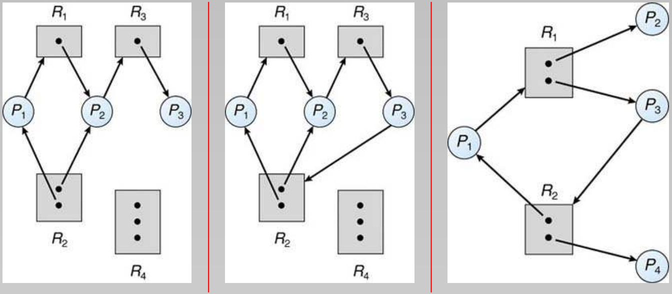

Figure: Left: Resource-allocation graph. Middle: Resource-allocation graph with a deadlock. Right: Resource-allocation graph with a cycle but no deadlock

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- If the graph does contain a cycle, then a deadlock may exist.
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- A *knot* must exist; a cycle with no non-cycle outgoing path from any involved node

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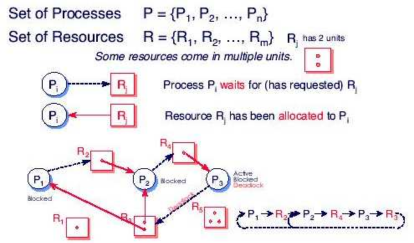
- In summary, if a resource-allocation graph does not have a cycle, then the system is not in a deadlocked state.
- If there is a cycle, then the system may or may not be in a deadlocked state.

Resource-Allocation Graph V

- An example of resource allocation graphs (see Fig. 6);



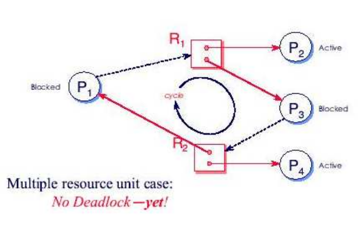


Figure: Resource Allocation Graphs. Lower; either P_2 or P_4 could relinquish (release) a resource allowing P_1 or P_3 (which are currently blocked) to continue.

Resource-Allocation Graph VI

Another example of how resource graphs can be used; three processes, *A*, *B*, and *C*, and three resources *R*, *S*, and *T* (see Fig. 7);.

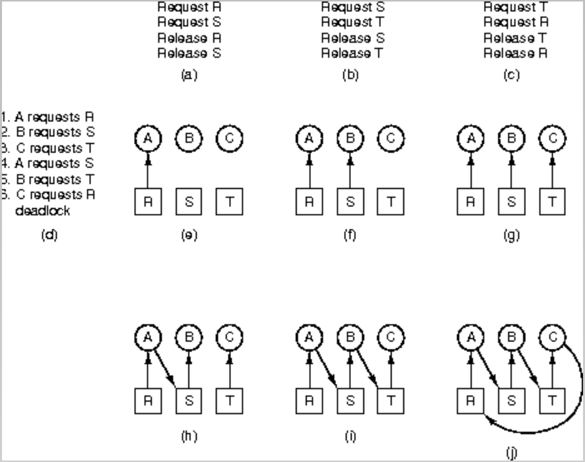


Figure: An example of how deadlock occurs.

Resource-Allocation Graph VII

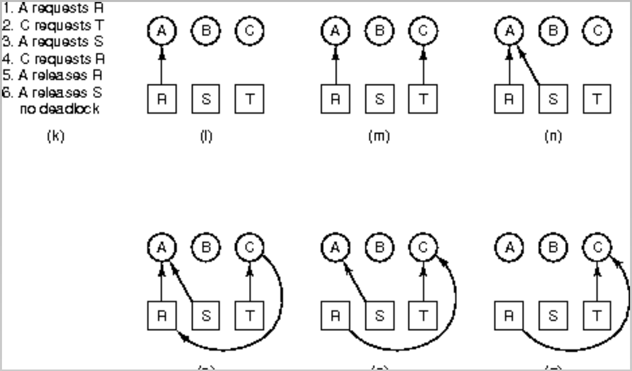


Figure: An example of how deadlock can be avoided.

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  3. We can **ignore** (The Ostrich Algorithm; maybe if you ignore it, it will ignore you) the problem altogether and pretend that deadlocks never occur in the system.

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  - Swap space on the disk is another limited resource. In fact, almost every table in the OS represents a finite resource.
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- The various approaches to deadlock prevention are summarized in Fig. 9.

Condition	Approach
Mutual exclusion	Spool everything
Hold and wait	Request all resources initially
No preemption	Take resources away
Circular wait	Order resources numerically

Figure: Summary of approaches, to deadlock prevention.

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- In general, however, we cannot prevent deadlocks by denying the mutual-exclusion condition, because some resources are intrinsically nonsharable.

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  - The process will be restarted only when it can regain its old resources, as well as the new ones that it is requesting.

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  - With this knowledge of the complete sequence of requests and releases for each process, the system can decide for each request whether or not the process should wait in order to avoid a possible future deadlock.

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- The resource-allocation state is defined by the number of available and allocated resources and the maximum demands of the processes.

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  - If no such sequence exists, then the system state is said to be **unsafe**.

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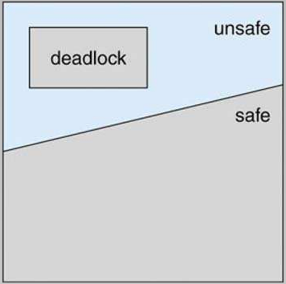

Figure: Safe, unsafe, and deadlock state spaces.

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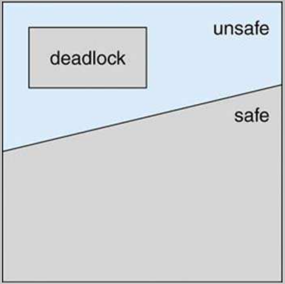

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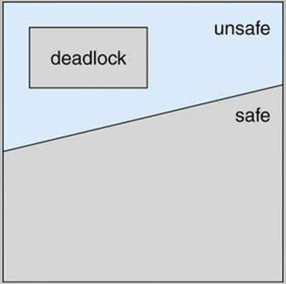

Figure: Safe, unsafe, and deadlock state spaces.

- An unsafe state may lead to a deadlock.
- The difference between a safe state and an unsafe state is that from a safe state the system can guarantee that all processes will finish; from an unsafe state, no such guarantee can be given.

Safe State III

- To illustrate, we consider a system with 12 magnetic tape drives and three processes: P_0, P_1, and P_2 .

P_i	Maximum Needs	Current Needs
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- Our mistake was in granting the request from process P_2 for one more tape drive.

Safe State IV

	Has	Max
A	3	9
B	2	4
C	2	7

Free: 3
(a)

	Has	Max
A	3	9
B	4	4
C	2	7

Free: 1
(b)

	Has	Max
A	3	9
B	0	–
C	2	7

Free: 5
(c)

	Has	Max
A	3	9
B	0	–
C	7	7

Free: 0
(d)

	Has	Max
A	3	9
B	0	–
C	0	–

Free: 7
(e)

	Has	Max
A	3	9
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(b)

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C	2	7

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B	—	—
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Free: 4
(d)

Figure: Demonstration that the state in is safe (Upper), is not safe (Lower).

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- In this scheme, if a process requests a resource that is currently available, it may still have to wait.
- Thus, resource utilization may be lower than it would otherwise be.

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Single Instance of Each Resource Type I

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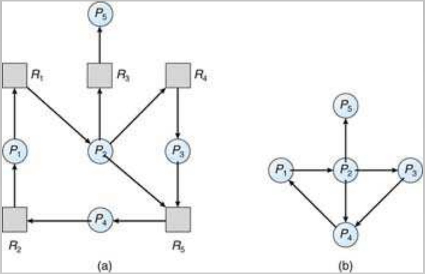

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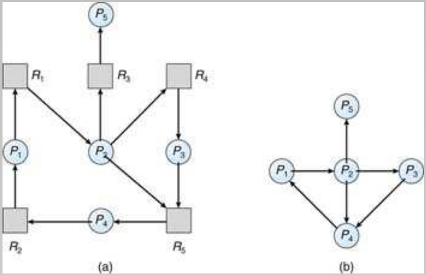

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- As before, a deadlock exists in the system if and only if the wait-for graph contains a cycle.

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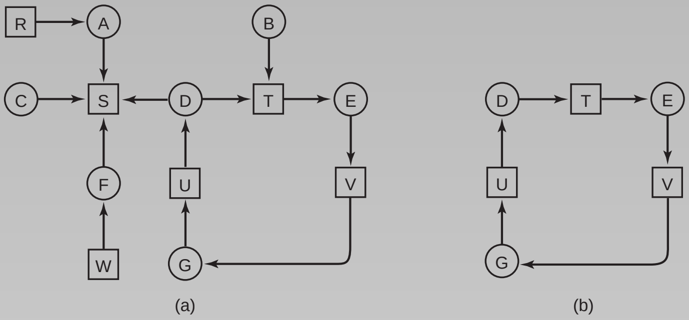

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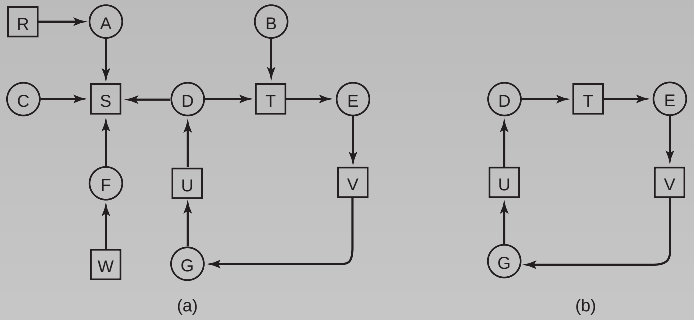

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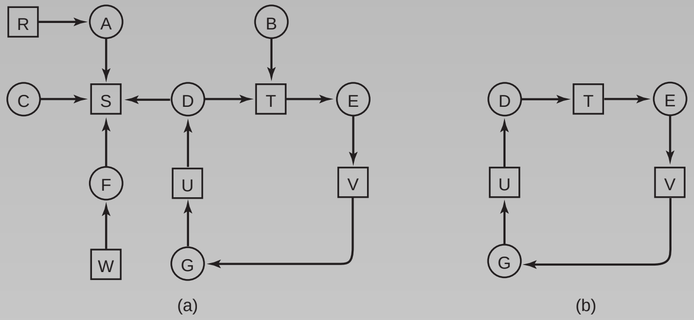

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- The remedy is to add fast memory between the CPU and main memory (**cache** memory).

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- We first need to make sure that each process has a separate memory space.

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- We can provide this protection by using two registers, usually a **base** and a **limit**, as illustrated in Fig. 14.

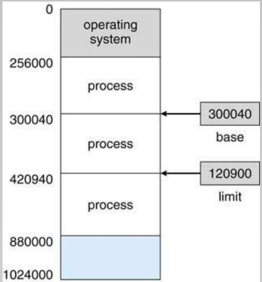

Figure: A base and a limit register define a logical address space.

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- We can provide this protection by using two registers, usually a **base** and a **limit**, as illustrated in Fig. 14.
    - The **base register** holds the smallest legal physical memory address;

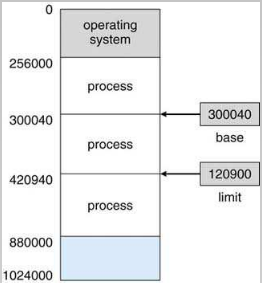

Figure: A base and a limit register define a logical address space.

Basic Hardware III

- We can provide this protection by using two registers, usually a **base** and a **limit**, as illustrated in Fig. 14.
  - The **base register** holds the smallest legal physical memory address;
  - The **limit register** specifies the size of the range.

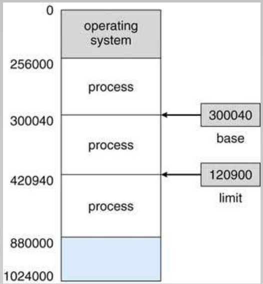

Figure: A base and a limit register define a logical address space.

Basic Hardware III

- We can provide this protection by using two registers, usually a **base** and a **limit**, as illustrated in Fig. 14.
  - The **base register** holds the smallest legal physical memory address;
  - The **limit register** specifies the size of the range.
  - For example, if the base register holds 300040 and limit register is 120900, then the program can legally access all addresses from 300040 through 420940 (inclusive).

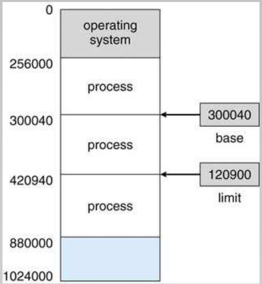

Figure: A base and a limit register define a logical address space.

Basic Hardware IV

- Any attempt by a program executing in user mode to access operating-system memory or other users' memory results in a trap to the OS, which treats the attempt as a fatal error (see Fig. 15).

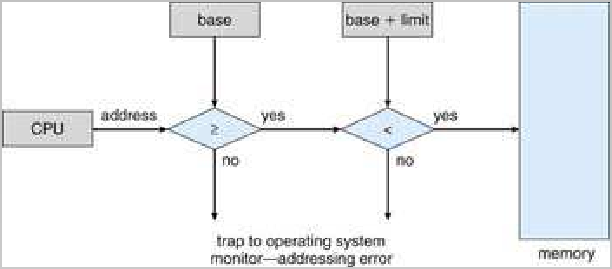

Figure: Hardware address protection with base and limit registers.

Basic Hardware IV

- Any attempt by a program executing in user mode to access operating-system memory or other users' memory results in a trap to the OS, which treats the attempt as a fatal error (see Fig. 15).

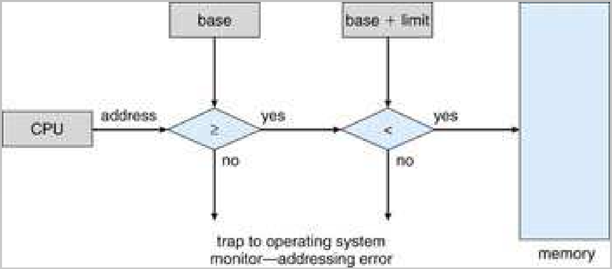

Figure: Hardware address protection with base and limit registers.

- This scheme prevents a user program from (accidentally or deliberately) modifying the code or data structures of either the OS or other users.