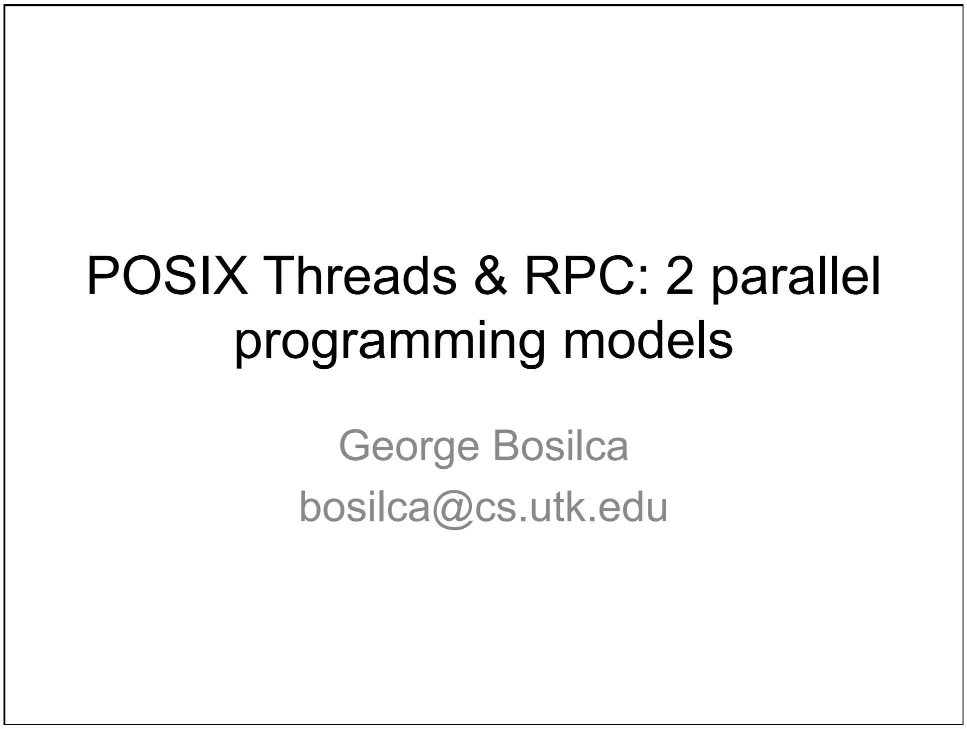

POSIX Threads & RPC: 2 parallel programming models

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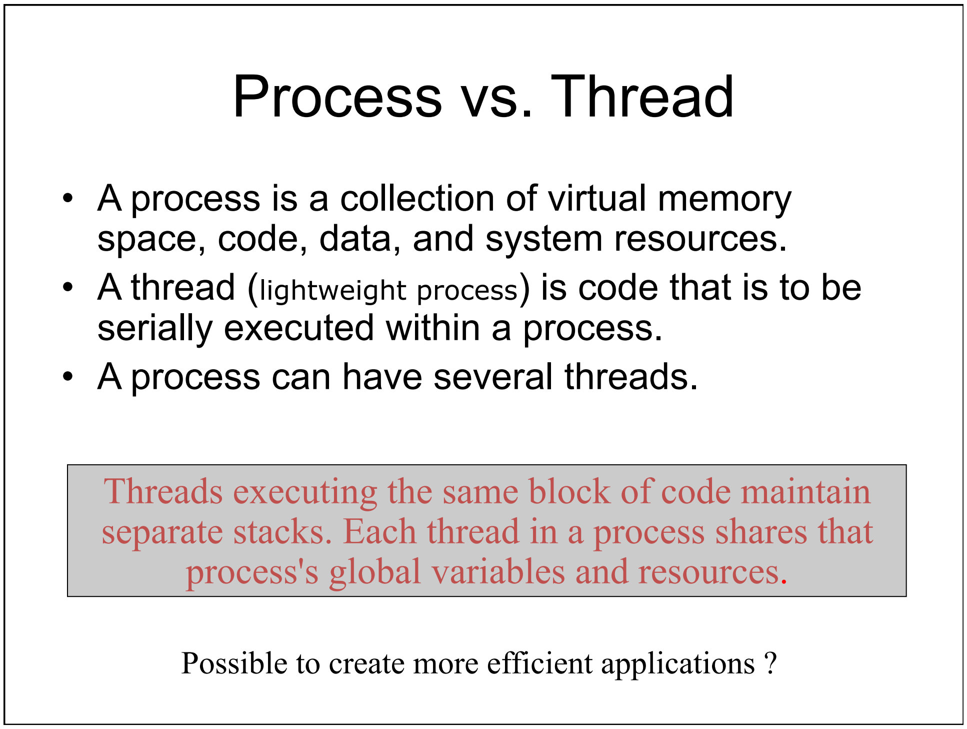


Process vs. Thread

- A process is a collection of virtual memory space, code, data, and system resources.
- A thread (lightweight process) is code that is to be serially executed within a process.
- A process can have several threads.

Threads executing the same block of code maintain separate stacks. Each thread in a process shares that process's global variables and resources.

Possible to create more efficient applications ?

Process vs. Thread

- Multithreaded applications must avoid two threading problems: deadlocks and races.
- A deadlock occurs when each thread is waiting for the other to do something.
- A race condition occurs when one thread finishes before another on which it depends, causing the former to use a bogus value because the latter has not yet supplied a valid one.

The key is synchronization

- Synchronization = gaining access to a shared resource.
- Synchronization REQUIRE cooperation.

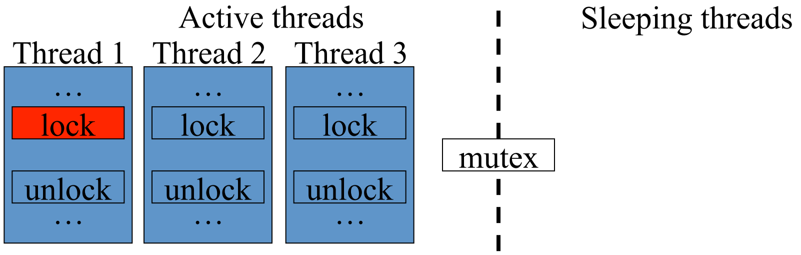
POSIX Thread

- What’ s POSIX ?
  - Widely used UNIX specification
  - Most of the UNIX flavor operating systems

POSIX is the Portable Operating System Interface, the open operating interface standard accepted world-wide. It is produced by IEEE and recognized by ISO and ANSI.

Mutual exclusion

- Simple lock primitive with 2 states: lock and unlock
- Only one thread can lock the mutex.
- Several politics: FIFO, random, recursive



Active threads

Sleeping threads

Thread 1

…
lock
unlock
…

Thread 2

…
lock
unlock
…

Thread 3

…
lock
unlock
…

mutex

Mutual exclusion

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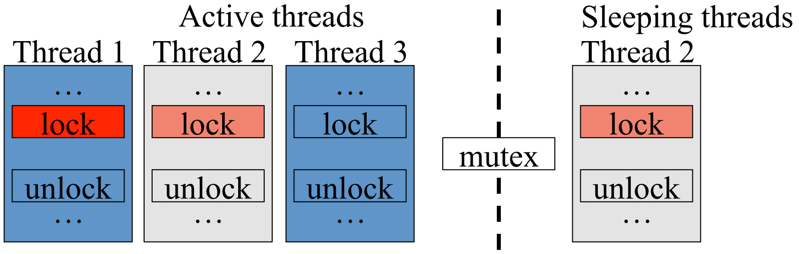

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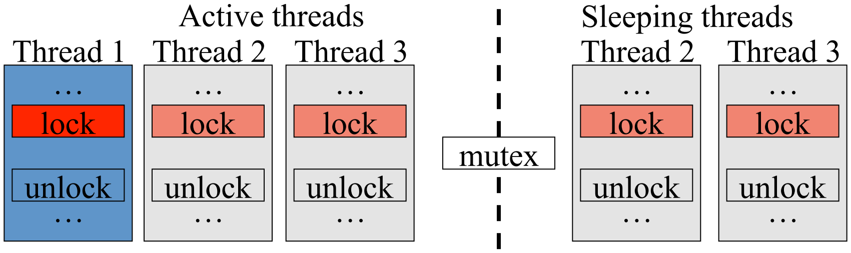

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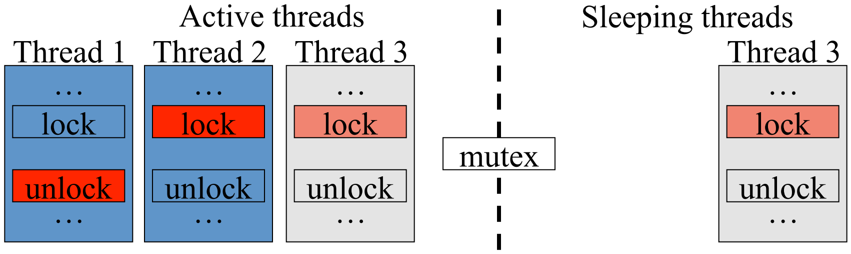

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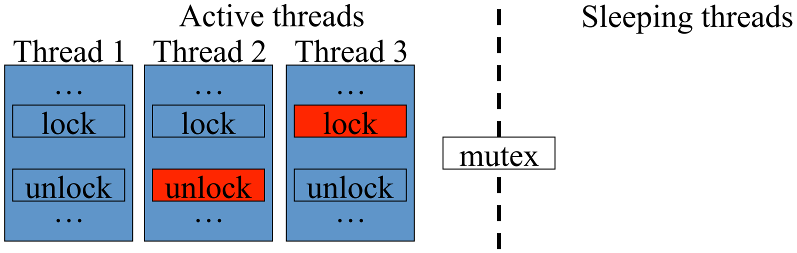

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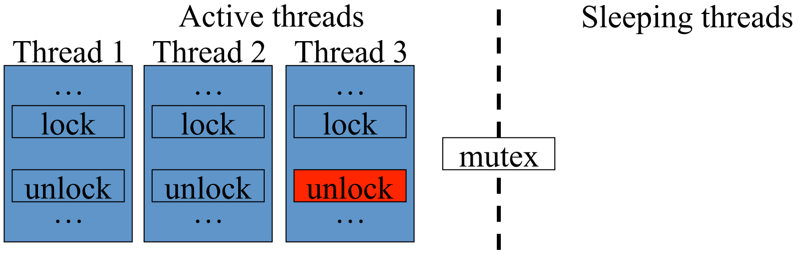


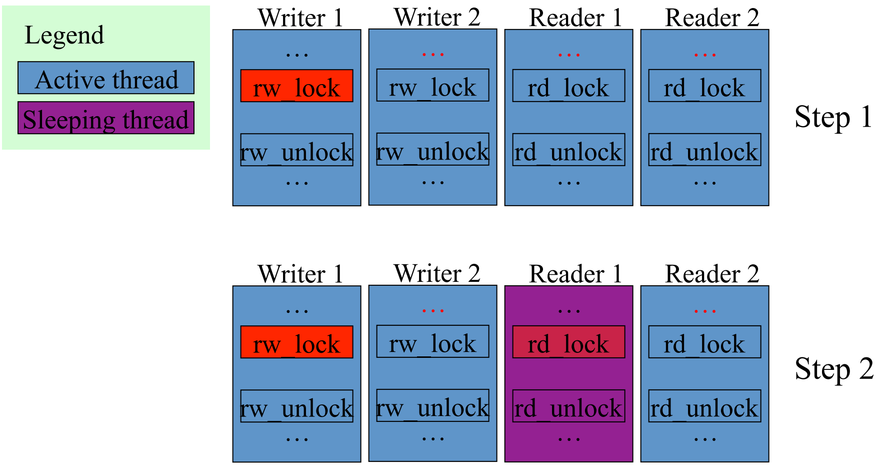
Mutual exclusion

- Spin vs. sleep ?
- What’s the desired lock grain ?
  - Fine grain – spin mutex
  - Coarse grain – sleep mutex
- Spin mutex: use CPU cycles and increase the memory bandwidth, but when the mutex is unlock the thread continue his execution immediately.

Shared/Exclusive Locks

- ReadWrite Mutual exclusion
- Extension used by the reader/writer model
- 4 states: write_lock, write_unlock, read_lock and read_unlock.
- multiple threads may hold a shared lock simultaneously, but only one thread may hold an exclusive lock.
- if one thread holds an exclusive lock, no threads may hold a shared lock.

Shared/Exclusive Locks



Legend

Active thread

Sleeping thread

Writer 1 … rw_lock rw_unlock …

Writer 2 … rw_lock rw_unlock …

Reader 1 … rd_lock rd_unlock …

Reader 2 … rd_lock rd_unlock …

Step 1

Writer 1 … rw_lock rw_unlock …

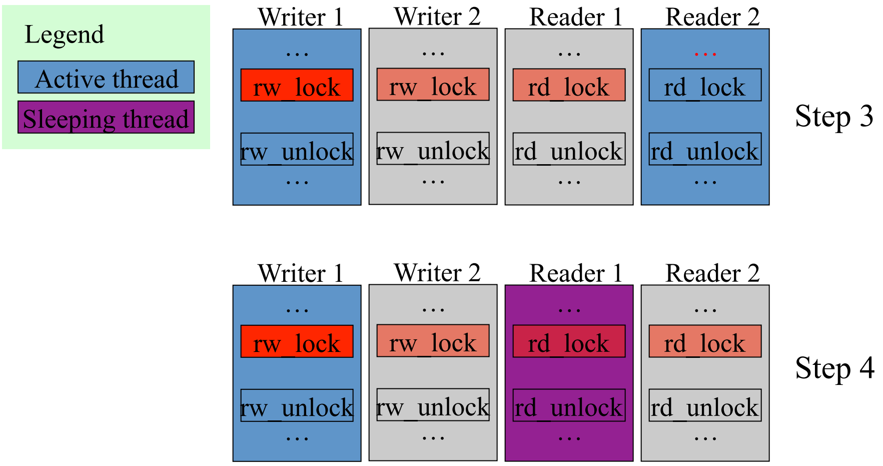
Writer 2 … rw_lock rw_unlock …

Reader 1 … rd_lock rd_unlock …

Reader 2 … rd_lock rd_unlock …

Step 2

Shared/Exclusive Locks



Legend

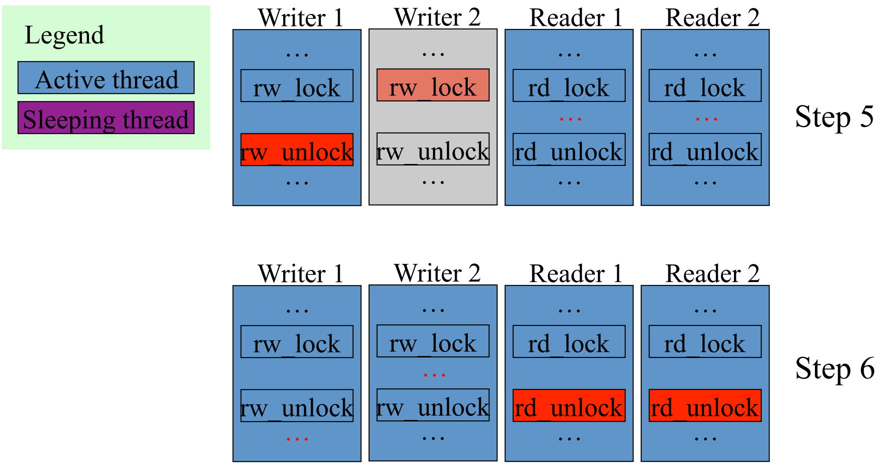
Active thread

Sleeping thread

Writer 1	Writer 2	Reader 1	Reader 2	
…	…	…	…	
rw_lock	rw_lock	rd_lock	rd_lock	Step 3
rw_unlock	rw_unlock	rd_unlock	rd_unlock	
…	…	…	…	

Writer 1	Writer 2	Reader 1	Reader 2	
…	…	…	…	
rw_lock	rw_lock	rd_lock	rd_lock	Step 4
rw_unlock	rw_unlock	rd_unlock	rd_unlock	
…	…	…	…	

Shared/Exclusive Locks



Legend

Active thread

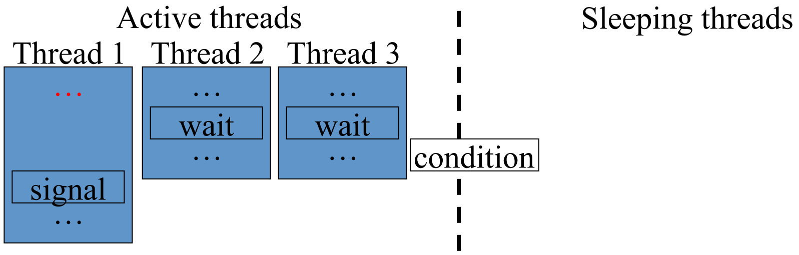
Sleeping thread

Writer 1	Writer 2	Reader 1	Reader 2	
…	…	…	…	
rw_lock	rw_lock	rd_lock	rd_lock	Step 5
		…	…	
rw_unlock	rw_unlock	rd_unlock	rd_unlock	
…	…	…	…	

Writer 1	Writer 2	Reader 1	Reader 2	
…	…	…	…	
rw_lock	rw_lock	rd_lock	rd_lock	Step 6
	…			
rw_unlock	rw_unlock	rd_unlock	rd_unlock	
…	…	…	…	

Condition Variable

- Block a thread while waiting for a condition
- Condition_wait / condition_signal
- Several thread can wait for the same condition, they all get the signal



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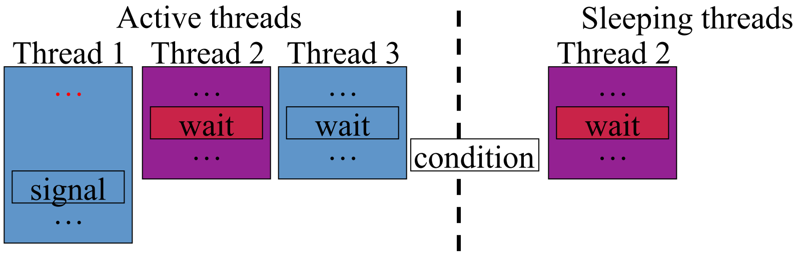

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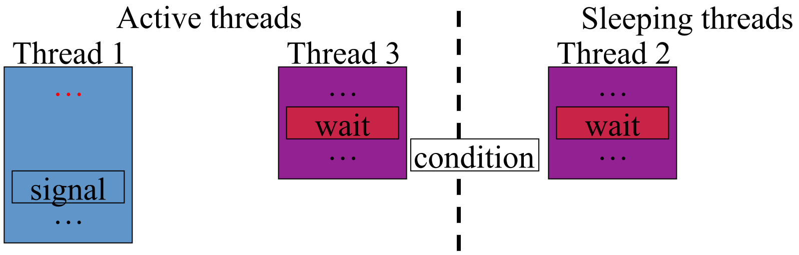

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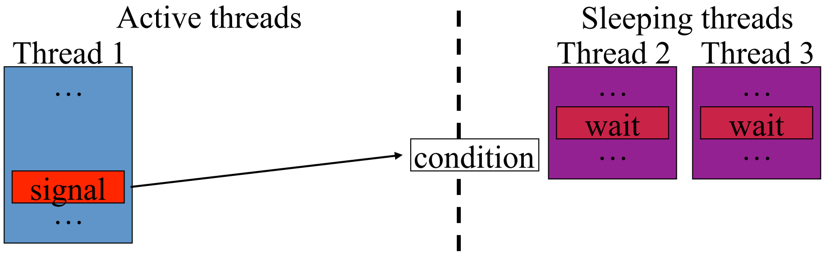

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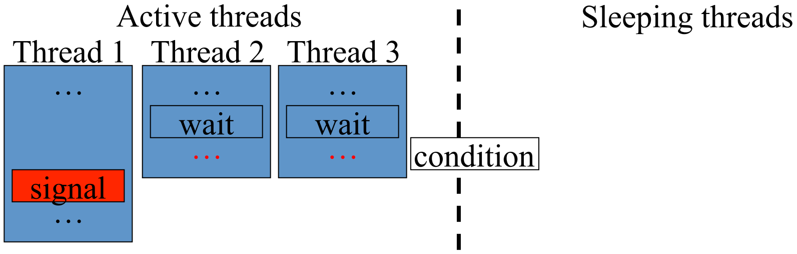
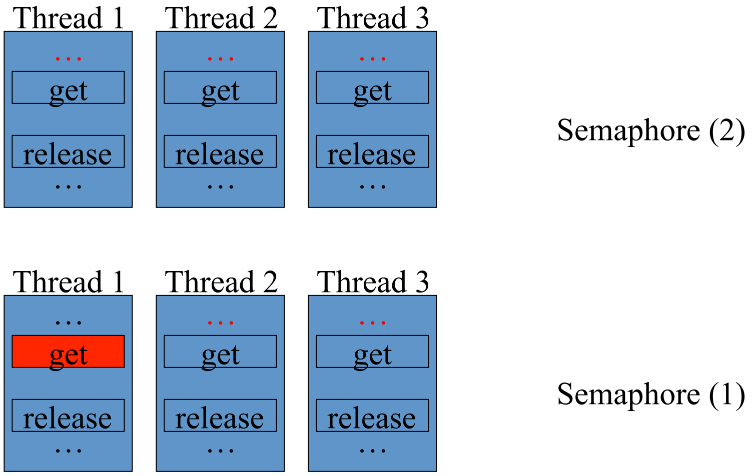


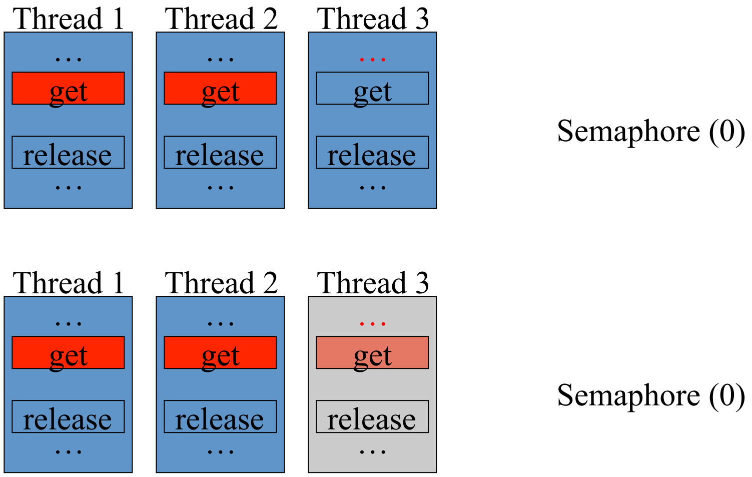
Semaphores

- simple counting mutexes
- The semaphore can be hold by as many threads as the initial value of the semaphore.
- When a thread get the semaphore it decrease the internal value by 1.
- When a thread release the semaphore it increase the internal value by 1.

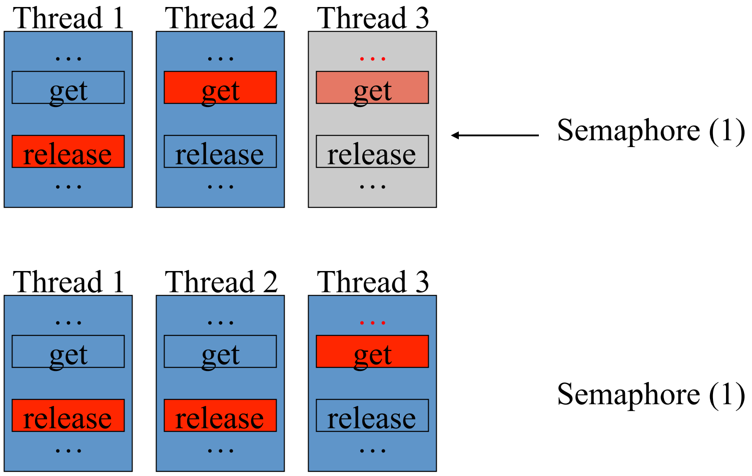
Semaphores



Semaphores



Semaphores



Thread 1
…
get
release
…

Thread 2
…
get
release
…

Thread 3
…
get
release
…

Semaphore (1)

Thread 1
…
get
release
…

Thread 2
…
get
release
…

Thread 3
…
get
release
…

Semaphore (1)

Atomic instruction

- Is any operation that a CPU can perform such that all results will be made visible to each CPU at the same time and whose operation is safe from interference by other CPUs
  - TestAndSet
  - CompareAndSwap
  - DoubleCompareAndSwap
  - Atomic increment
  - Atomic decrement