Monitors

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Monitors (1)

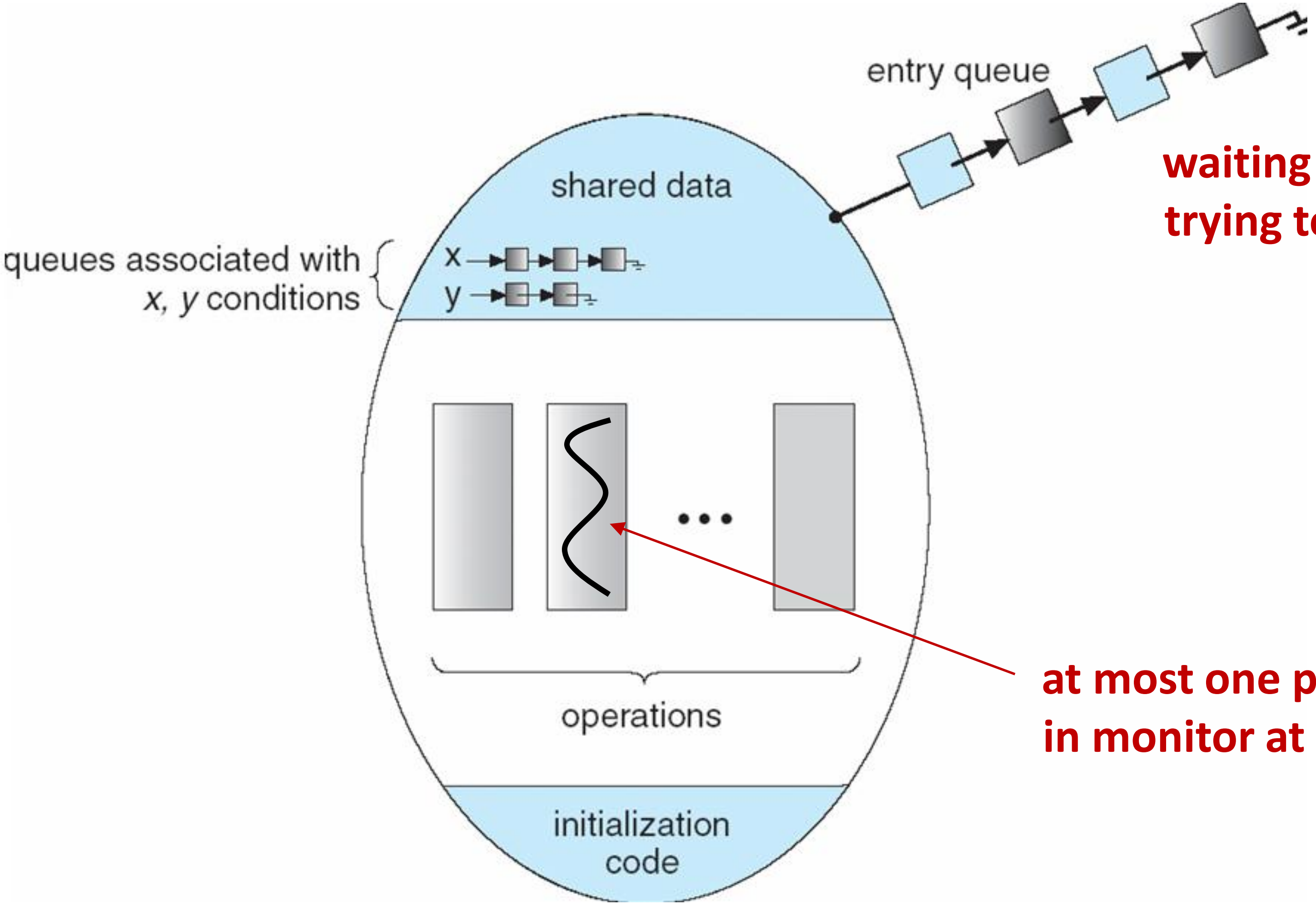
- Monitor is a programming language construct that supports controlled access to shared data
  - Synchronization code added by compiler, enforced at runtime
  - Allows the safe sharing of an abstract data type among concurrent processes
- A monitor is a software module that encapsulates:
  - Shared data structures
  - ________________ that operate on the shared data
  - Synchronization between concurrent processes that invoke those procedures
- Monitor protects the data from unstructured access
  - Guarantees only access data through procedures, hence in legitimate ways

Monitors (2)

- **Mutual exclusion**
  - Only one process can be executing inside at any time
    - Thus, synchronization implicitly associated with monitor
  - If a second process tries to enter a monitor procedure, it blocks until the first has left the monitor
    - More restrictive than semaphores, but easier to use most of the time

- **Condition variables**
  - Once inside, a process may discover it can't continue, and may wish to sleep, or allow some other waiting process to continue
  - Condition variables are provided within monitor
    - Processes can wait or signal others to continue
    - Can only be accessed from inside monitor

Monitors (3)



waiting queue of processes trying to enter the monitor

at most one process in monitor at a time

Source: A. Silberschatz et al., Operating System Concepts, 2008.

Condition Variables

- Provide a mechanism to wait for events (a "rendezvous point")

- `wait(c)`
  - Release monitor lock, so somebody else can get in
  - Wait for somebody else to signal condition
  - Thus, condition variables have wait queues
- `signal(c)`
  - Wake up at most one waiting process
  - If no waiting processes, signal is lost
  - This is different from semaphores: no history!
- `broadcast(c)`
  - Wake up all waiting processes

Bounded Buffer with Monitors

```
Monitor bounded_buffer {
   buffer resources[N];
   condition not_full, not_empty;

   procedure add_entry(resource x)  {
       while (array “resources” is full)
           wait(not_full);
       add “x” to array “resources”;
       signal(not_empty);
   }

   procedure remove_entry(resource *x)  {
       while (array “resources” is empty)
           wait(not_empty);
       *x = get resource from array “resources”
       signal(not_full);
   }
}
```

Monitors Semantics

- Hoare monitors
  - `signal(c)` immediately switches from the caller to a waiting thread, blocking the caller
    - The condition that the waiter was anticipating is guaranteed to hold when waiter executes
    - Signaler must restore monitor invariants before signaling

- Mesa monitors
  - `signal(c)` places a waiter on the ready queue, but signaler continues inside monitor
    - Condition is not necessarily true when waiter runs again
    - Being woken up is only a hint that something has changed
    - Must recheck conditional case

Monitors Semantics: Comparison

Hoare monitors	**Mesa monitors**
`if (notReady) wait(c);`	`while (notReady) wait(c);`

- Mesa monitors easier to use
  - More efficient
  - Fewer switches
  - Directly supports `broadcast()`
- Hoare monitors leave less to chance
  - When wake up, condition guaranteed to be what you expect

Monitors using Semaphores

- ________ monitors

```
Semaphore mutex = 1;
Semaphore next = 0;
int next_count = 0;
struct condition {
   Semaphore sem;
   int count;
} x = {0, 0};

procedure F()  {
   wait(mutex);
   …
   Body of F
   …
   if (next_count)
       signal(next);
   else
       signal(mutex);
}
```

```
procedure cond_wait(x)  {
   x.count++;
   if (next_count)
       signal(next);
   else
       signal(mutex);
   wait(x.sem);
   x.count--;
}

procedure cond_signal(x)  {
   if (x.count)  {
       next_count++;
       signal(x.sem);
       wait(next);
       next_count--;
   }
}
```

Monitors vs. Semaphores

- Condition variables do not have any __________, but semaphores do

- On a condition variable `signal()`, if no one is waiting, the signal is a no-op
  - If a thread then does `wait()` on the condition variable, it waits

- On a semaphore `signal()`, if no one is waiting, the value of the semaphore is increased
  - If a thread then does `wait()` on the semaphore, the value is decreased and the thread continues