R

بسم الله الرحمن الرحیم

سیستم عامل

جلسه نهم – بن‌بست

جلسه‌ی گذشته

مسائل هم‌روندی و مانیتور

بن‌بست راه حل اولیه‌ی شام فیلسوف‌ها

- هر ۵ فیلسوف چوب دستشان است!
- یک فیلسوف چوب برداشته بدون اینکه غذا بخورد ☹
- همه با دست راست شروع به غذا خوردن کردند.

- پس اجازه ندهیم حداقل یکی از این‌ها رخ بدهد.

Working Towards a Solution

وضعیت هر فیلسوف

```
int state[N]
semaphore mutex = 1
semaphore sem[i]
```

برای متغیرهای مشترک

برای منتظر غذا ماندن فیلسوف

Readers and Writers Problem

- Multiple readers and writers want to access a database (each one is a thread)
- Multiple readers can proceed concurrently
- Writers must synchronize with readers and other writers
  - *only one writer at a time !*
  - *when someone is writing, there must be no readers !*

Goals:

  - *Maximize concurrency*
  - *Prevent starvation*

دو سناریو

- First readers-writers problem
  - *no reader should wait for other readers to finish simply because a writer is waiting.*
- Second readers-writers problem
  - *once a writer is ready, that writer perform its write as soon as possible.*
  - *If a writer is waiting to access the object, no new readers may start reading.*

پیاده‌سازی ReadWriteLock

- از کتاب بخوانید... (بخش ۷٫۱٫۲)

پیاده‌سازی ReadWriteLock

- از کتاب بخوانید... (بخش ۷/۱/۲)

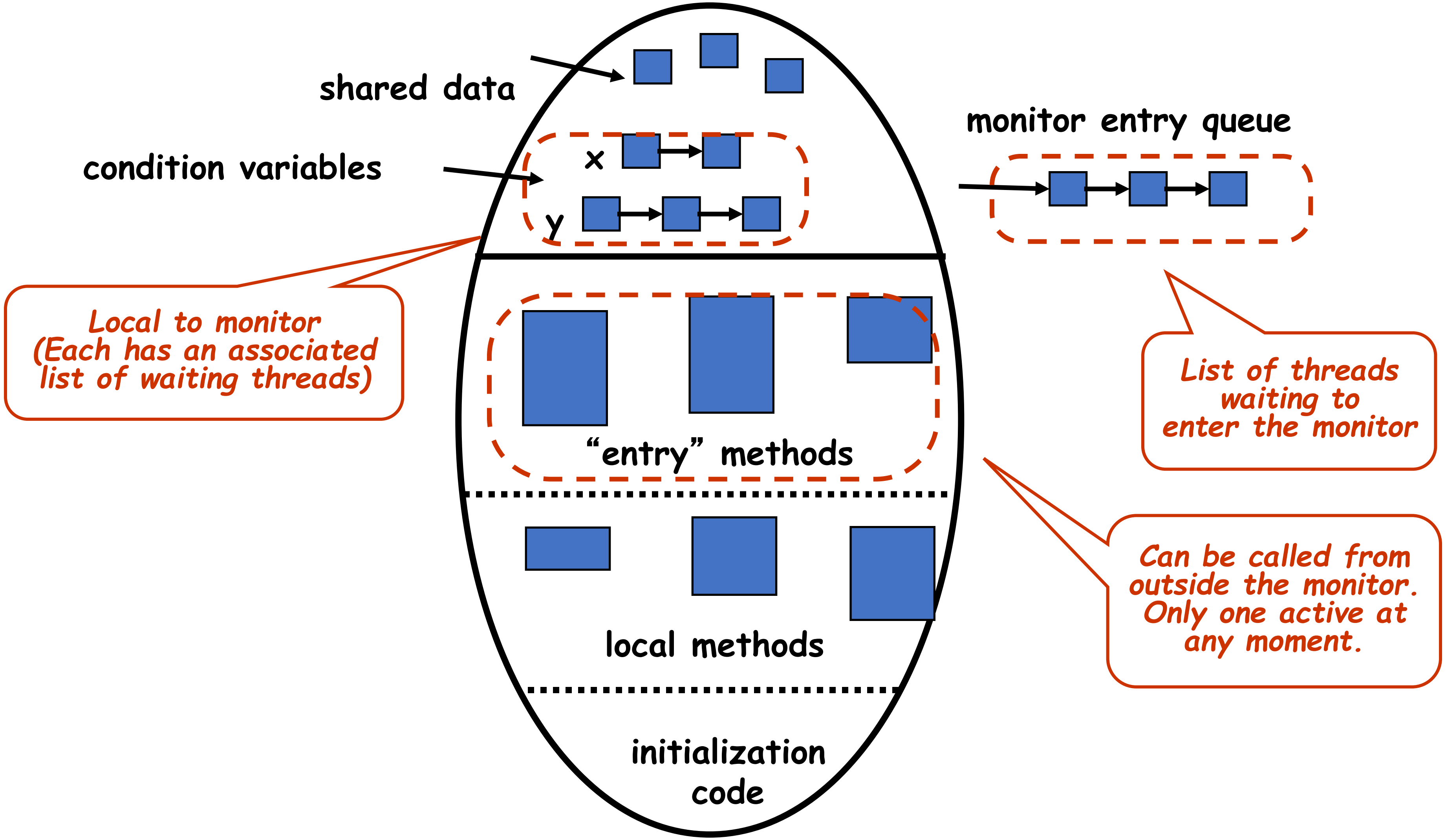
Monitors & Condition Variables

- We need two flavors of synchronization
- Mutual exclusion
  - *Only one at a time in the critical section*
  - *Handled by the monitor's mutex*
- Condition synchronization
  - *Wait until a certain condition holds*
  - *Signal waiting threads when the condition holds*

Monitors & Condition Variables

- Condition variables (cv) for use within monitors
  - *cv.wait(mon-mutex)*
    - Thread blocked (queued) until condition holds
    - Must not block while holding mutex!
    - Monitor mutex must be released!
    - Monitor mutex need not be specified by programmer if compiler is enforcing mutual exclusion
  - *cv.signal()*
    - Signals the condition and unblocks (dequeues) a thread

Monitor Structures



Monitor Example

```
monitor : BoundedBuffer
var buffer               : array[0..n-1] of char
    nextIn,nextOut       : 0..n-1 := 0
    fullCount            : 0..n   := 0
    notEmpty, notFull    : condition
```

```
  entry deposit(c:char)
  begin
    if (fullCount = n) then
        wait(notFull)
    end if

    buffer[nextIn] := c
    nextIn := nextIn+1 mod n
    fullCount := fullCount+1

    signal(notEmpty)
  end deposit
```

```
entry remove(var c: char)
begin
  if (fullCount = n) then
    wait(notEmpty)
  end if

  c := buffer[nextOut]
  nextOut := nextOut+1 mod n
  fullCount := fullCount-1

  signal(notFull)
end remove
```

```
end BoundedBuffer
```

Monitor Design Choices

- A signals a condition that unblocks B
  - *Does A block until B exits the monitor?*
  - *Does B block until A exits the monitor?*
  - *Does the condition that B was waiting for still hold when B runs?*
- A signals a condition that unblocks B & C
  - *Is B unblocked, but C remains blocked?*
  - *Is C unblocked, but B remains blocked?*
  - *Are both B & C unblocked, i.e. broadcast signal*
    - … if so, they must compete for the mutex!

Option 1: Hoare Semantics

- What happens when a Signal is performed?
  - *Signaling thread (A) is suspended*
  - *Signaled thread (B) wakes up and runs immediately*
- Result:
  - *B can assume the condition it was waiting for now holds*
  - *Hoare semantics give certain strong guarantees*
- When B leaves monitor, A can run
  - *A might resume execution immediately*
  - *... or maybe another thread (C) will slip in!*

Option 2: MESA Semantics

- What happens when a Signal is performed?
  - *The signaling thread (A) continues*
  - *The signaled thread (B) waits*
  - *When A leaves the monitor, then B resumes*
- Issue: What happens while B is waiting?
  - *Can the condition that caused A to generate the signal be changed before B runs?*
- In MESA semantics a signal is more like a hint
  - *Requires B to recheck the condition on which it waited to see if it can proceed or must wait some*

Example Use of Hoare Semantics

```
monitor BoundedBuffer
  var buffer: array[n] of char
     nextIn, nextOut: int = 0
     cntFull: int = 0
     notEmpty: Condition
     notFull: Condition

  entry deposit(c: char)
     if cntFull == N
       notFull.Wait()
     endIf
     buffer[nextIn] = c
     nextIn = (nextIn+1) mod N
     cntFull = cntFull + 1
     notEmpty.Signal()
   endEntry

  entry remove()
     ...

endMonitor
```

Hoare Semantics

Example Use of Mesa Semantics

```
monitor BoundedBuffer
  var buffer: array[n] of char
     nextIn, nextOut: int = 0
     cntFull: int = 0
     notEmpty: Condition
     notFull: Condition

  entry deposit(c: char)
     while cntFull == N
       notFull.Wait()
     endWhile
     buffer[nextIn] = c
     nextIn = (nextIn+1) mod N
     cntFull = cntFull + 1
     notEmpty.Signal()
   endEntry

  entry remove()
     ...

endMonitor
```

MESA Semantics

Message Passing

- Interprocess Communication
  - *Via shared memory*
  - *Across machine boundaries*
- Message passing can be used for synchronization or general communication
- Processes use send and receive primitives
  - *receive can block (like waiting on a Semaphore)*
  - *send unblocks a process blocked on receive (just as a signal unblocks a waiting process)*

Message Passing Example

- **Producer-consumer example:**
  - *After producing, the producer sends the data to consumer in a message*
  - *The system buffers messages (kept in order)*
  - *The producer can out-run the consumer*
- How does the producer avoid overflowing the buffer?
  - *The consumer sends empty messages to the producer*
  - *The producer blocks waiting for empty messages*
  - *The consumer starts by sending N empty messages*
    - N is based on the buffer size

Message Passing Example

```
const N = 100              -- Size of message buffer
var em: char
for i = 1 to N             -- Get things started by
  Send (producer, &em)     --    sending N empty messages
endFor
```

```
thread consumer
  var c, em: char
  while true
    Receive(producer, &c)    -- Wait for a char
    Send(producer, &em)      -- Send empty message back
    // Consume char...
  endWhile
end
```

Message Passing Example

```
thread producer
  var c, em: char
  while true
    // Produce char c...
    Receive(consumer, &em)    -- Wait for an empty msg
    Send(consumer, &c)        -- Send c to consumer
  endWhile
end
```

Buffering Design Choices

- **Option 1:** **Mailboxes**
  - *System maintains a buffer of sent, but not yet received, messages*
  - *Must specify the size of the mailbox ahead of time*
  - *Sender will be blocked if the buffer is full*
  - *Receiver will be blocked if the buffer is empty*

Buffering Design Choices

- <u>**Option 2:**</u> **No buffering**
  - *If Send happens first, the sending thread blocks*
  - *If Receive happens first, the receiving thread blocks*
  - *Sender and receiver must Rendezvous (ie. meet)*
  - *Both threads are ready for the transfer*
  - *The data is copied / transmitted*
  - *Both threads are then allowed to proceed*

جلسه‌ی جدید: بن‌بست

معرفی مدل تئوری بررسی، مثالی از بن‌بست، تعریف مسئله، معرفی روش‌های حمله برای حل مسئله (یا حذف صورت مسئله!)

مدل‌سازی مسئله

System Model

- System consists of resources
- Resource types $R_1, R_2, \ldots, R_m$
  - *CPU cycles, memory space, I/O devices*
- Each resource type R_i has W_i instances.
- Each process utilizes a resource as follows:
  - ***request***
  - ***use***
  - ***release***

Example of Resources?

- Printers
- disk drives
- kernel data structures (scheduling queues …)
- locks/semaphores to protect critical sections

Resource Usage Model

- Sequence of events required to use a resource
  - *request the resource (eg. acquire mutex)*
  - *use the resource*
  - *release the resource (eg. release mutex)*
- Must wait if request is denied
  - *block*
  - *busy wait*
  - *fail with error code*

Preemptable Resources

- **Preemptable** resources
  - *Can be taken away with no ill effects*
- **Nonpreemptable** resources
  - *Will cause the holding process to fail if taken away*
  - *May corrupt the resource itself*
- Deadlocks occur when processes are granted exclusive access to non-preemptable resources and wait when the resource is not available

Definition of Deadlock

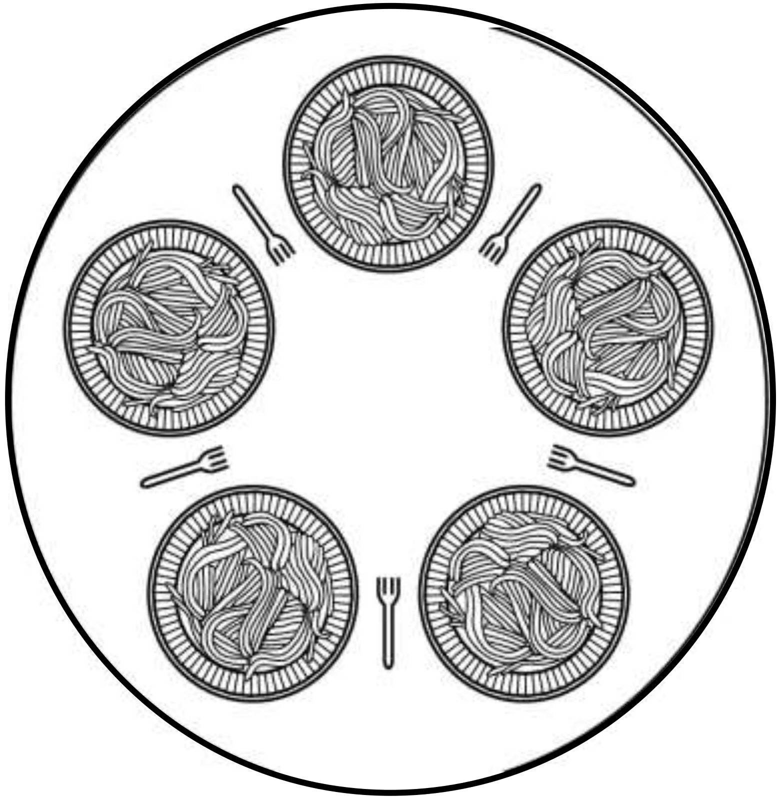
A set of processes is deadlocked if each process in the set is waiting for an event that only another process in the set can cause

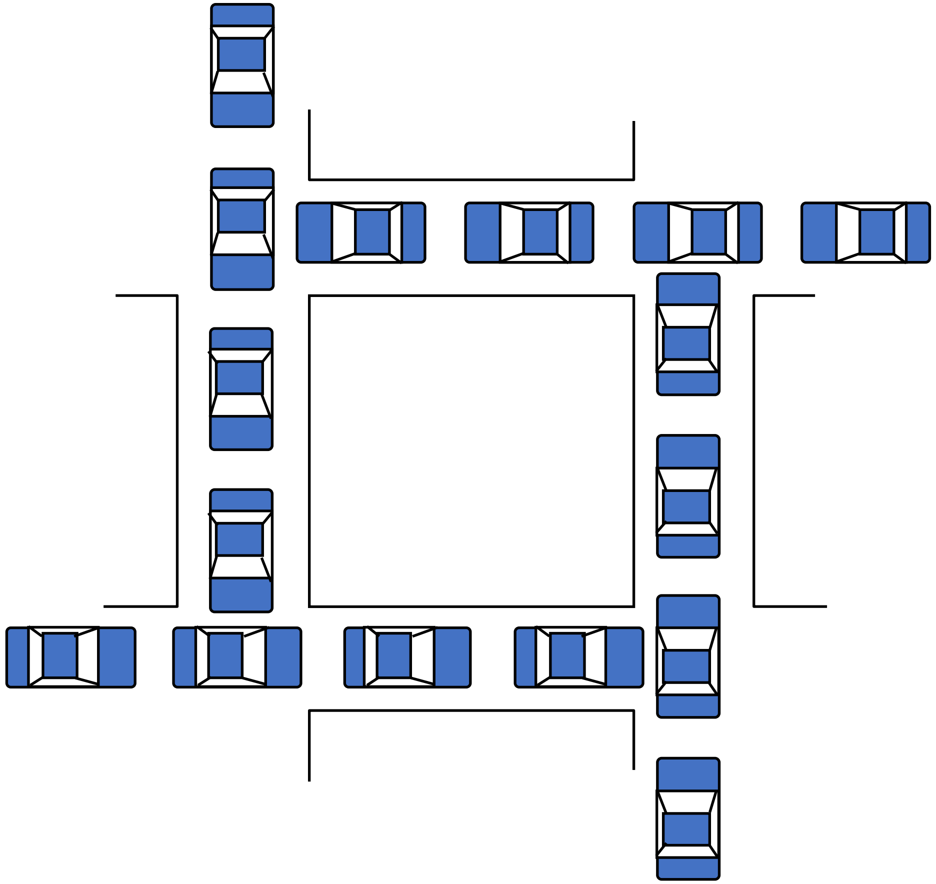
- Usually, the event is the release of a currently held resource
- None of the processes can …
  - *Be awakened*
  - *Run*
  - *Release its resources*

Deadlock Conditions

- A deadlock situation can occur *if and only if* the following conditions hold simultaneously
  - ***Mutual exclusion*** *condition – resource assigned to one process only*
  - ***Hold and wait*** *condition – processes can get more than one resource*
  - ***No preemption*** *condition*
  - ***Circular wait*** *condition – chain of two or more processes (must be waiting for resource from next one in chain)*

Examples of Deadlock





Livelock!

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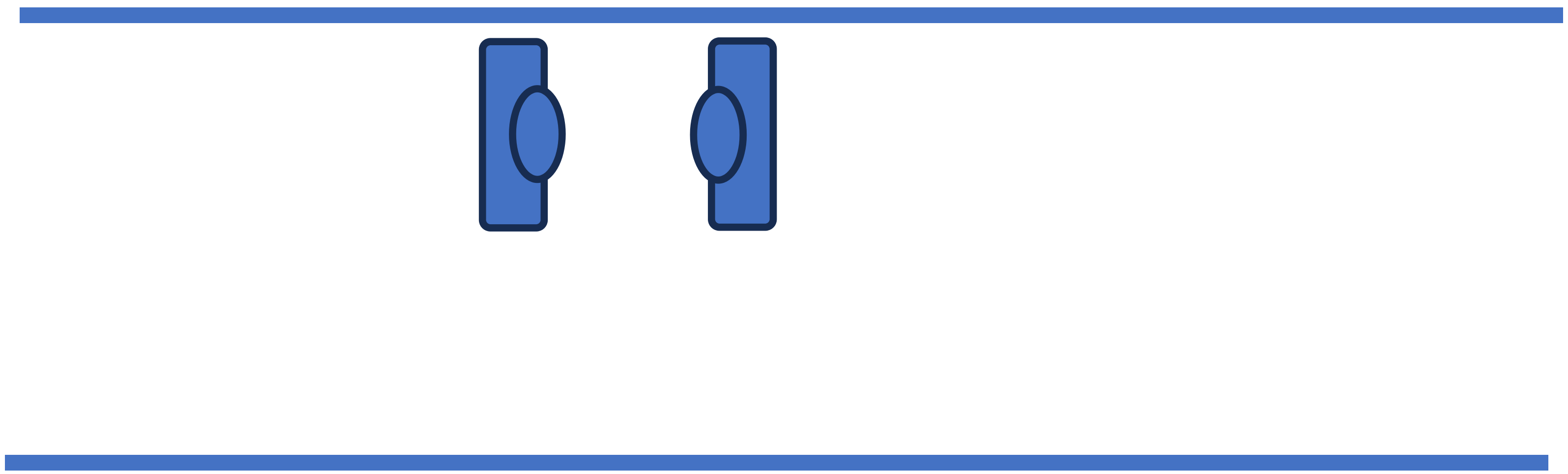

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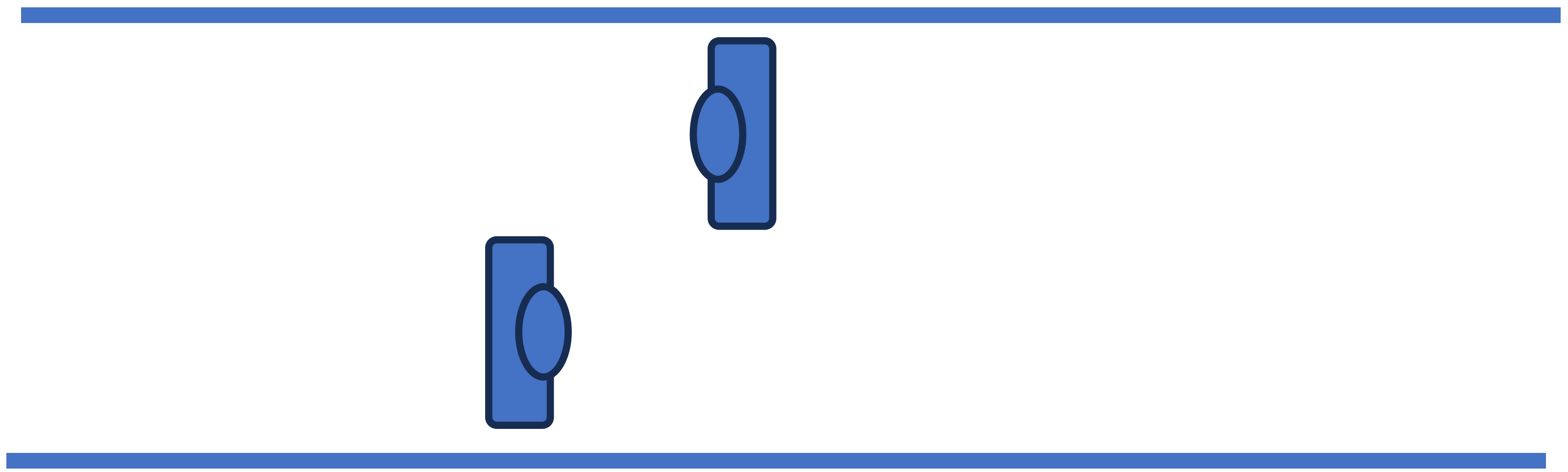

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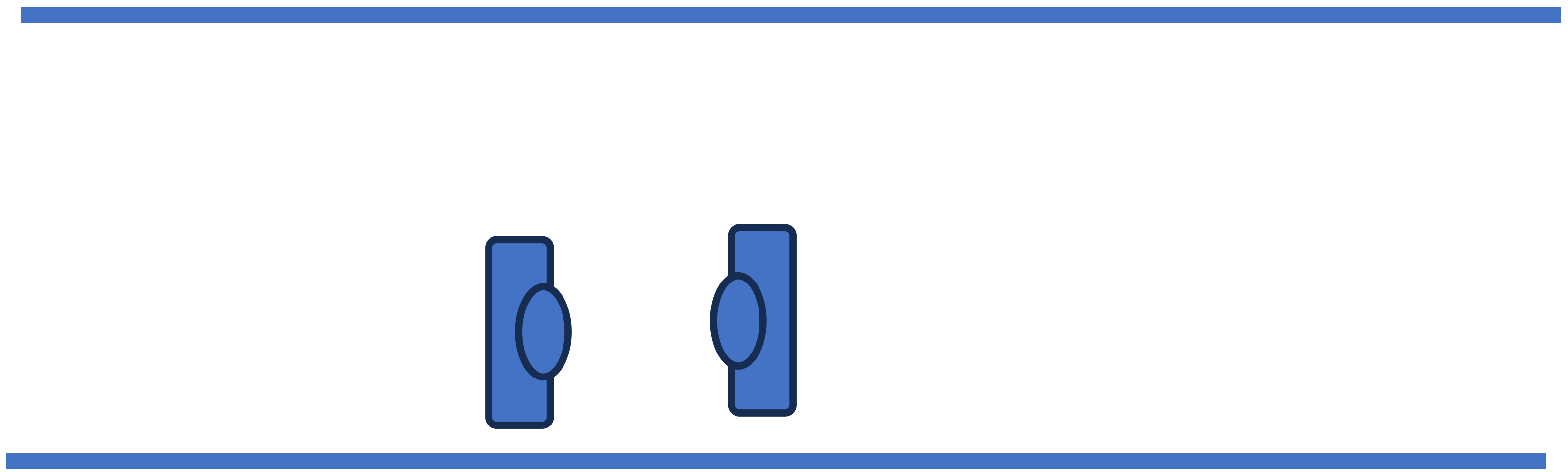

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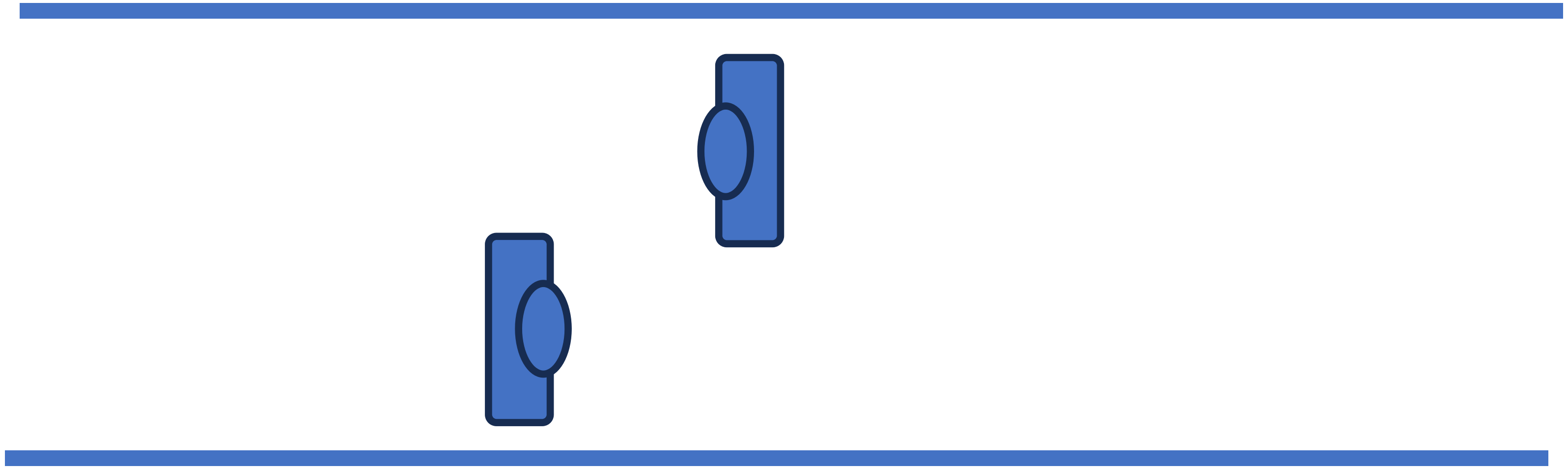

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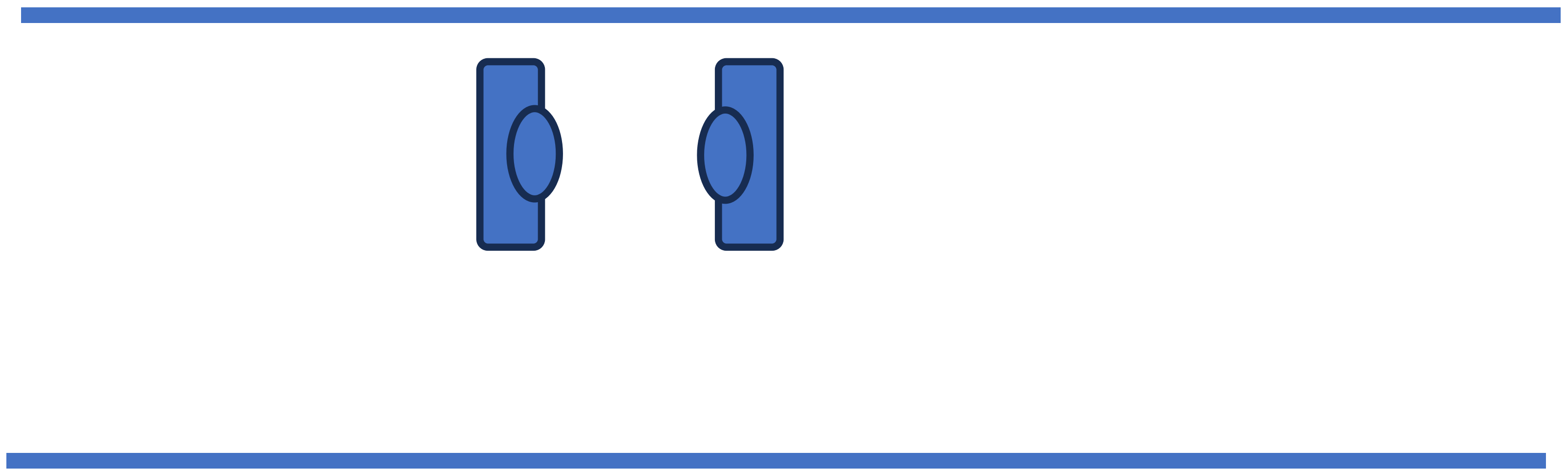

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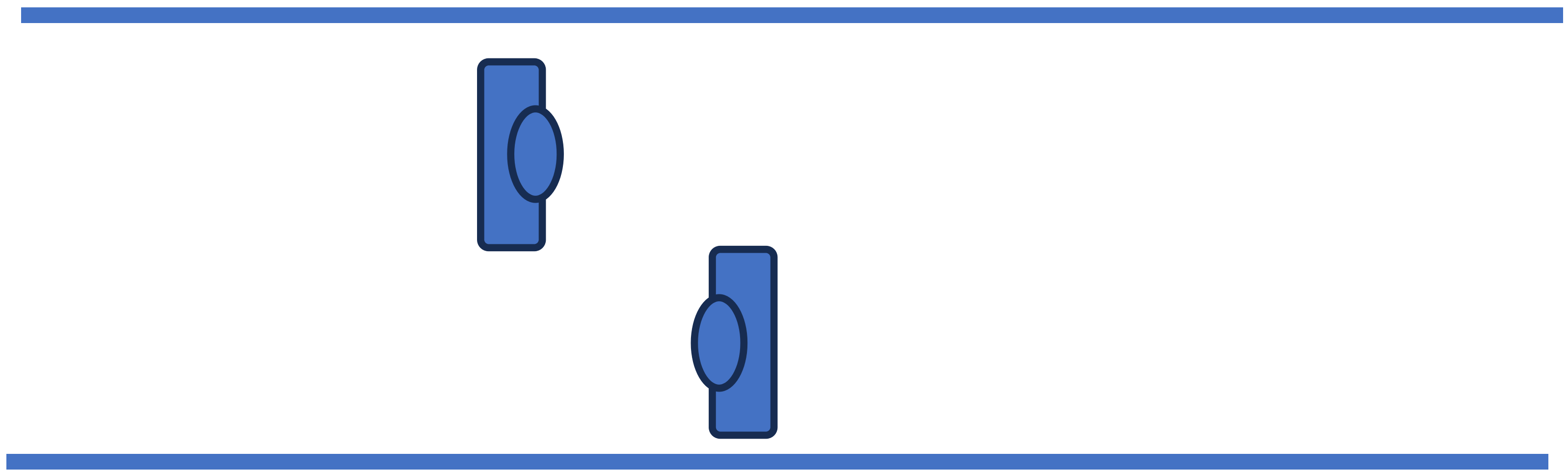

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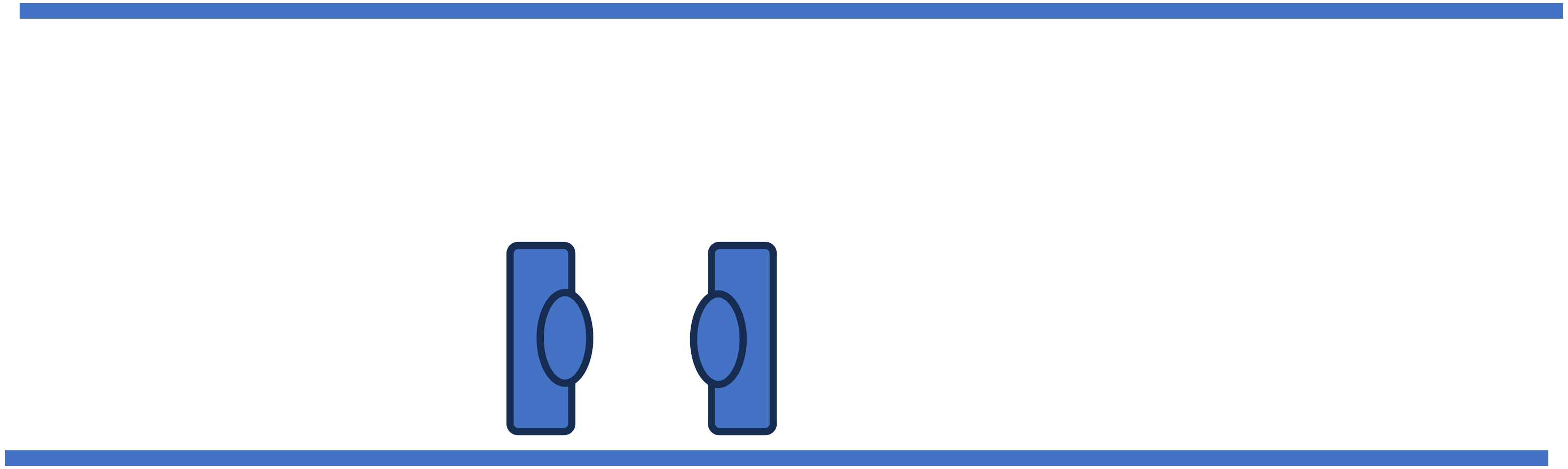


چند مثال از گرفتن منابع

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
use resource_1
release (resource_1)
```

Example:

```
var r1_mutex: Mutex
...
r1_mutex.Lock()
Use resource_1
r1_mutex.Unlock()
```

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
use resource_1
release (resource_1)
```

Another Example:

```
var r1_sem: Semaphore
r1_sem.Up()
...
r1_sem.Down()
Use resource_1
r1_sem.Up()
```

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
use resource_1
release (resource_1)
```

Thread B:

```
acquire (resource_2)
use resource_2
release (resource_2)
```

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
use resource_1
release (resource_1)
```

Thread B:

```
acquire (resource_2)
use resource_2
release (resource_2)
```

No deadlock can occur here!

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
acquire (resource_2)
use resources 1 & 2
release (resource_2)
release (resource_1)
```

Thread B:

```
acquire (resource_1)
acquire (resource_2)
use resources 1 & 2
release (resource_2)
release (resource_1)
```

Resource Acquisition Scenarios

__Thread A:__

```
acquire (resource_1)
acquire (resource_2)
use resources 1 & 2
release (resource_2)
release (resource_1)
```

__Thread B:__

```
acquire (resource_1)
acquire (resource_2)
use resources 1 & 2
release (resource_2)
release (resource_1)
```

No deadlock can occur here!

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
use resources 1
release (resource_1)
acquire (resource_2)
use resource 2
release (resource_2)
```

Thread B:

```
acquire (resource_2)
use resources 2
release (resource_2)
acquire (resource_1)
use resource 1
release (resource_1)
```

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
use resources 1
release (resource_1)
acquire (resource_2)
use resource 2
release (resource_2)
```

Thread B:

```
acquire (resource_2)
use resources 2
release (resource_2)
acquire (resource_1)
use resource 1
release (resource_1)
```

No deadlock can occur here!

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
acquire (resource_2)
use resources 1 & 2
release (resource_2)
release (resource_1)
```

Thread B:

```
acquire (resource_2)
acquire (resource_1)
use resources 1 & 2
release (resource_1)
release (resource_2)
```

Resource Acquisition Scenarios

Thread A:

```
acquire (resource_1)
acquire (resource_2)
use resources 1 & 2
release (resource_2)
release (resource_1)
```

Thread B:

```
acquire (resource_2)
acquire (resource_1)
use resources 1 & 2
release (resource_1)
release (resource_2)
```

Deadlock is possible!

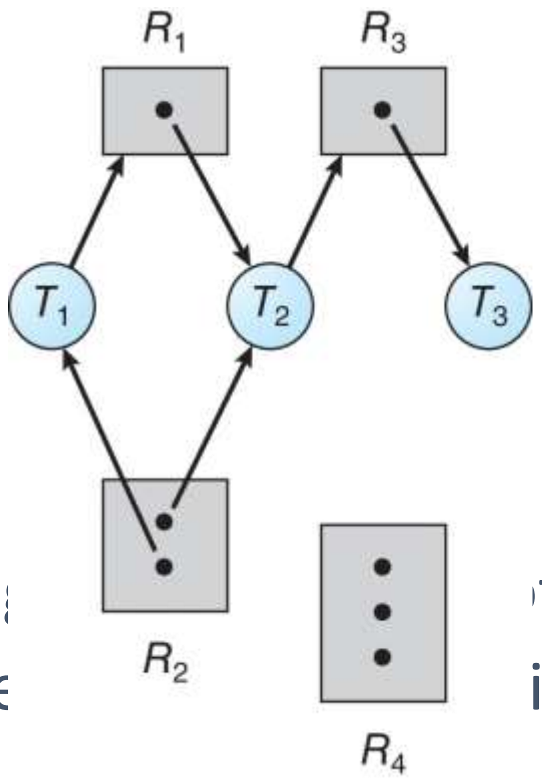
گراف تخصیص منابع

Resource-Allocation Graph

A set of vertices *V* and a set of edges *E*.

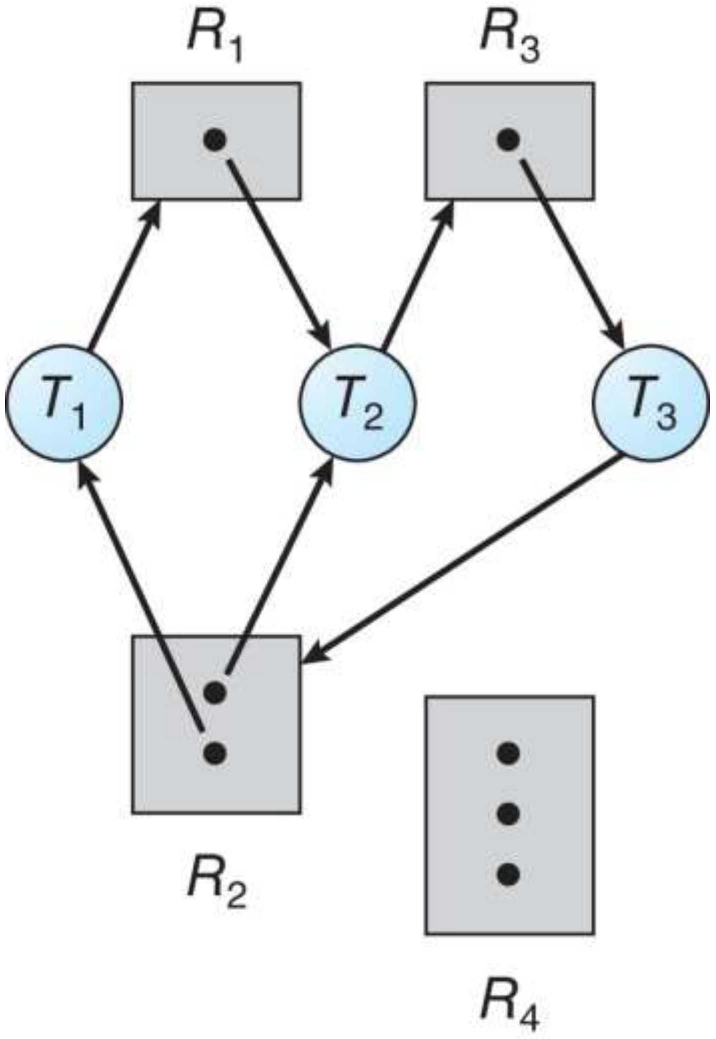
- V is partitioned into two types:
  - $T = \{T_1, T_2, \ldots, T_n\}$, *the set consisting of all the threads in the system.*
  - $R = \{R_1, R_2, \ldots, R_m\}$, *the set consisting of all resource types in the system*
- **request edge** – directed edge $T_i \rightarrow R_j$
- **assignment edge** – directed edge $R_j \rightarrow T_i$

Resource Allocation Graph Example

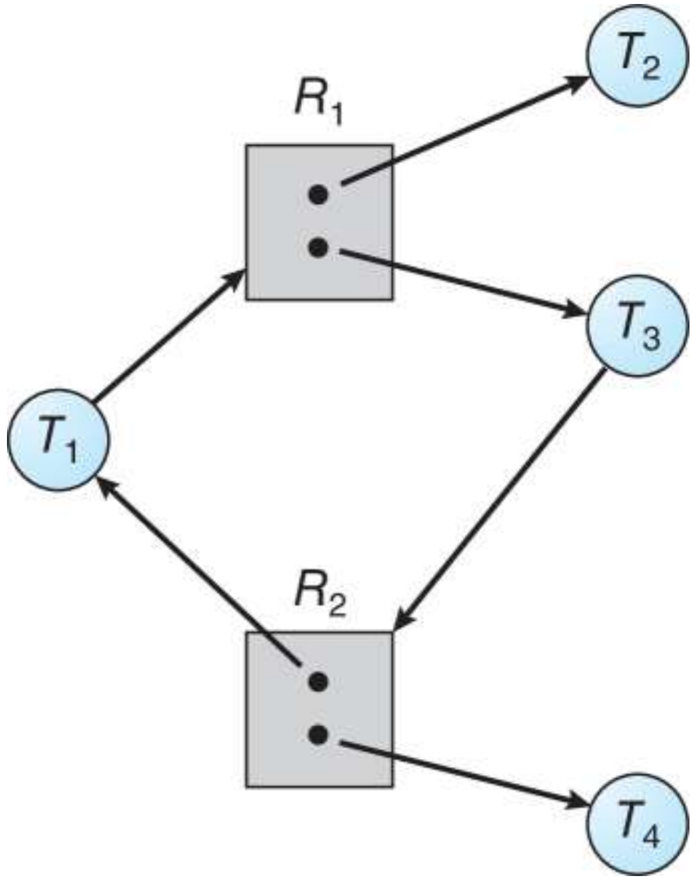


- One instance of R_1
- Two instances of R_2
- One instance of R_3
- Three instance of R_4
- T_1 holds one instance of R_2 and is waitin f R_1
- T_2 holds one instance of R_1, one instance ing for an instance of R_3
- T_3 is holds one instance of R_3

Resource Allocation Graph with a Deadlock



Graph with a Cycle But no Deadlock



خب، حالا چیکار کنیم؟

Dealing With Deadlock

- Ignore the problem
- Detect it and recover from it
- Dynamically avoid is via careful resource allocation
- Prevent it by attacking one of the four necessary conditions

Deadlock Prevention

Prevent it by attacking one of the four necessary conditions

- **Mutual Exclusion** – not required for sharable resources (e.g., read-only files); must hold for non-sharable resources
- **Hold and Wait** – must guarantee that whenever a thread requests a resource, it does not hold any other resources
  - *Require threads to request and be allocated all its resources before it begins execution or allow thread to request resources only when the thread has none allocated to it.*
  - *Low resource utilization; starvation possible*

Deadlock Prevention (Cont.)

- **No Preemption**:
  - *If a process that is holding some resources requests another resource that cannot be immediately allocated to it, then all resources currently being held are released*
  - *Preempted resources are added to the list of resources for which the thread is waiting*
  - *Thread will be restarted only when it can regain its old resources, as well as the new ones that it is requesting*
- **Circular Wait:**
  - *Impose a total ordering of all resource types, and require that each thread requests resources in an increasing order of enumeration*

جلسه‌ی بعد

- Deadlock Detection
- Deadlock Avoidance