Android Concurrency: The Monitor Object Pattern (Part 2)

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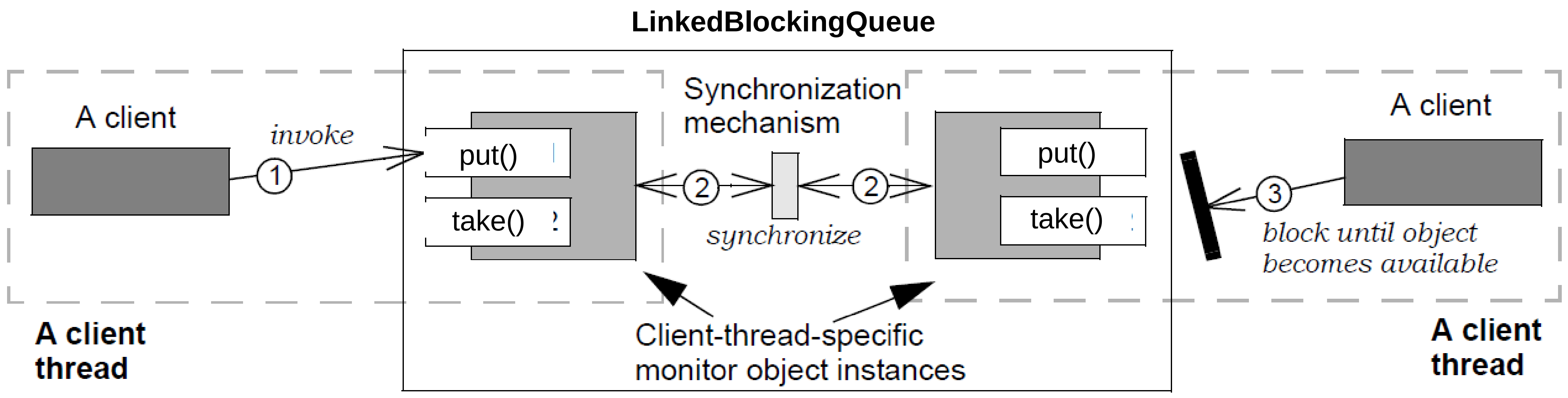
Learning Objectives in this Part of the Module

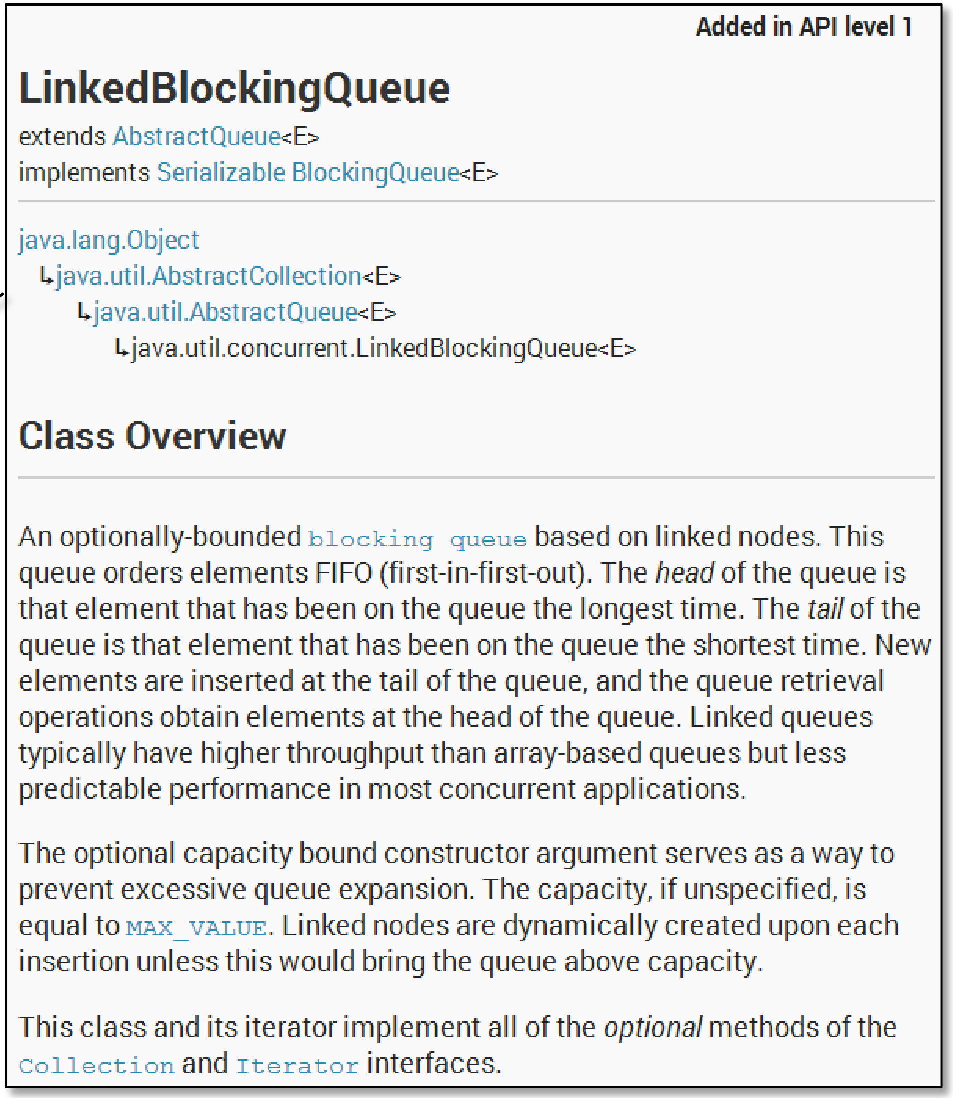
- Understand how *Monitor Object* is implemented & applied in Android


LinkedBlockingQueue
A client
invoke
1
put()
take()
Synchronization mechanism
2
synchronize
2
put()
take()
A client
3
block until object becomes available
Client-thread-specific monitor object instances
A client thread
A client thread

Monitor Object POSA2 Concurrency

Implementation

LinkedBlockingQueue is a bounded BlockingQueue based on linked nodes that queues elements in FIFO order



Added in API level 1

LinkedBlockingQueue

extends AbstractQueue<E>
implements Serializable BlockingQueue<E>

java.lang.Object
↳java.util.AbstractCollection<E>
↳java.util.AbstractQueue<E>
↳java.util.concurrent.LinkedBlockingQueue<E>

Class Overview

An optionally-bounded `blocking queue` based on linked nodes. This queue orders elements FIFO (first-in-first-out). The *head* of the queue is that element that has been on the queue the longest time. The *tail* of the queue is that element that has been on the queue the shortest time. New elements are inserted at the tail of the queue, and the queue retrieval operations obtain elements at the head of the queue. Linked queues typically have higher throughput than array-based queues but less predictable performance in most concurrent applications.

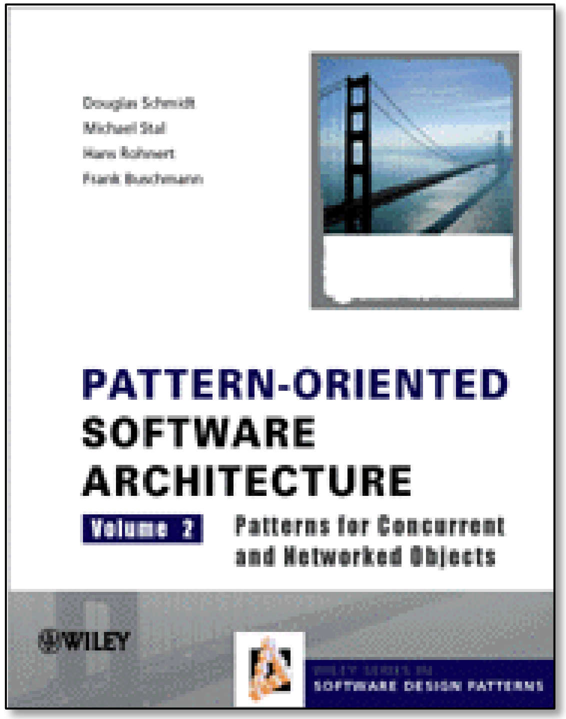
The optional capacity bound constructor argument serves as a way to prevent excessive queue expansion. The capacity, if unspecified, is equal to `MAX_VALUE`. Linked nodes are dynamically created upon each insertion unless this would bring the queue above capacity.

This class and its iterator implement all of the *optional* methods of the `Collection` and `Iterator` interfaces.

developer.android.com/reference/java/util/concurrent/LinkedBlockingQueue.html

Monitor Object POSA2 Concurrency

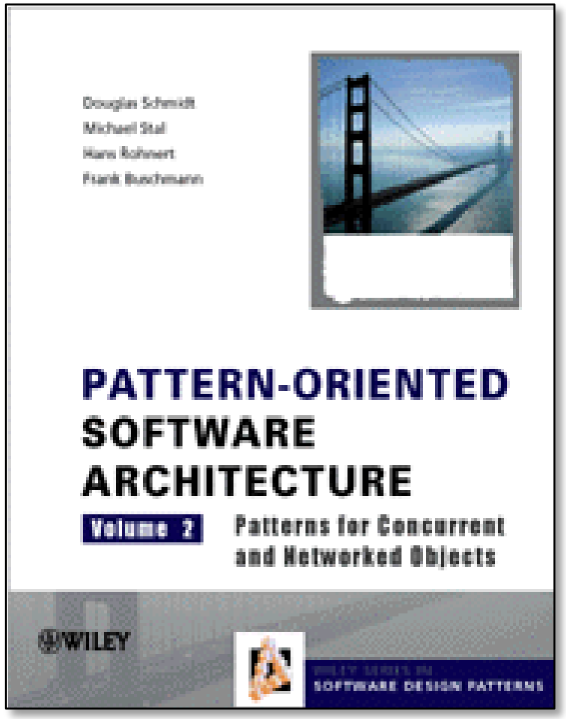
Implementation Steps


Douglas Schmidt
Michael Stal
Hans Rohnert
Frank Buschmann
PATTERN-ORIENTED SOFTWARE ARCHITECTURE
Volume 2
Patterns for Concurrent and Networked Objects
WILEY
WILEY SERIES IN SOFTWARE DESIGN PATTERNS

www.dre.vanderbilt.edu/~schmidt/POSA/POSA2 has info on POSA book

Monitor Object POSA2 Concurrency

Implementation Steps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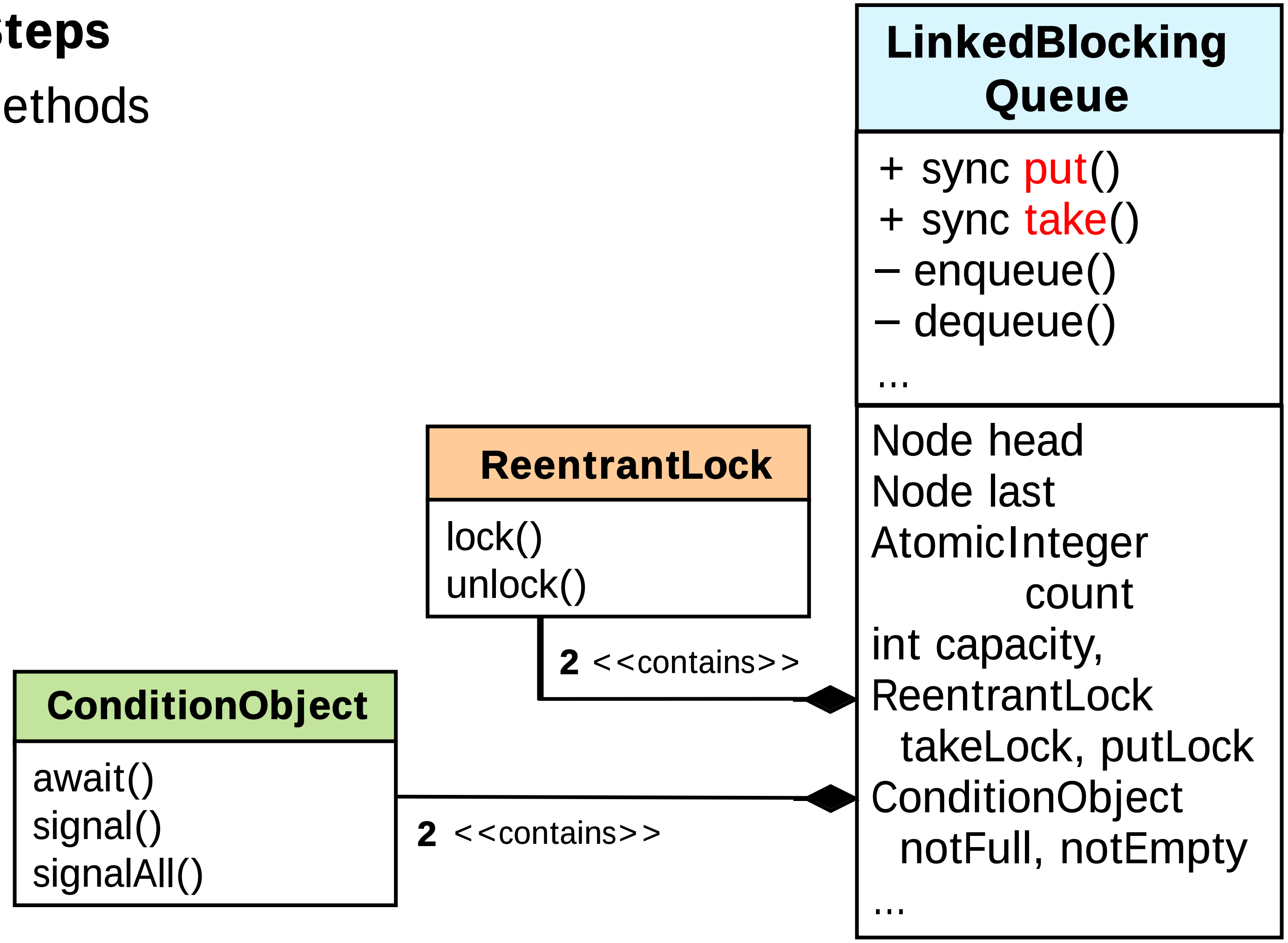
See www.dre.vanderbilt.edu/~schmidt/PDF/monitor.pdf for *Monitor Object*

Monitor Object POSA2 Concurrency

Implementation Steps

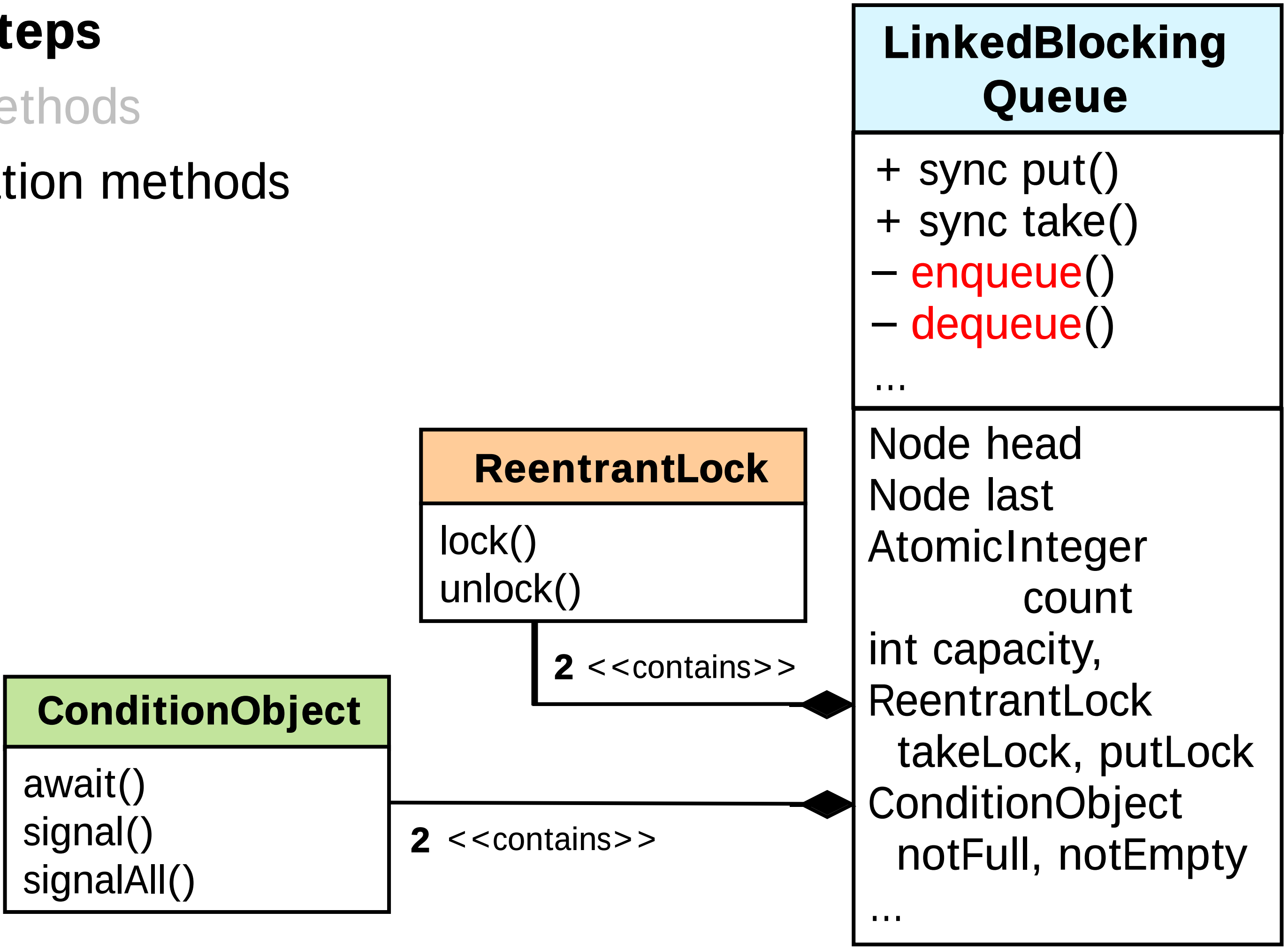
- Define interface methods



Monitor Object POSA2 Concurrency

Implementation Steps

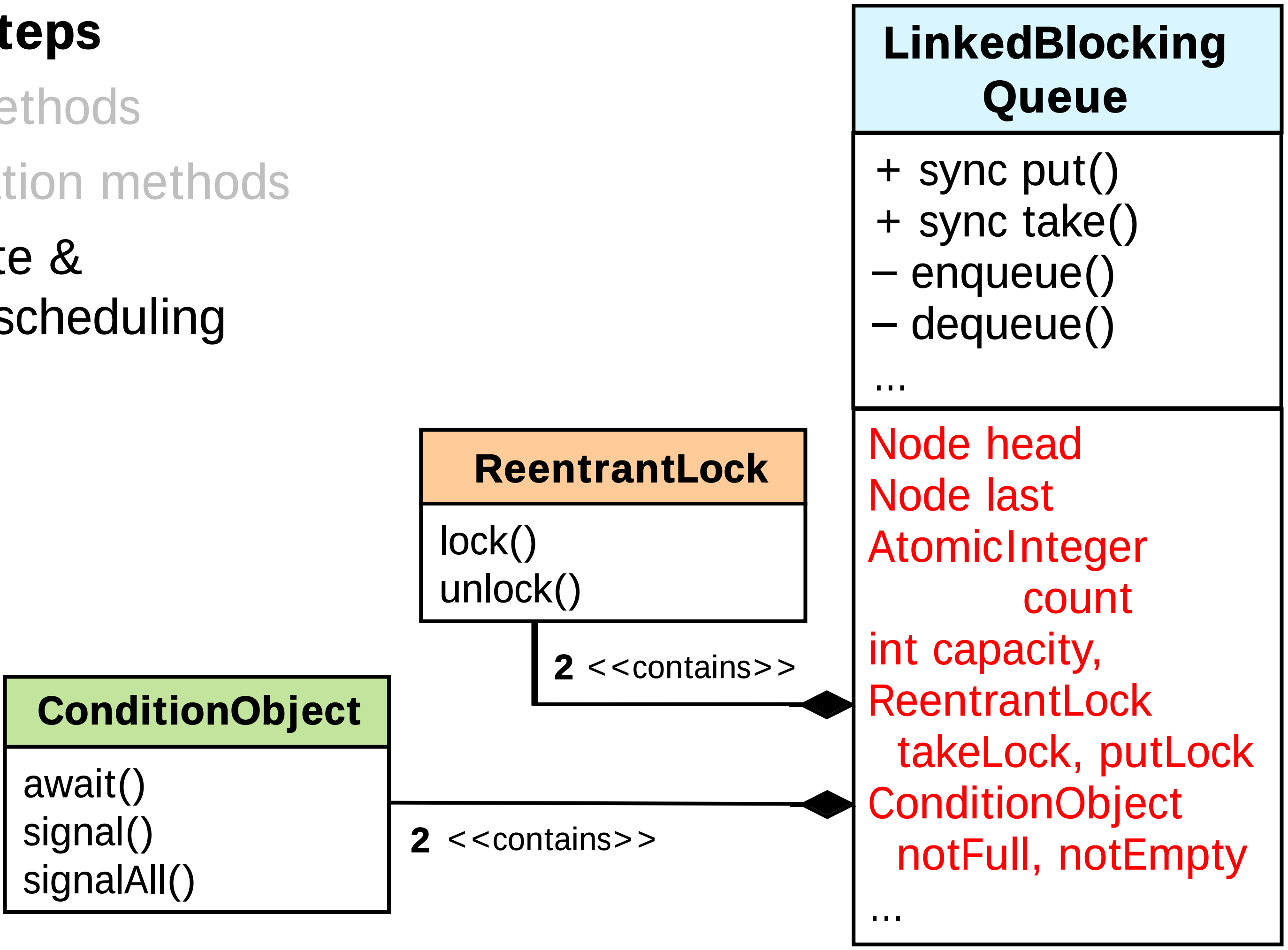
- Define interface methods
- Define implementation methods



Monitor Object POSA2 Concurrency

Implementation Steps

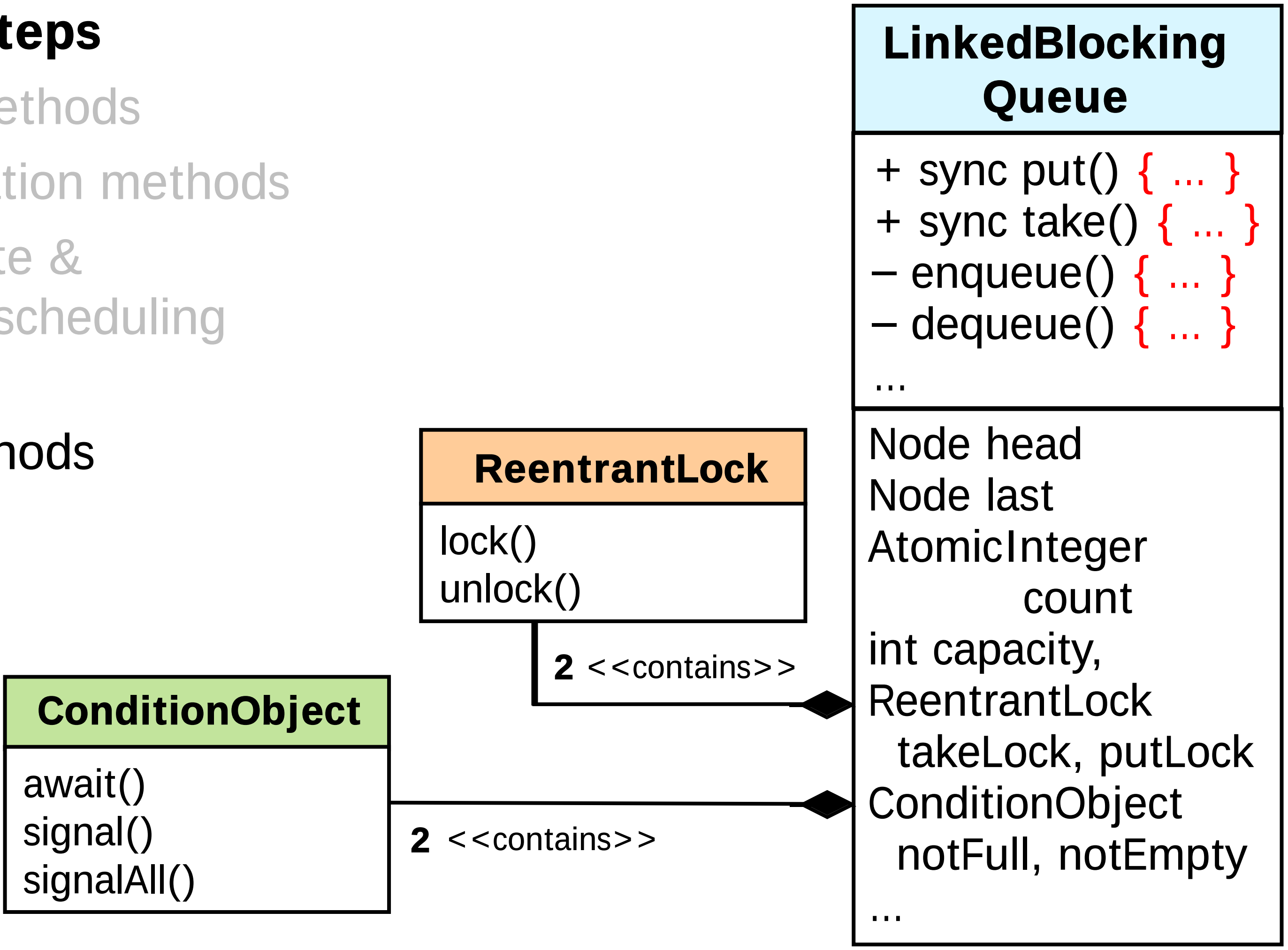
- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms



Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members



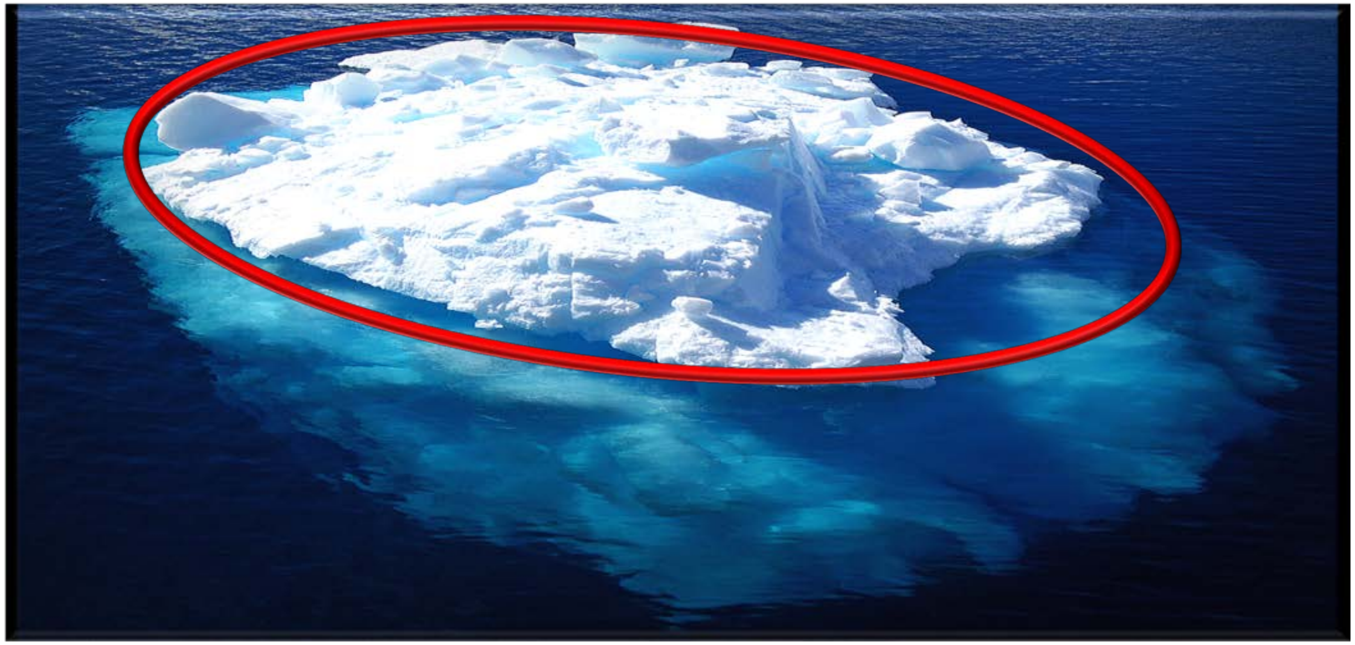
Defining the Interface & Implementation Methods

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods

Monitor Object
+ sync method$_1$() ... + sync method$_n$()



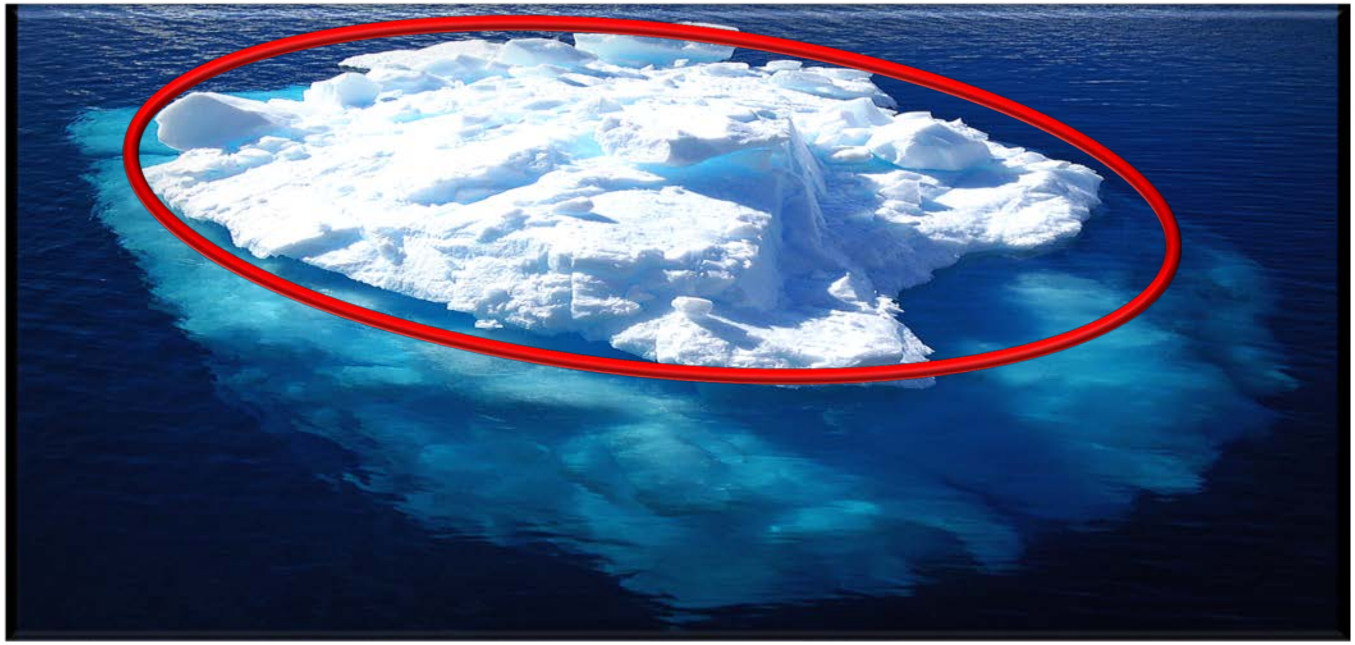
Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods

Monitor Object

+ sync $\text{method}_1()$
...
+ sync $\text{method}_n()$



Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
  - e.g., methods inherited from the BlockingQueue interface

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...
}
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
  - e.g., methods inherited from the BlockingQueue interface

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...
}
```

developer.android.com/reference/java/util/concurrent/BlockingQueue.html

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
  - e.g., methods inherited from the BlockingQueue interface

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...
```

Insert the specified element into a queue, waiting if necessary for space to become available

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
  - e.g., methods inherited from the BlockingQueue interface

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...
}
```

Retrieve & remove the head of the queue, waiting if necessary until an elements becomes available

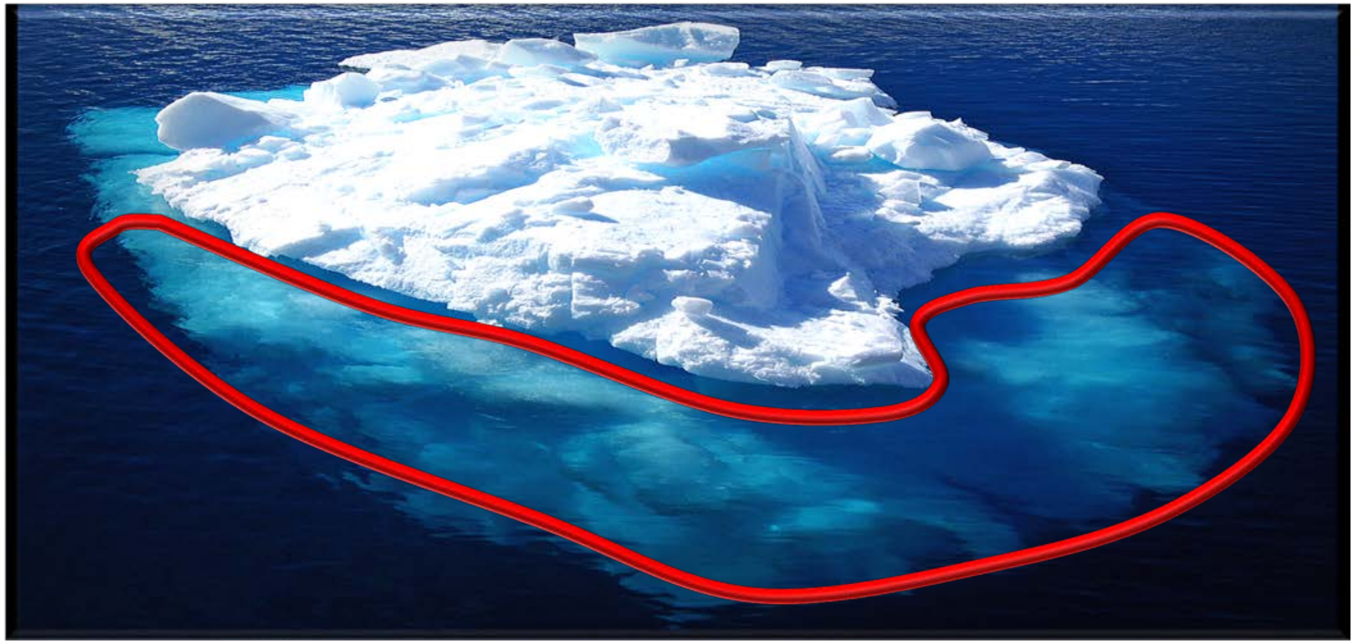
Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods

Monitor Object

+ sync $method_1()$
...
+ sync $method_n()$
– $method_1()$
...
– $method_n()$



Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
  - See the POSA2 *Thread-Safe Interface* pattern for design rationale

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...

  ...
}
```

www.dre.vanderbilt.edu/~schmidt/PDF/locking-patterns.pdf has more info

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
  - See the POSA2 *Thread-Safe Interface* pattern for design rationale

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
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  public void put(E e) ...

  public E take() ...

  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...

  ...
}
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
  - See the POSA2 *Thread-Safe Interface* pattern for design rationale

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...

  ...
}
```

Links a node at the end of the queue

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
  - See the POSA2 *Thread-Safe Interface* pattern for design rationale

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...

  ...
}
```

Removes a node from the head of the queue

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
  - See the POSA2 *Thread-Safe Interface* pattern for design rationale

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {

  public void put(E e) ...

  public E take() ...

  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...

  ...
}
```

These interface methods acquire & release the monitor locks

Defining Internal State & Synchronization & Scheduling Mechanisms

Monitor Object POSA2 Concurrency

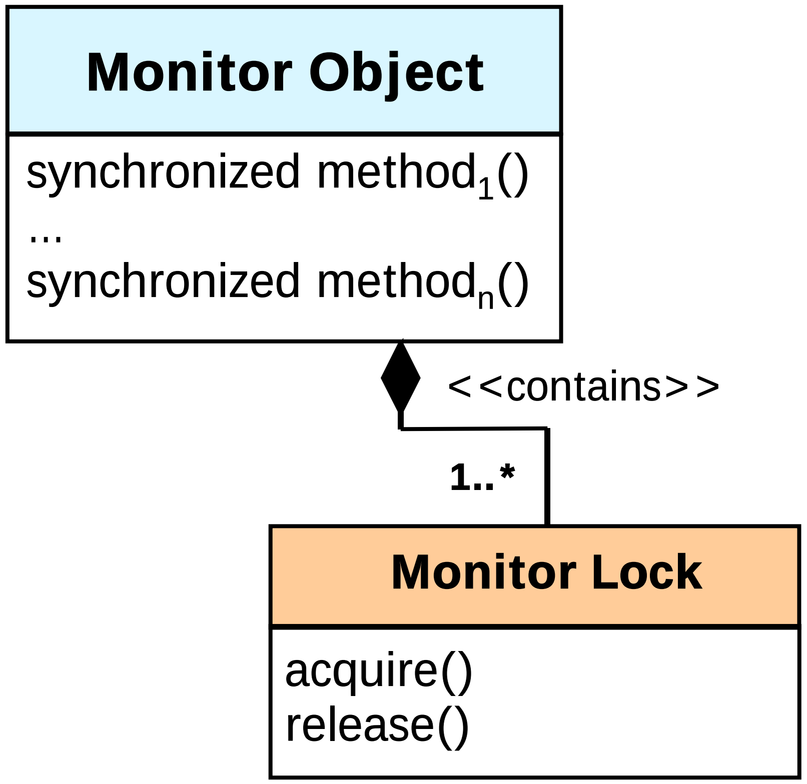
Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

Monitor Object POSA2 Concurrency

Implementation Steps

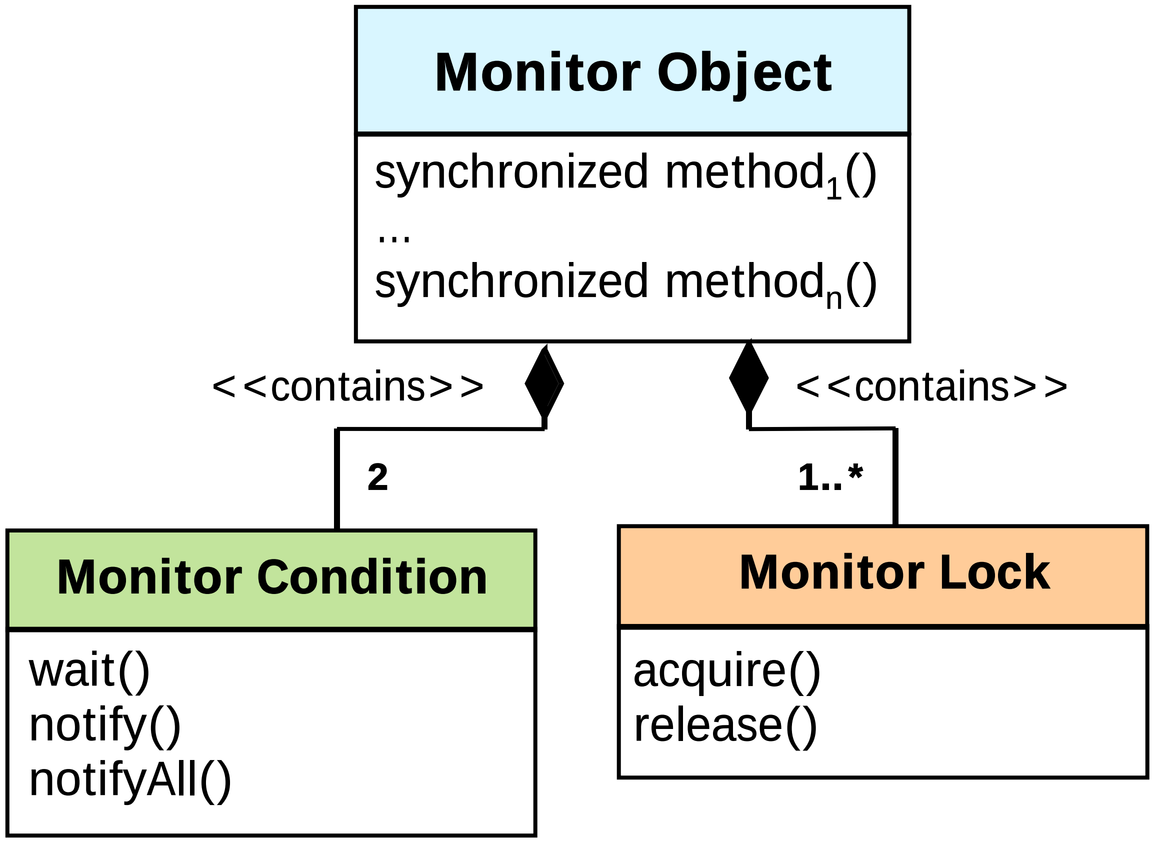
- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms



Monitor Object POSA2 Concurrency

Implementation Steps

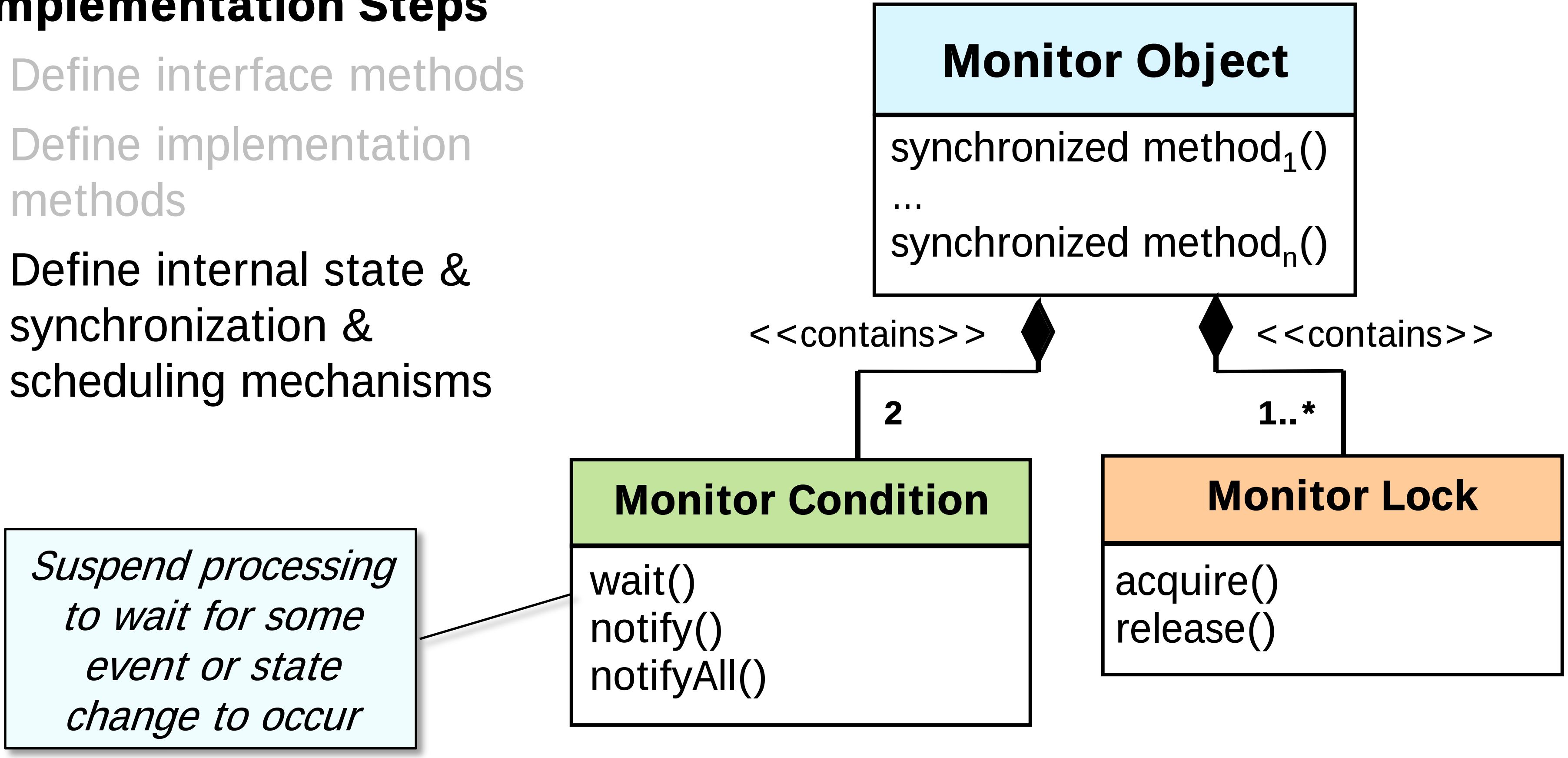
- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms



Monitor Object POSA2 Concurrency

Implementation Steps

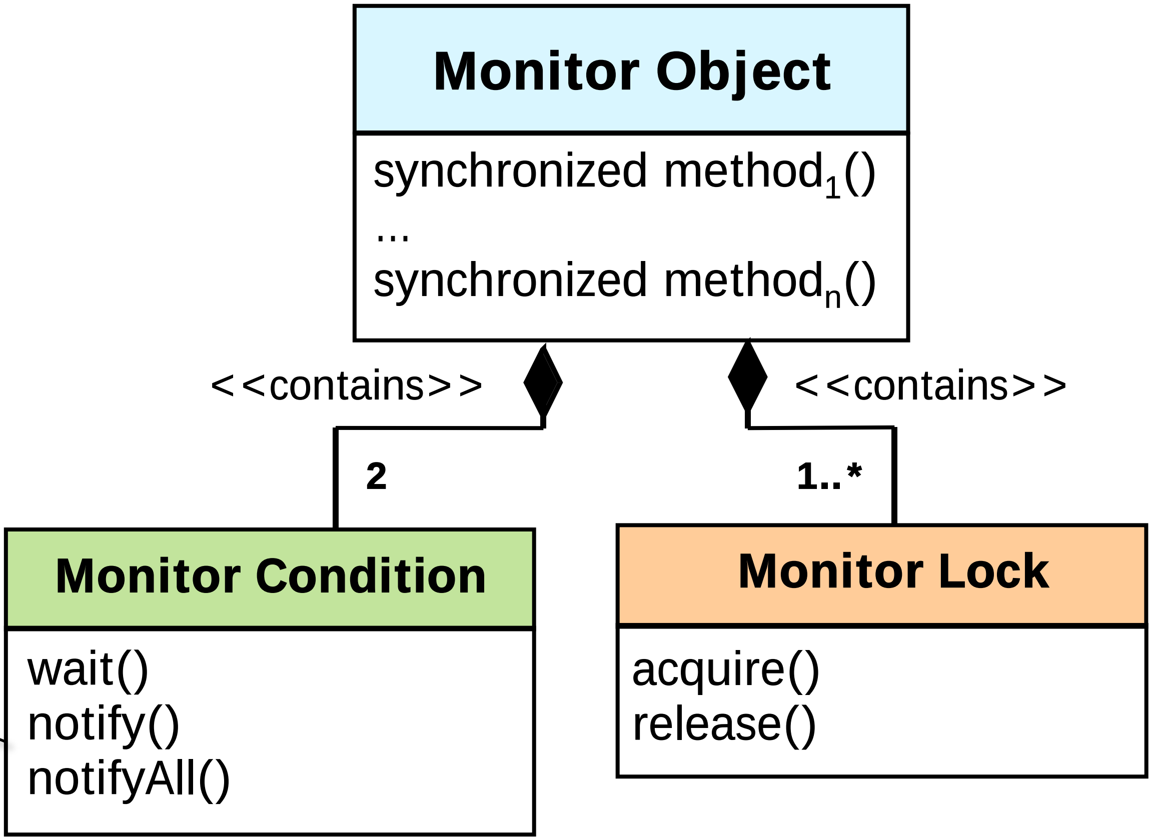
- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms


Monitor Object
synchronized method$_1$()
...
synchronized method$_n$()
<<contains>>
<<contains>>
2
1..*
Monitor Condition
wait()
notify()
notifyAll()
Monitor Lock
acquire()
release()
Suspend processing to wait for some event or state change to occur

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

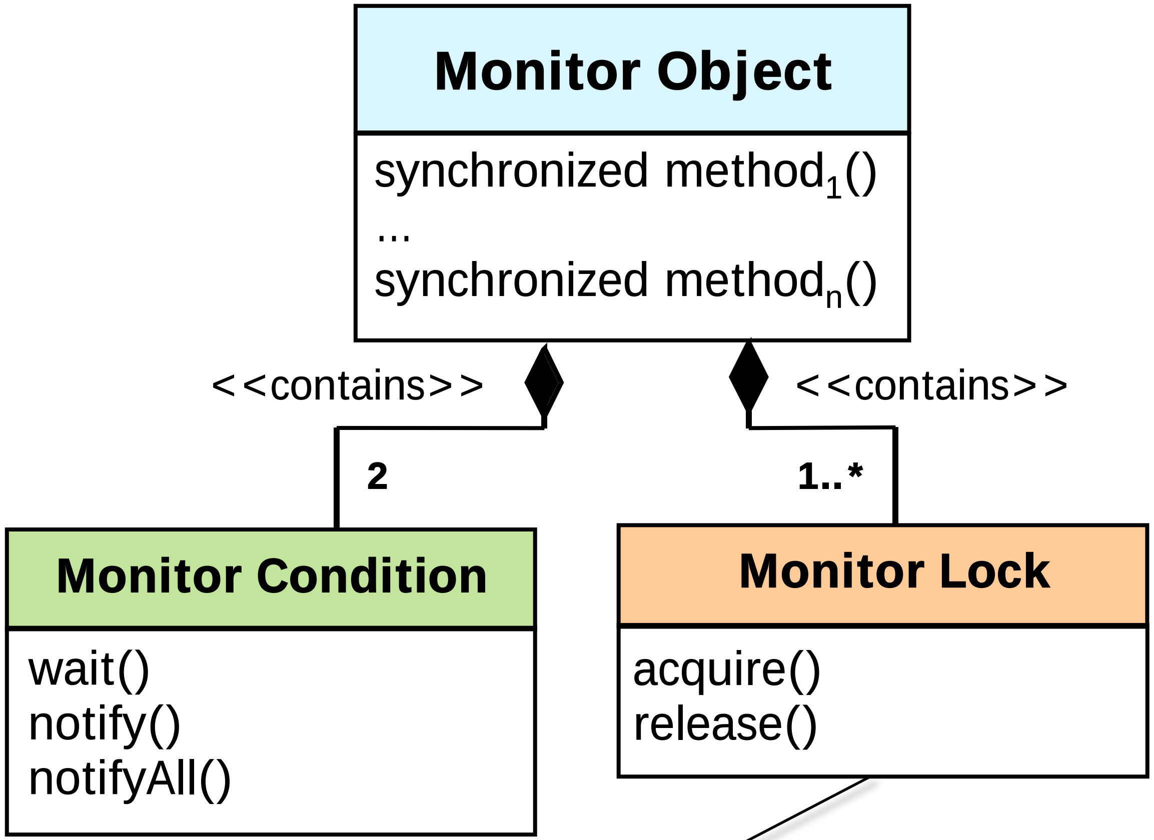


Resume other threads whose synchronized methods have suspended themselves previously

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms



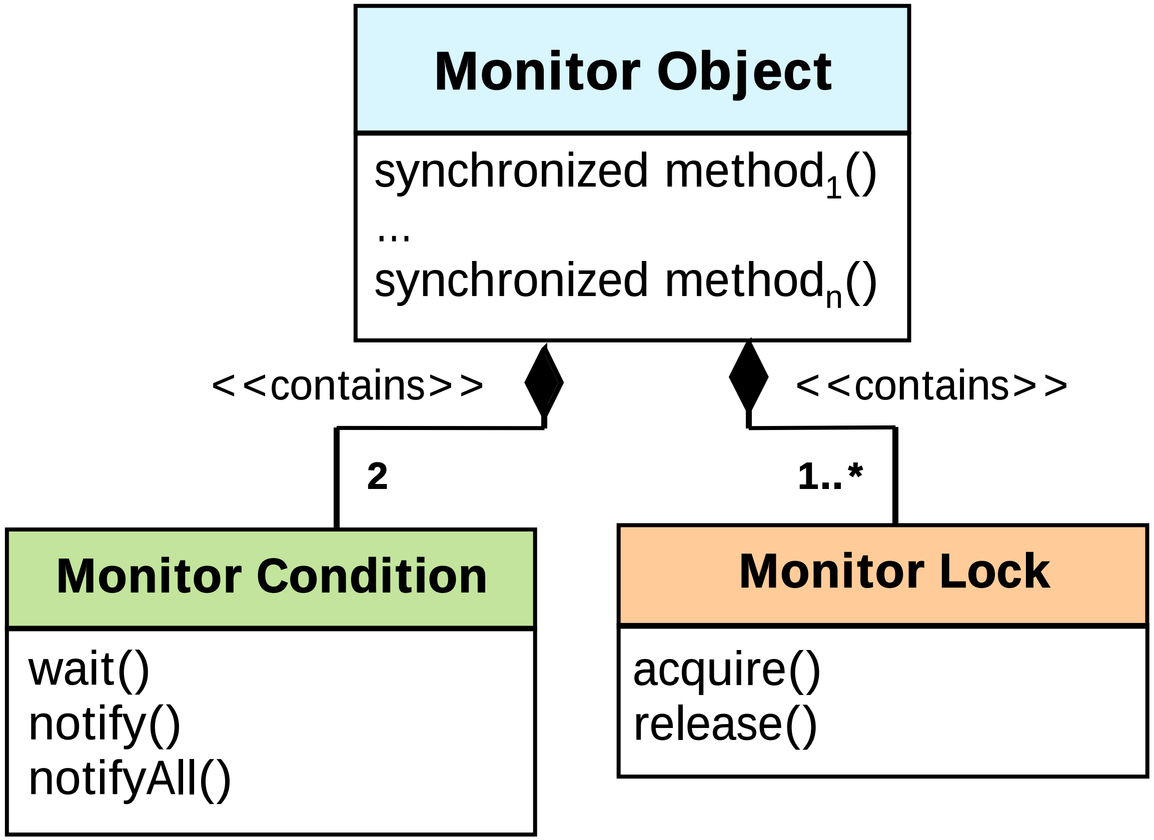
A monitor lock must be held as long as invariants are not satisfied

en.wikipedia.org/wiki/Invariant_(computer_science) has more on invariants

Monitor Object POSA2 Concurrency

Implementation Steps

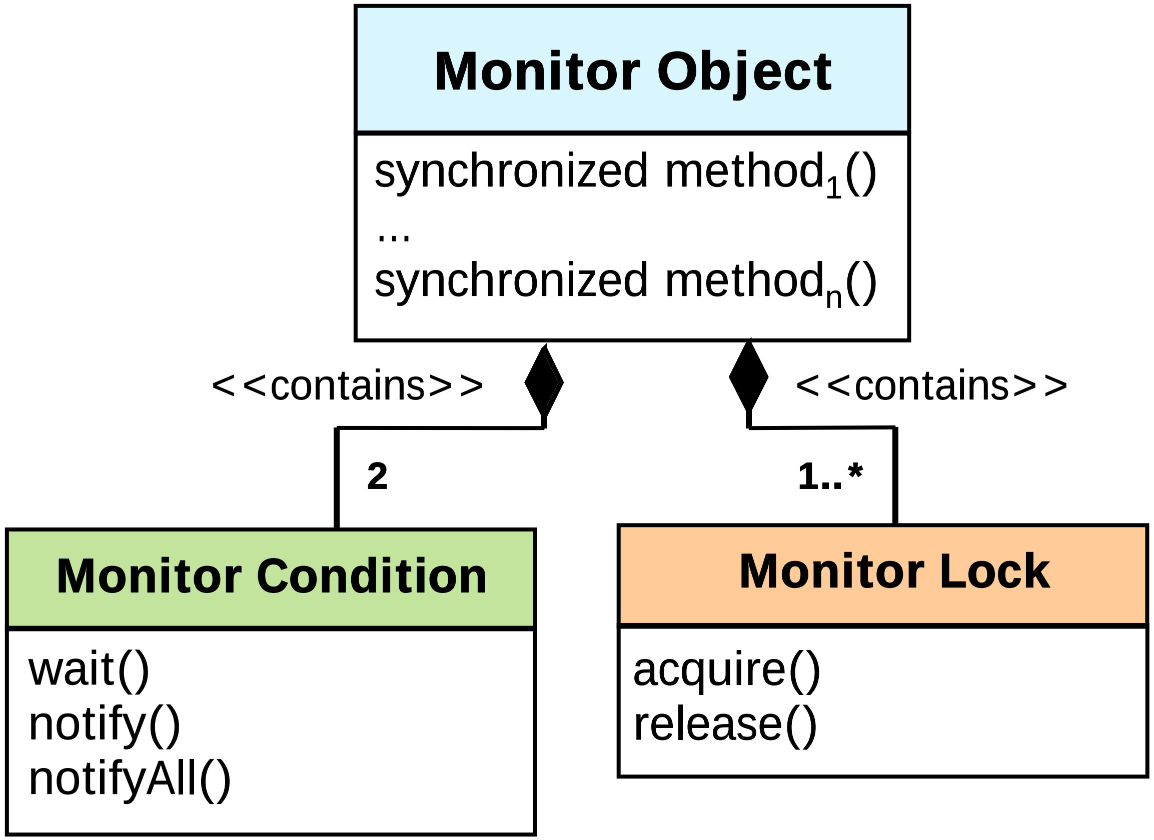
- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
  - Invariants must hold when a synchronized method waits on a monitor condition



Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
  - Invariants must hold when a synchronized method waits on a monitor condition
  - They must also hold before processing resumes after a monitor condition is notified



Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  static class Node<E> {
    E item;
    Node<E> next;
    Node(E x) { item = x; }
  }

  private transient Node<T> head;
  private transient Node<T> last;
  private final int capacity;
  private final AtomicInteger count
    = new AtomicInteger(0);
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
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Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

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    = new AtomicInteger(0);
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Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

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Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

```
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     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
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  static class Node<E> {
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    Node<E> next;
    Node(E x) { item = x; }
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  private transient Node<T> head;
  private transient Node<T> last;
  private final int capacity;
  private final AtomicInteger count
    = new AtomicInteger(0);
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
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    E item;
    Node<E> next;
    Node(E x) { item = x; }
  }

  private transient Node<T> head;
  private transient Node<T> last;
  private final int capacity;
  private final AtomicInteger count
    = new AtomicInteger(0);
  ...
```

developer.android.com/reference/java/util/concurrent/atomic/AtomicInteger.html

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
    - LinkedBlockingQueue uses classes defined in the java.util.concurrent package

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  private final ReentrantLock takeLock
    ...;
  private final Condition notEmpty
    ...;
  private final ReentrantLock putLock
    ...;
  private final Condition notFull
    ...;
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
  - LinkedBlockingQueue uses classes defined in the java.util.concurrent package

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
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    ...;
  private final Condition notFull
    ...;
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
  - LinkedBlockingQueue uses classes defined in the java.util.concurrent package

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  private final ReentrantLock takeLock
    ...;
  private final Condition notEmpty
    ...;
  private final ReentrantLock putLock
    ...;
  private final Condition notFull
    ...;
  ...
```

www.cs.rochester.edu/~scott/papers/1996_PODC_queues.pdf has more info

Implementing All Methods & Data Members

Monitor Object POSA2 Concurrency

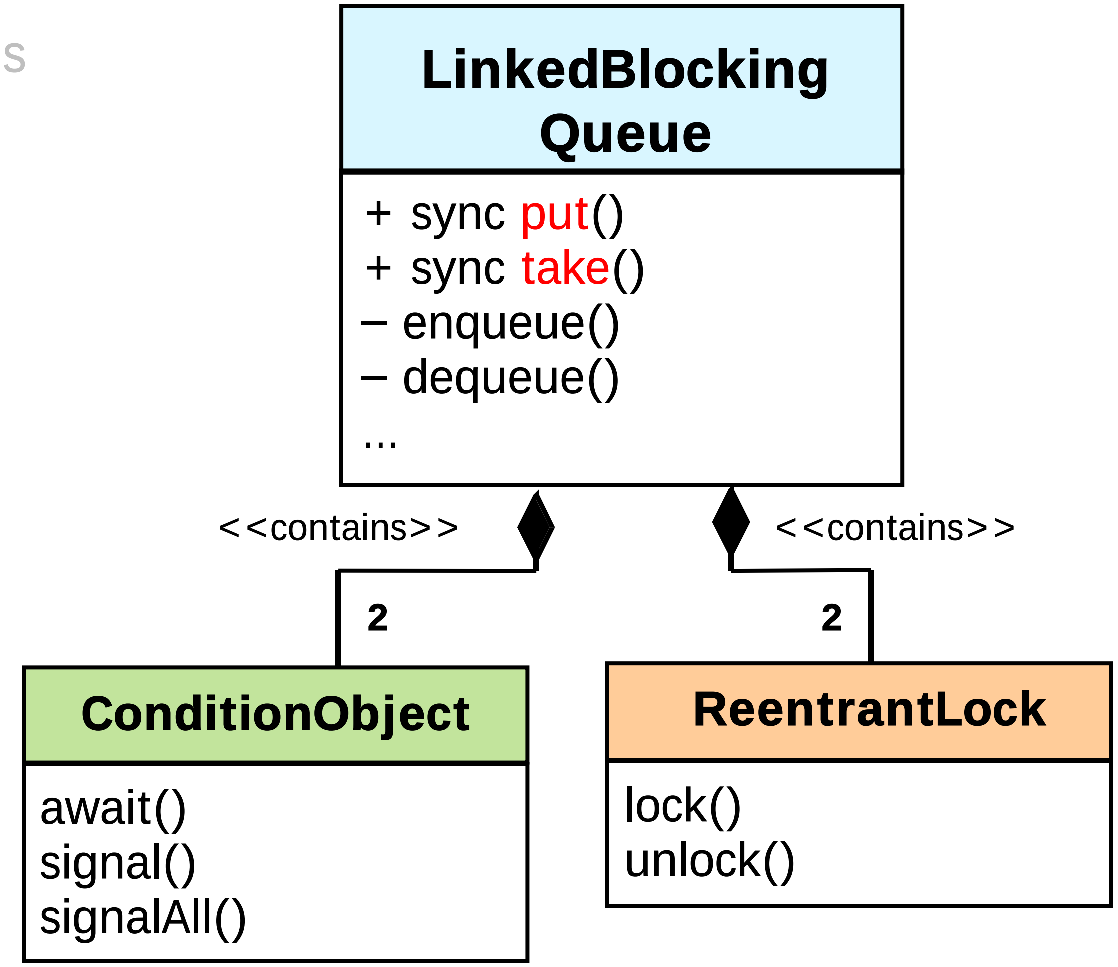
Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members



libcore/luni/src/main/java/java/util/concurrent/LinkedBlockingQueue.java

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  private final ReentrantLock takeLock
    = new ReentrantLock;
  private final Condition notEmpty
    = takeLock.newCondition();
  private final ReentrantLock putLock
    = new ReentrantLock;
  private final Condition notFull
    = putLock.newCondition();
  ...
  private final AtomicInteger count
    = new AtomicInteger(0);
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  private final ReentrantLock takeLock
    = new ReentrantLock;
  private final Condition notEmpty
    = takeLock.newCondition();
  private final ReentrantLock putLock
    = new ReentrantLock;
  private final Condition notFull
    = putLock.newCondition();
  ...
  private final AtomicInteger count
    = new AtomicInteger(0);
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
    - Initialize data members

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public LinkedBlockingQueue
           (int capacity) {
    if (capacity <= 0)
      throw new
        IllegalArgumentException();
    this.capacity = capacity;
    last = head = new Node<E>(null);
  }
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
    - Initialize data members

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
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    if (capacity <= 0)
      throw new
        IllegalArgumentException();
    this.capacity = capacity;
    last = head = new Node<E>(null);
  }
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members
  - Apply *Thread-Safe Interface* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ...

  public E take() ...

  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...
```

www.dre.vanderbilt.edu/~schmidt/PDF/locking-patterns.pdf has more info

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members
  - Apply *Thread-Safe Interface* pattern
  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ...

  public E take() ...


  ...

  private void enqueue(Node<E> x) ...

  private E dequeue() ...
```

en.wikipedia.org/wiki/Guarded_suspension has more on *Guarded Suspension*

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members
  - Apply *Thread-Safe Interface* pattern
  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
```

Insert the specified element into a queue, waiting if necessary for space to become available

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members
  - Apply *Thread-Safe Interface* pattern
  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
    int c = -1;
    Node<E> node = new Node(e);
    final ReentrantLock putlock =
      this.putLock;
    final AtomicInteger count =
      this.count;
    putLock.lockInterruptibly();
    ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members
  - Apply *Thread-Safe Interface* pattern
  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
    int c = -1;
    Node<E> node = new Node(e);
    final ReentrantLock putlock =
      this.putLock;
    final AtomicInteger count =
      this.count;
    putLock.lockInterruptibly();
    ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
- Define implementation methods
- Define internal state & synchronization & scheduling mechanisms
- Implement all methods & data members
  - Initialize data members
  - Apply *Thread-Safe Interface* pattern
  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
    try {
      while (count.get() == capacity)
         notFull.await();

      enqueue(node);
      ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

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    try {
      while (count.get() == capacity)
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Monitor Object POSA2 Concurrency

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      enqueue(node);
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     extends AbstractQueue<E>
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    ...
    try {
      while (count.get() == capacity)
         notFull.await();

      enqueue(node);
      ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

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- Define implementation methods
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  - Apply *Thread-Safe Interface* pattern
  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
    extends AbstractQueue<E>
    implements BlockingQueue<E>, ... {
  ...
  private void enqueue(Node<E> node) {
    last = last.next = node;
  }

  ...
```

Called only when the lock is held

Monitor Object POSA2 Concurrency

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```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
    try {
      ...
      c = count.getAndIncrement();
      if (c + 1 < capacity)
        notFull.signal();
    } finally {
      putLock.unlock();
    }
    ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
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    }
    ...
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Monitor Object POSA2 Concurrency

Implementation Steps

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public class LinkedBlockingQueue<E>
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     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
    try {
      ...
      c = count.getAndIncrement();
      if (c + 1 < capacity)
        notFull.signal();
    } finally {
      putLock.unlock();
    }
    ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
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  - Apply *Guarded Suspension* pattern

```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public void put(E e) ... {
    ...
    if (c == 0)
      signalNotEmpty();
  }
  ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

- Define interface methods
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     extends AbstractQueue<E>
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  public void put(E e) ... {
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      signalNotEmpty();
  }
  ...
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Monitor Object POSA2 Concurrency

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     extends AbstractQueue<E>
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  ...
  public void put(E e) ... {
    ...
    if (c == 0)
      signalNotEmpty();
  }
  ...

  private void signalNotEmpty() {
    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lock();
    try { notEmpty.signal(); }
    finally { takeLock.unlock(); }
  }
```

Monitor Object POSA2 Concurrency

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    takeLock.lock();
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```

Monitor Object POSA2 Concurrency

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    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lock();
    try { notEmpty.signal(); }
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  }
```

Monitor Object POSA2 Concurrency

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  - Apply *Thread-Safe Interface* pattern
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```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public E take() ... {
    ...
```

Retrieve & remove the head of the queue, waiting if necessary until an element becomes available

Monitor Object POSA2 Concurrency

Implementation Steps

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```
public class LinkedBlockingQueue<E>
     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public E take() ... {
    E x; ...
    final AtomicInteger count =
      this.count;
    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
        notEmpty.await();
      x = dequeue(); ...
    } finally { takeLock.unlock(); }
    ...
    return x; ...
```

Monitor Object POSA2 Concurrency

Implementation Steps

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      this.count;
    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
        notEmpty.await();
      x = dequeue(); ...
    } finally { takeLock.unlock(); }
    ...
    return x; ...
```

Monitor Object POSA2 Concurrency

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     extends AbstractQueue<E>
     implements BlockingQueue<E>, ... {
  ...
  public E take() ... {
    E x; ...
    final AtomicInteger count =
      this.count;
    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
        notEmpty.await();
      x = dequeue(); ...
    } finally { takeLock.unlock(); }
    ...
    return x; ...
```

Monitor Object POSA2 Concurrency

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     implements BlockingQueue<E>, ... {
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    E x; ...
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      this.count;
    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
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      x = dequeue(); ...
    } finally { takeLock.unlock(); }
    ...
    return x; ...
```

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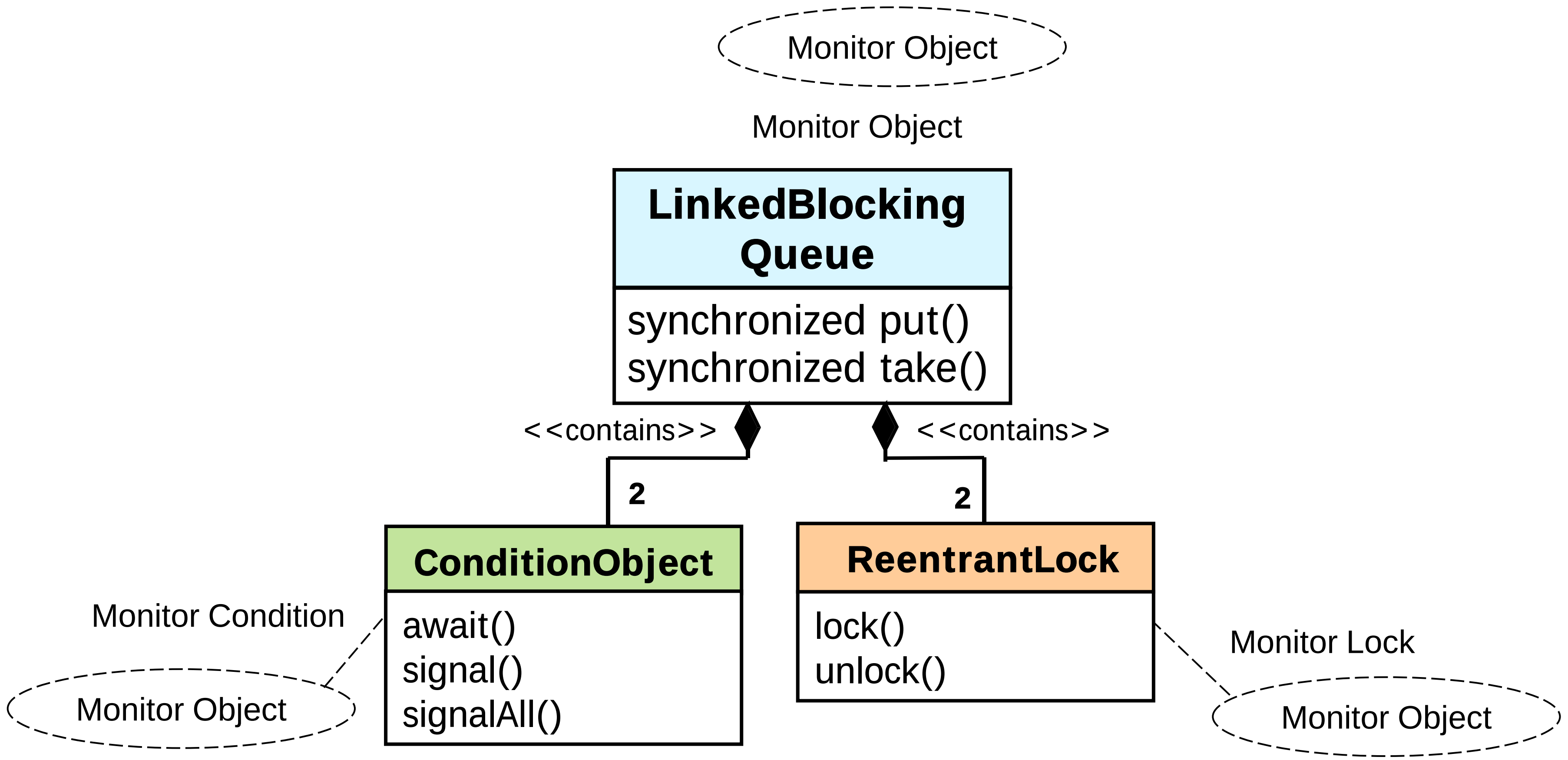
    final AtomicInteger count =
      this.count;
    final ReentrantLock takeLock =
      this.takeLock;
    takeLock.lockInterruptibly();
    try {
      while (count.get() == 0)
        notEmpty.await();
      x = dequeue(); ...
    } finally { takeLock.unlock(); }
    ...
    return x; ...
```

Applying Monitor Object in Android

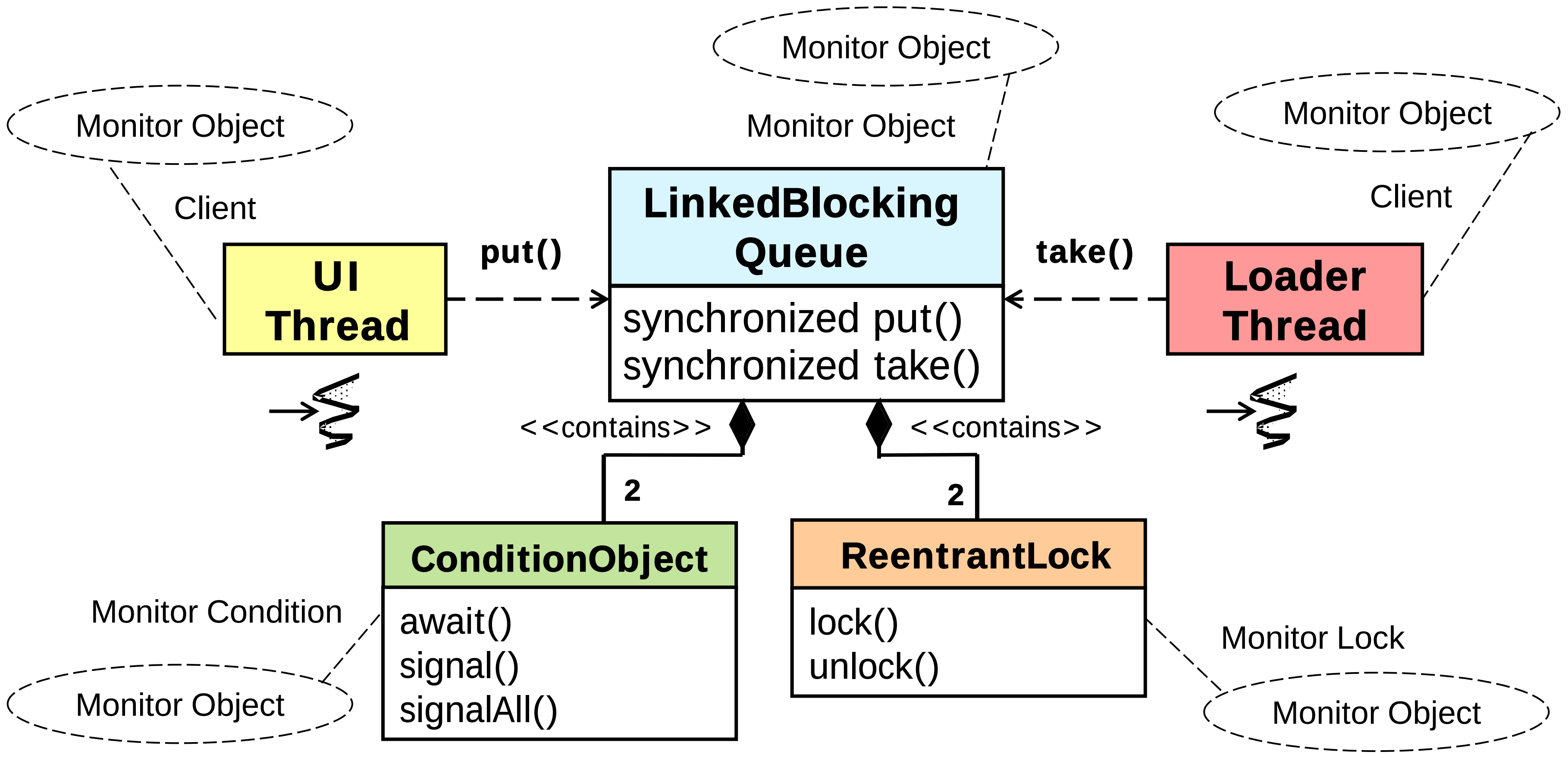
Monitor Object POSA2 Concurrency

Applying Monitor Object in Android



Monitor Object POSA2 Concurrency

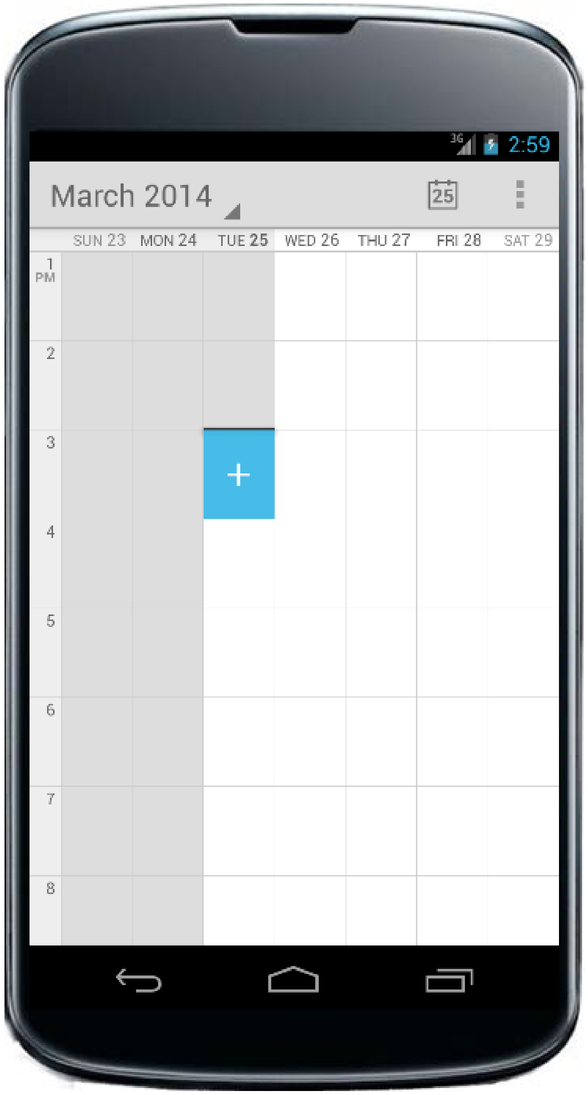
Applying Monitor Object in Android



Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device

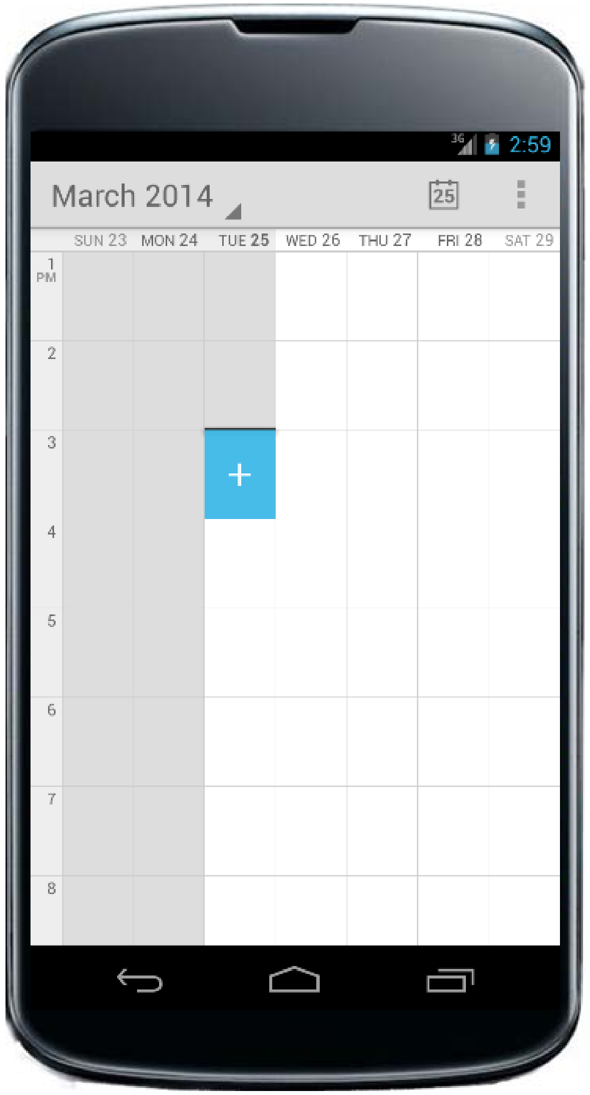


See packages/apps/Calendar for the Calendar application source code

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
  - e.g., it displays, creates, edits, & deletes calendar events



See packages/apps/Calendar for the Calendar application source code

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue

```
public class EventLoader {
  ...
  private LinkedBlockingQueue
    <LoadRequest> mLoaderQueue;

  public EventLoader(...) {
    ...
    mLoaderQueue = new
      LinkedBlockingQueue
        <LoadRequest>();
    ...
```

See packages/apps/Calendar/src/com/android/calendar/EventLoader.java

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

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Monitor Object POSA2 Concurrency

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See packages/apps/Calendar/src/com/android/calendar/EventLoader.java

Monitor Object POSA2 Concurrency

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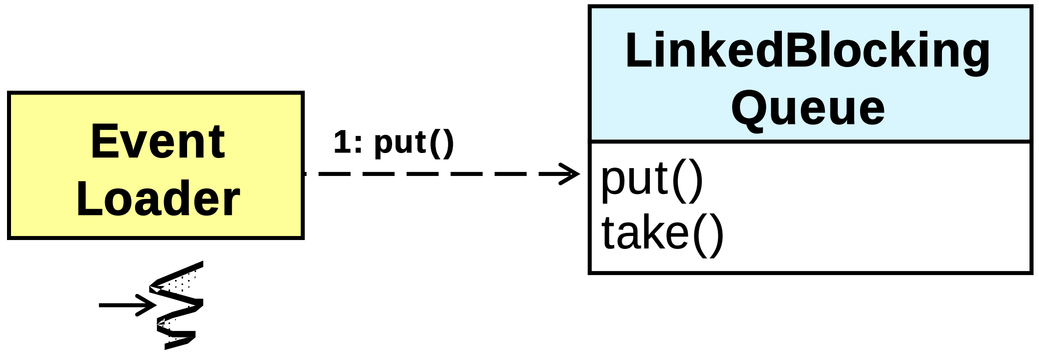
- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue

```
public class EventLoader {
  ...
  private LinkedBlockingQueue
    <LoadRequest> mLoaderQueue;
```

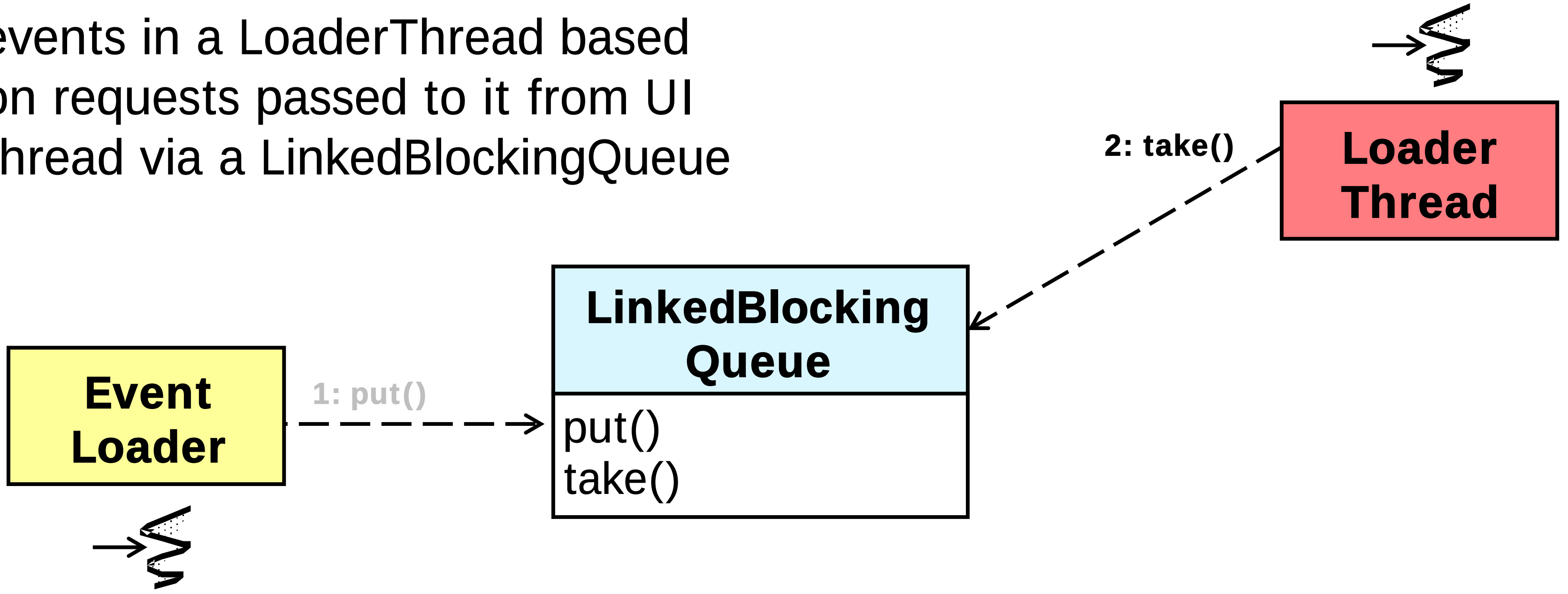


Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue

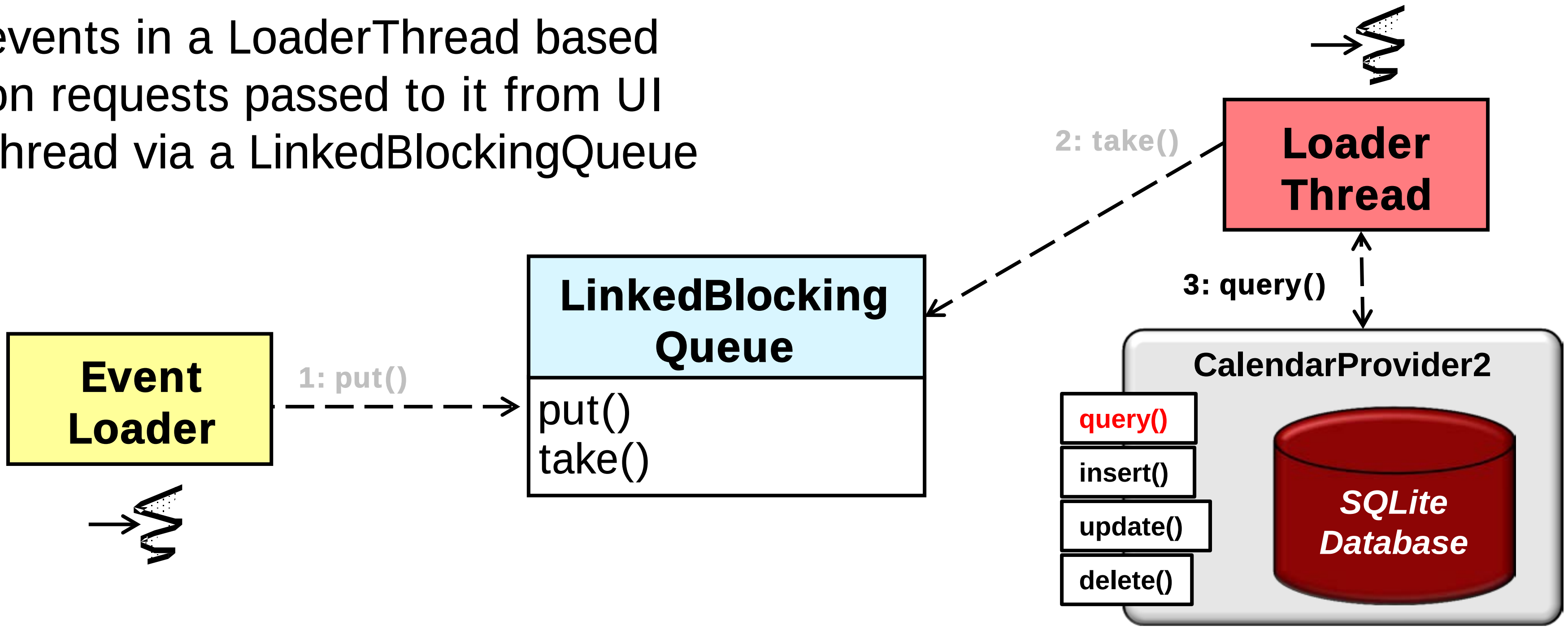
```
public class EventLoader {
  ...
  private LinkedBlockingQueue
    <LoadRequest> mLoaderQueue;
```



Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue

```
public class EventLoader {
  ...
  private LinkedBlockingQueue
    <LoadRequest> mLoaderQueue;
```



developer.android.com/guide/topics/providers/calendar-provider.html has more

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue

```
public class EventLoader {
  ...
  public void
    startBackgroundThread(){
      mLoaderThread =
        new LoaderThread
         (mLoaderQueue, this);
      mLoaderThread.start();
  ...
```

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue
- The loadEventsInBackground() method sends a load request to the LoaderThread via queue put()

```
public class EventLoader {
  ...
  public void
    loadEventsInBackground(...){
    ...
    LoadEventsRequest request =
      new LoadEventsRequest(...);
    ...
    mLoaderQueue.put(request);
    ...
```

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

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    ...
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Monitor Object POSA2 Concurrency

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- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue
- The loadEventsInBackground() method sends a load request to the LoaderThread via queue put()
- LoaderThread run() blocks on queue take() waiting for new requests

```
public class EventLoader {
  ...
  private static class
    LoaderThread extends Thread {
    LinkedBlockingQueue
      <LoadRequest> mQueue;
    ...
    public void run() {
      while (true) {
        ...
        LoadRequest request =
          mQueue.take();

        ...
        request.processRequest
          (...);
```

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue
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      <LoadRequest> mQueue;
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        ...
        request.processRequest
          (...);
```

Applying Monitor Object in Android

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- The loadEventsInBackground() method sends a load request to the LoaderThread via queue put()
- LoaderThread run() blocks on queue take() waiting for new requests
  - It processes these requests by querying the Calendar Provider

```
public class EventLoader {
  ...
  private static class
    LoaderThread extends Thread {
    LinkedBlockingQueue
      <LoadRequest> mQueue;
    ...
    public void run() {
      while (true) {
        ...
        LoadRequest request =
          mQueue.take();

        ...
        request.processRequest
          (...);
```

Monitor Object POSA2 Concurrency

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- LoaderThread run() blocks on queue take() waiting for new requests
  - It processes these requests by querying the Calendar Provider

```
public class EventLoader {
  ...
  private static class
    LoadEventsRequest ... {
    ...
    public void processRequest
      (EventLoader eventLoader) {
      Event.loadEvents(...);
      ...
```

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

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```
public class EventLoader {
  ...
  private static class
    LoadEventsRequest ... {
    ...
    public void processRequest
      (EventLoader eventLoader) {
      Event.loadEvents(...);
      ...
```

These long-running queries run in the background thread

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue
- The loadEventsInBackground() method sends a load request to the LoaderThread via queue put()
- LoaderThread run() blocks on queue take() waiting for new requests
- processRequest() posts a callback to the UI thread

```
public class EventLoader {
  ...
  private static class
    LoadEventsRequest ... {
    ...
    public void processRequest
      (EventLoader eventLoader) {
      Event.loadEvents(...);
      ...
      eventLoader.mHandler.
        post(successCallback);
      ...
```

See upcoming module on "Android Concurrency Frameworks"

Monitor Object POSA2 Concurrency

Applying Monitor Object in Android

- Android's Calendar application manages events from each account synchronized with a device
- EventLoader loads calendar events in a LoaderThread based on requests passed to it from UI thread via a LinkedBlockingQueue
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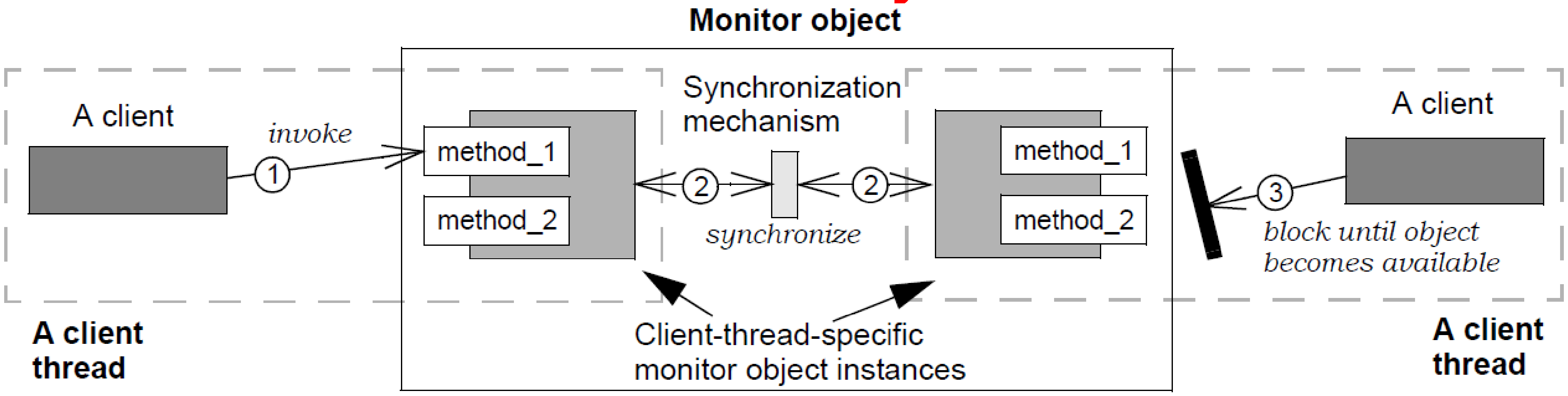
- processRequest() posts a callback to the UI thread

```
public class EventLoader {
  ...
  private static class
    LoadEventsRequest ... {
    ...
    public void processRequest
      (EventLoader eventLoader) {
      Event.loadEvents(...);
      ...
      eventLoader.mHandler.
        post(successCallback);
      ...
```

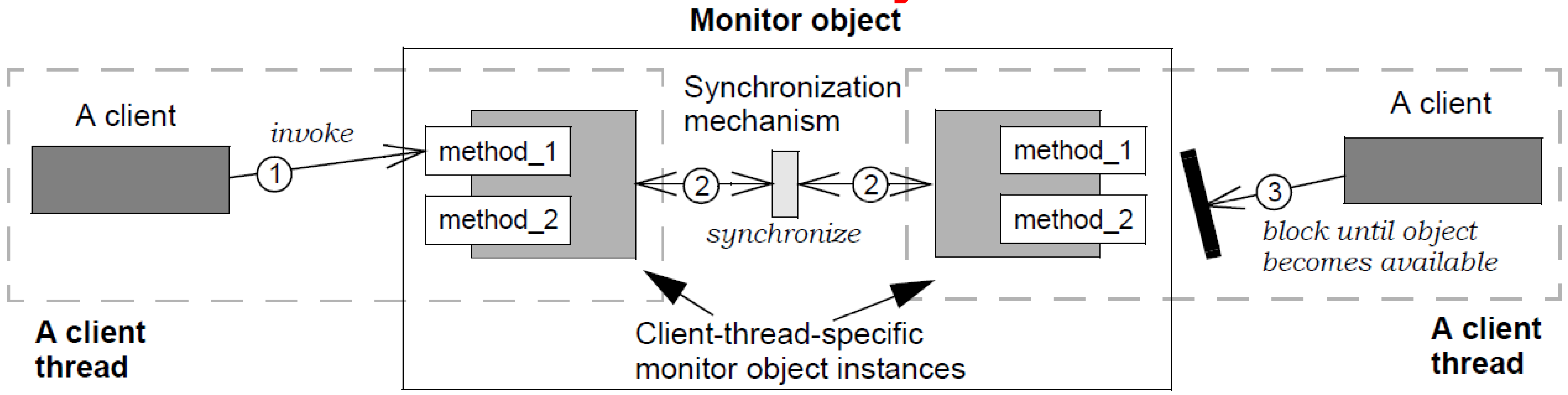
Summary

Summary

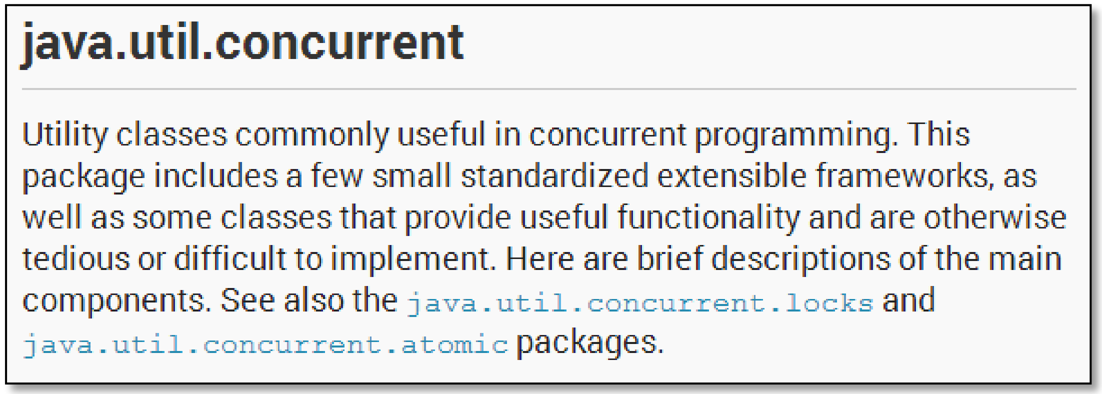


- Android applies *Monitor Object* to many class libraries & frameworks accessed concurrently by multiple threads

Summary



- Android applies *Monitor Object* to many class libraries & frameworks accessed concurrently by multiple threads
  - e.g., AsyncTask, *BlockingQueue, LinkedBlockingDeque, *ThreadPoolExecutor, etc.

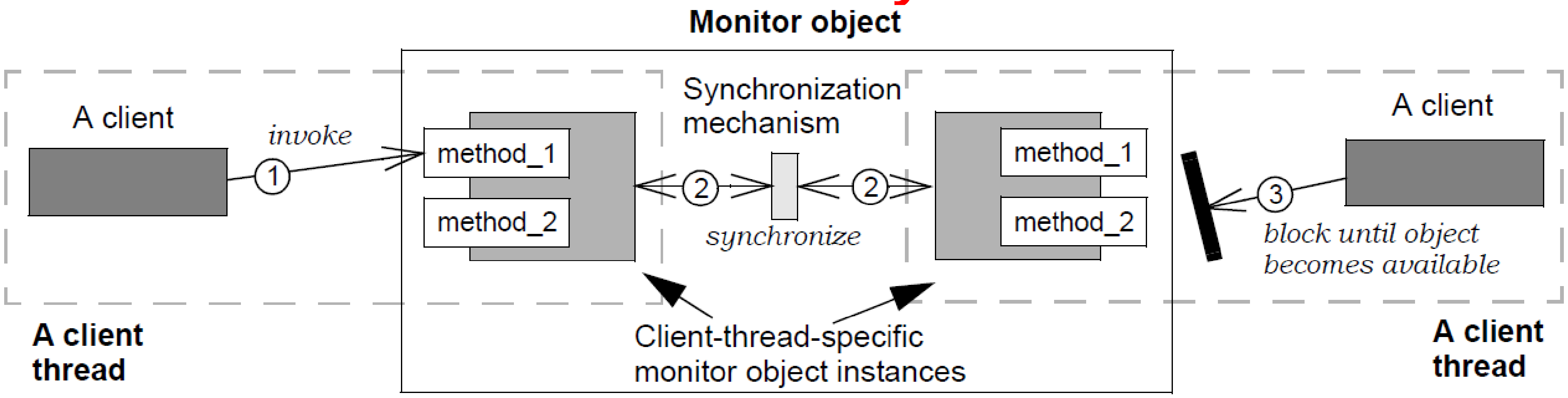


java.util.concurrent

Utility classes commonly useful in concurrent programming. This package includes a few small standardized extensible frameworks, as well as some classes that provide useful functionality and are otherwise tedious or difficult to implement. Here are brief descriptions of the main components. See also the `java.util.concurrent.locks` and `java.util.concurrent.atomic` packages.

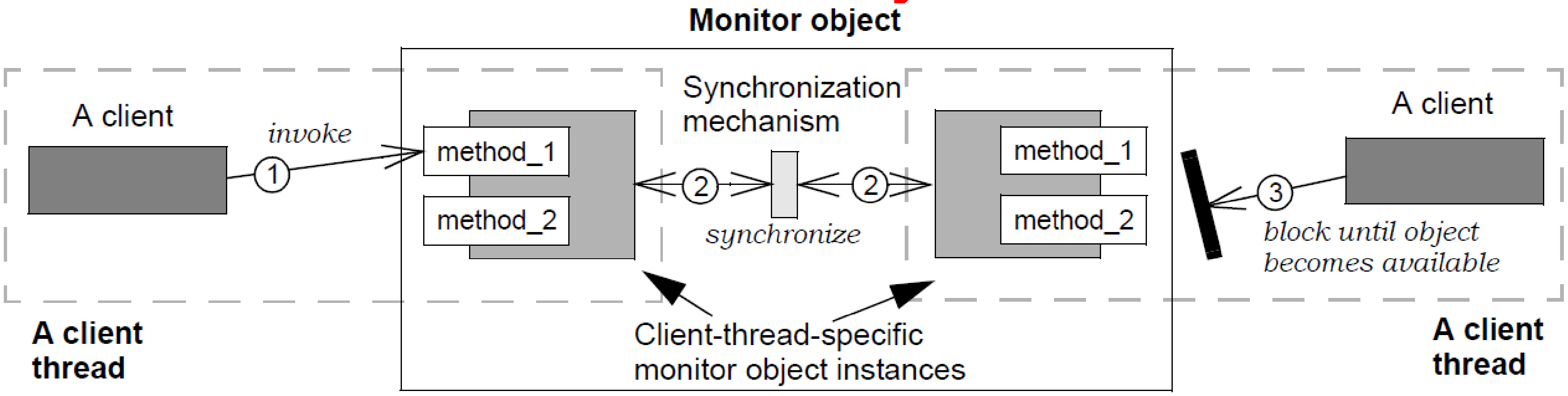
developer.android.com/reference/java/util/concurrent/package-summary.html

Summary



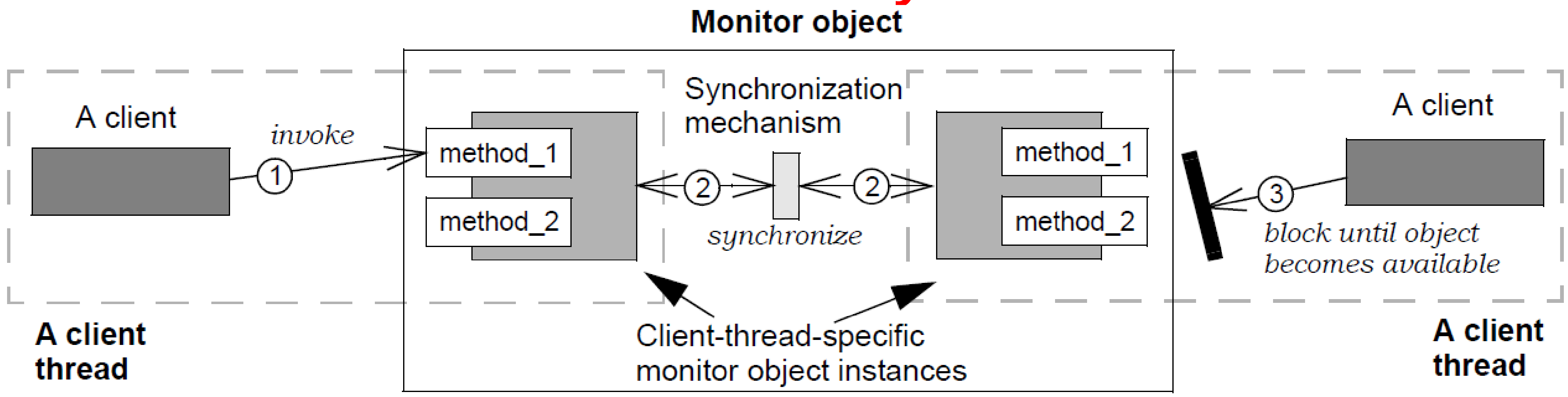
- Android applies *Monitor Object* to many class libraries & frameworks accessed concurrently by multiple threads
- Android's monitor objects use java.util.concurrent classes more than Java's built-in monitor objects

Summary



- Android applies *Monitor Object* to many class libraries & frameworks accessed concurrently by multiple threads
- Android's monitor objects use java.util.concurrent classes more than Java's built-in monitor objects
  - java.util.concurrent provides greater flexibility & capabilities

Summary



- Android applies *Monitor Object* to many class libraries & frameworks accessed concurrently by multiple threads
- Android's monitor objects use java.util.concurrent classes more than Java's built-in monitor objects
- The *Monitor Object* pattern guides these Android components