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Operating System Revision: Part 4

Special class

Vishvadeep Gothi • June 9, 2023

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Operating System: Process Synchronization

By: Vishvadeep Gothi

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Types of Process

1. Independent
2. Cooperating/Coordinating/Communicating

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Lack of Synchronization

Problems without Synchronization:

- Inconsistency
- Loss of Data
- Deadlock

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Critical Section

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Race Condition

Solution for Critical Section Problem

Solution for Critical Section Problem

Requirements of Critical Section problem solution:

1. Mutual Exclusion
2. Progress
3. Bounded Waiting

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Solution 1

```
Boolean lock=false;

while(true)
{
   while(lock);
   lock=true;
     CS
   lock=false;
     RS;
}
```

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Solution 2

```
int turn=0;

while(true)
{
   while(turn!=0);
     CS
   turn=1;
     RS;
}
```

```
while(true)
{
   while(turn!=1);
     CS
   turn=0;
     RS;
}
```

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Peterson's Solution

```
Boolean Flag[2];
int turn;
```

```
while(true) {
    Flag[i]=true;
    turn=j;
    while(Flag[j] && turn==j)
        CS
    Flag[i]=False;
        RS;
}
```

```
while(true){
    Flag[j]=true;
    turn=i;
    while(Flag[i] && turn==i)
        CS
    Flag[j]=False;
        RS;
}
```

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Synchronization Hardware

1. TestAndSet()
2. Swap()

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TestAndSet()

Returns the current value flag and sets it to true.

TestAndSet()

```
Boolean Lock=False;

boolean TestAndSet(Boolean *trg){
boolean rv = *trg;
*trg = True;
Return  rv;
}
```

```
while(true)
{
  while(TestAndSet(&Lock));
        CS
  Lock=False;
}
```

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Swap()

```
Boolean Key, Lock=False;

void Swap(Boolean *a, Boolean *b)
{
boolean temp = *a;
*a=*b;
*b=temp;
}
```

```
while(true){
  Key = True;
  while (key==True)
        Swap(&Lock, &Key);
     CS
  Lock=False;
     RS
}
```

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Semaphore

```
wait(S)
{
   while(S<=0);
   S--;
}
```

```
Signal(S)
{
   S++;
}
```

Critical Section Solution using Semaphore

Question GATE-2005

- Given below is a program which when executed spawns two concurrent processes:

```
Semaphore X:=0;
/* Process now forks into concurrent processes P1 & P2 */
        P1 : repeat forever          P2:repeat forever
        V(X);                              P(X);
        Compute;                       Compute;
        P(X);                              V(X);
```

Consider the following statements about processes P1 and P2:

I: It is possible for process P1 to starve.

II. It is possible for process P2 to starve.

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Question GATE-2004

- Consider two processes P1 and P2 accessing the shared variables X and *Y* protected by two binary semaphores S_X and S_Y respectively, both initialized to 1. P *and* V denote the usual semaphore operators, where P decrements the semaphore value and V increments the semaphore value. The pseudo-code of P1 and P2 is as follows:

P1:	*P2:*
while true do {	*while true 0do {*
L_1:	L_3: .....
L_2:	L_4: .....
$X = X + 1;$	$Y = Y + 1;$
$Y = Y - 1;$	$X = Y - 1;$
$V(S_X);$	$V(S_Y);$
$V(S_Y);\}$	$V(S_X);\}$

In order to avoid deadlock the correct operators at L_1, L_2, L_3 and L_4 are respectively

(A) $P(S_Y), P(S_X); P(S_X), P(S_Y)$
(B) $P(S_X), P(S_Y); P(S_Y), P(S_X)$
(C) $P(S_X), P(S_X); P(S_Y), P(S_Y)$
(D) $P(S_X), P(S_Y); P(S_X), P(S_Y)$

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Question GATE-2013

- A shared variable *x*, initialized to zero, is operated on by four concurrent processes W, X, Y, Z as follows. Each of the process W and X reads *x* from memory , increments by one, stores it to memory and then terminates. Each of the processes Y and Z reads *x* from memory , decrements by two, stores it to memory and then terminates. Each processes before reading *x* invokes the P operation (i.e., wait) on a counting semaphore S and invokes *the* V operation (i.e., signal) on the semaphore S after storing *x* to memory. Semaphore S is initialized to two. What is the maximum possible value of *x* after all processes complete execution?

(A) -2 (B) -1 (C) 1 (D) 2

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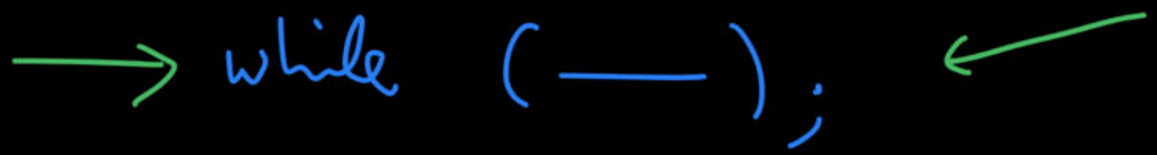
Busy Waiting (Spin-lock)



Solutions Without Busy Waiting

```
wait(Semaphore s){
    s=s-1;
    if (s<0) {
        // add process to queue
        block();
    }
}
```

```
signal(Semaphore s){
    s=s+1;
    if (s<=0) {
        // remove process p from queue
        wakeup(p);
    }
}
```

S = 1

wait(S)

C.S.

signal(S)

Classical Problems on Synchronization

1. Producer-Consumer Problem or Bounded Buffer Problem
2. Reader-Writer Problem
3. Dining Philosopher Problem

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Producer – Consumer

Both share a buffer of bounded size (Size = n).
Producer can produce any item until any empty place is available in buffer.
Consumer can consume any item until there is any item in buffer.

Variables used in Algorithm:

- Empty: Semaphore to denote number of empty places in buffer (Initialized to n)
- Full: Semaphore to denote number of occupied places in buffer (Initialized to 0)
- Mutex: Semaphore to provide mutual execution (Initialized to 1)

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Producer – Consumer

Producer:

```
while(true)
{
   wait(Empty);
   wait(Mutex);
      //Produce an item in buffer;
   signal(Mutex);
   signal(Full);
}
```

Consumer:

```
while(true)

{

   wait(Full);

   wait(Mutex);

      //Consume an item from buffer;

   signal(Mutex);

   signal(Empty);}
```

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Reader-Writer

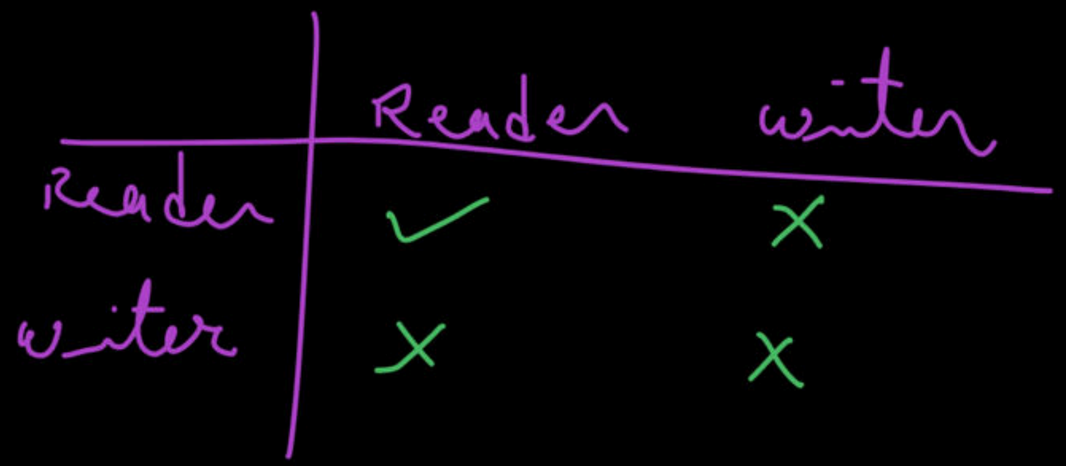
Multiple readers can read

If one writer is writing then no any writer or reader can perform their task.

If reader is reading then writer can not perform its task.

Variables used in Algorithm:

- Wrt: Semaphore to provide mutual exclusion on write
- Mutex: Semaphore to provide mutual exclusion on shared variable
- ReadCount: ~~Semaphore to provide mutual execution (initialized to 1)~~ initialized to 0



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Reader-Writer

Writer:

```
while(true)
{
   wait(Wrt);
        //Perform
         Writing;
   signal(Wrt);
}
```

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Reader-Writer

Reader:

```
while(true)
{
   Wait(Mutex);
   ReadCount++;
   if (ReadCount==1)
         Wait(Wrt);
   Signal(Mutex);
         //Perform Reading

   Wait(Mutex);
   ReadCount--;
   if (ReadCount==0)
         Signal (Wrt);
   Signal(Mutex);
   }
```

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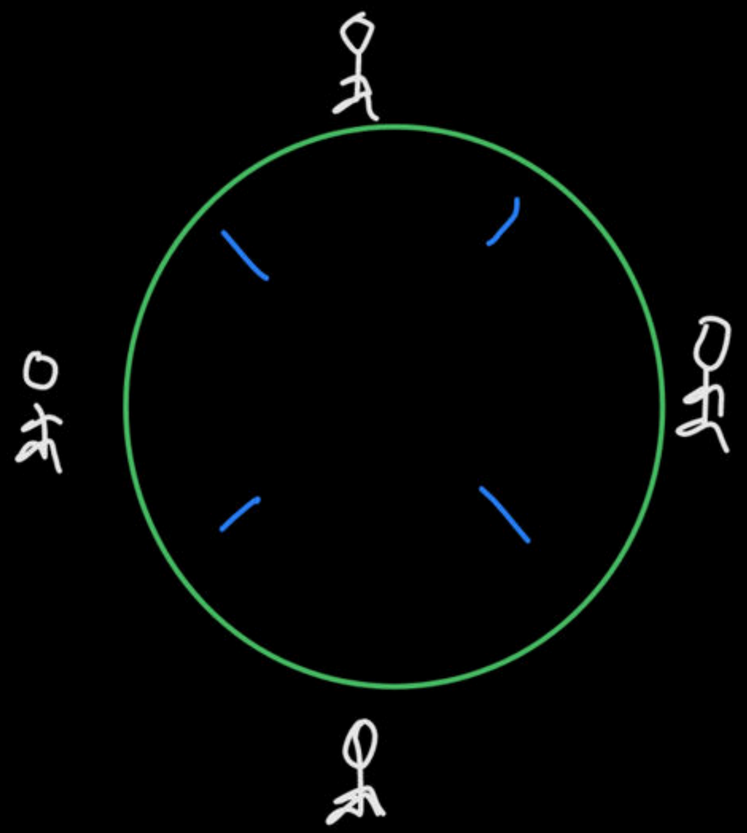
Dining Philosopher

- n philosophers are sitting on a round table.
- They can either eat or think.
- n chopsticks are shared among them.



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Dining Philosopher

Pi

```
while(true)
{
        wait(chopstick[i]);
        wait(chopstick[ (i+1) % n] );
            // Eat
        signal(chopstick[i]);
        signal(chopstick[ (i+1) % n] );
            // Think
}
```

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Dining Philosopher

- Given solution is causing Deadlock
- So, Deadlock free solution should be like:
  1. Allow $n - 1$ philosophers at a time to sit and eat
  2. Allow a philosopher to pick chopsticks only if both are available ⟶ hold or wait
  3. Use an asymmetric solution

↳ no circular wait

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Deadlock

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Deadlock

If two or more processes are waiting for such an event which is never going to occur.

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Deadlock

3 operations on resources:

1. **Request**
2. **Use**
3. **Release**

4. wait

Necessary Conditions for Deadlock

1. Mutual Exclusion
2. Hold & wait
3. no preemption of resources
4. circular wait

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Resource Request Graph

Nodes / vertices

- ① Process

- ② Resource

R_i

Edges

- ① Allocation from instance of resource to process
- ② Request from process to resource

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Deadlock Recovery

1. Prevent the system from deadlock or avoid deadlock
   Make Sure that deadlock never occur
2. Allow deadlock, detect and recover
3. Pretend that there is no any deadlock

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Deadlock Prevention

Do not let occur any of the necessary conditions for deadlock

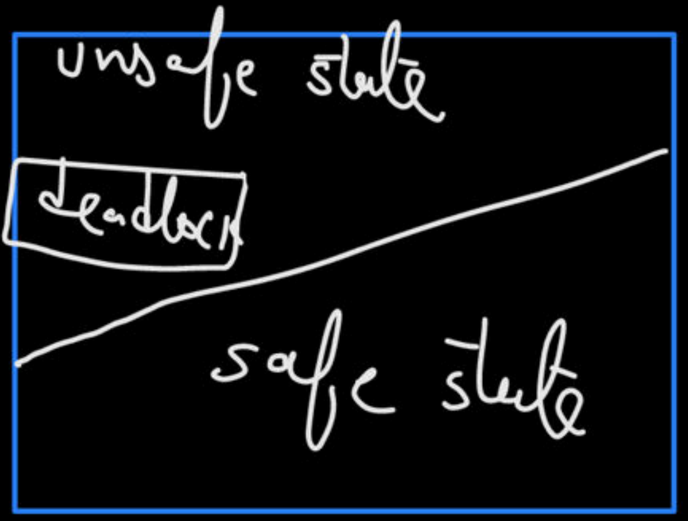
1. **Mutual Exclusion**
2. **Hold & Wait**
3. **No Preemption**
4. **Circular Wait**

Deadlock Avoidance

↳ Tried to keep system in safe state

Bankers Algorithm:

1. **Safety Algorithm**
2. **Resource-Request Algorithm**



Banker's Algorithm: Safety Algorithm

- **Available**
- **Max**
- **Allocation**
- **Need**

Banker's Algorithm: Safety Algorithm

Process	Allocation	Max	Available
	A B C	A B C	A B C
P_0	0 1 0	7 5 3	3 3 2
P_1	2 0 0	3 2 2	
P_2	3 0 2	9 0 2	
P_3	2 1 1	2 2 2	
P_4	0 0 2	4 3 3	

Need

P_i

$Need_i \leq Available$

$Available = Avail + Allocation_i$

multiple safe sequences possible

Banker's Algorithm: Safety Algorithm

1) Let Work and Finish be vectors of length 'm' and 'n' respectively.
Initialize: Work = Available
Finish[i] = false; for i=1, 2, 3, 4….n

2) Find an i such that both
a) Finish[i] = false
b) $Need_i$ <= Work
if no such i exists goto step (4)

3) Work = Work + Allocation[i]
Finish[i] = true
goto step (2)

4) if Finish [i] = true for all i
then the system is in a safe state

Banker's Algorithm: Resource Request Algorithm

What will happen if process P1 requests one additional instance of resource type A and two instances of resource type C?

Process	Allocation	Max	Available
	A B C	A B C	A B C
P_0	0 1 0	7 5 3	3 3 2
P_1	2 0 0	3 2 2	
P_2	3 0 2	9 0 2	
P_3	2 1 1	2 2 2	
P_4	0 0 2	4 3 3	

Banker's Algorithm: Resource Request Algorithm

1) If $Request_i <= Need_i$
Goto step (2) ; otherwise, raise an error condition, since the process has exceeded its maximum claim

2) If $Request_i <= Available$
Goto step (3); otherwise, P_i must wait, since the resources are not available

3) Have the system pretend to have allocated the requested resources to process Pi by modifying the state as
follows:
Available = Available – Requesti
$Allocation_i = Allocation_i + Request_i$
$Need_i = Need_i – Request_i$

4. Run safety algo. if safe then allocate,
if not safe then reject

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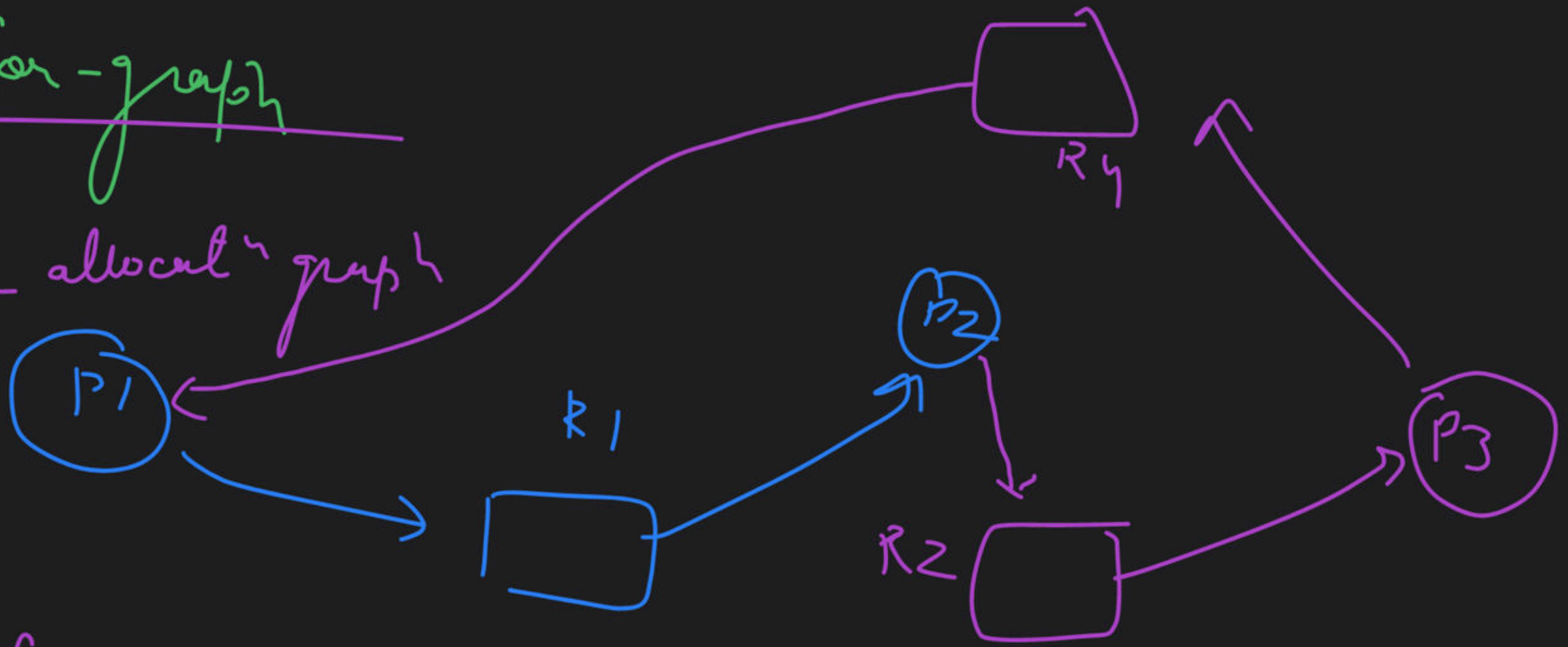
Deadlock Detection

Single Instances of Resources → wait-for-graph

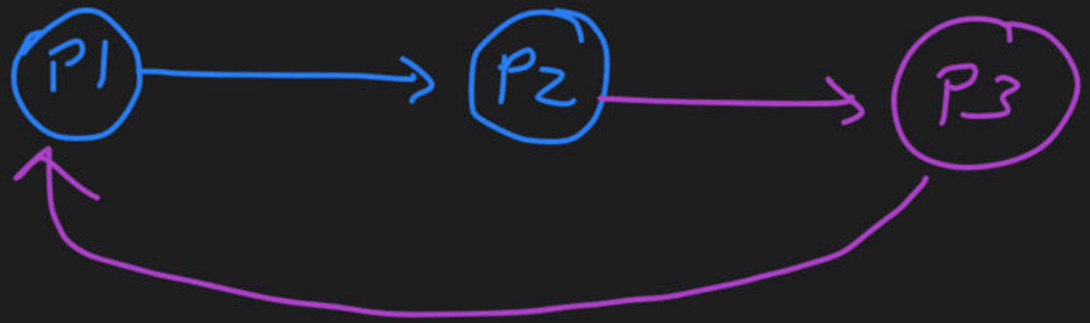
Multiple Instances of Resources → Banker's algo

wait-for-graph

Resource-allocation graph



wait-for-graph: (cycle => deadlock)



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Deadlock Detection

Available
Allocation
Request

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Deadlock Detection

	Allocation			Request			Available		
	A	B	C	A	B	C	A	B	C
P0	0	1	0	0	0	0	0	0	0
P1	2	0	0	2	0	2			
P2	3	0	3	0	0	0			
P3	2	1	1	1	0	0			
P4	0	0	2	0	0	2			

P_i $\quad Req_i \leq Available$

	Allocation		Request
P_1	4	3	1
P_2	3	2	1
P_3	2	1	1

Available

1

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Process Termination

1. Abort all processes
2. Abort one process at a time until deadlock cycle is eliminated

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Resource Preemption

Issues with resource preemption:

1. Selecting a victim
2. Rollback
3. Starvation

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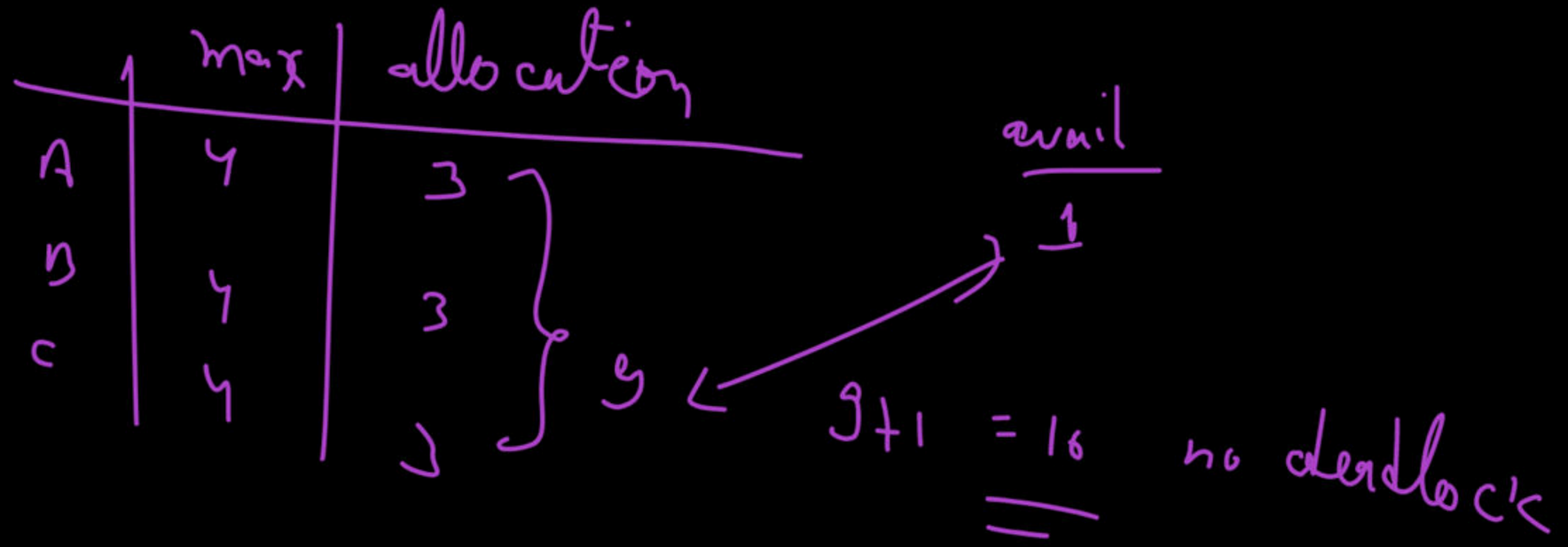
Question

Consider a system with 3 processes A, B and C. All 3 processes require 4 resources each to execute. The minimum number of resources the system should have such that deadlock can never occur?



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Question

Consider a system with 3 processes that share 4 instances of the same resource type. Each process can request a maximum of K instances. Resource instances can be requested and released only one at a time. The largest value of K that will always avoid deadlock is ____.

$$3 * (k-1) + 1 \leq 4$$

$$3k - 3 \leq 3$$

$$3k \leq 6 \qquad k \leq 2$$

$$k_{max} = 2$$

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Question

Consider a system with n processes with single resource R. Each process requires k instances to execute. What is the maximum instances of R to cause a deadlock?

$= n * (k-1)$

$= n/k - n$

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Question

A computer has six tape drives, with n processes competing for them. Each process may need two drives. What is the maximum value of n for the system to be deadlock free?

$$n * (2-1) + 1 \leq 6$$

$$n \leq 5$$

$$n_{max} = 5$$

Ans : 5

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Happy Learning.!