Synchronizer

Synchronizer

1. Mutex (Covered)
2. SpinLock (Today)
3. Semaphore (Today)
4. Barrier (Today)

...

SpinLock vs Mutex

SpinLock is similar to Mutex
- But Spinlock keeps spinning to get the lock (use CPU cycles)
- Mutex paused and awaken when lock is available

Modern Implementation: Hybrid

Semaphore

Invented by Dutch computer scientist Edsger Dijkstra in 1962 or 1963

You can sit wherever you wants

Functionality

Keeps track a set of virtual permits or tokens

- `acquire` gets a permit
- `release` returns a permit

-> Counting Semaphore

-> Allows number of concurrent executions

Acquire

- Waits until a token available and takes it
- Other names: `wait`, `P`

wait: If the value of semaphore variable is not negative, decrements it by 1. Otherwise, the process executing wait is blocked (i.e., added to the semaphore's queue) until the value is greater or equal to 1. Wikipedia)

Release

- Puts token back, can release "blocking acquirer"
- Other names: `signal`, `V`

signal: Increments the value of semaphore variable by 1. After the increment, if the pre-increment value was negative (meaning there are processes waiting for a resource), it transfers a blocked process from the semaphore's waiting queue to the ready queue. Wikipedia)

P & V

P = Probeer ('Try')

V = Verhoog ('Increment', 'Increase by one').

Origins of P( ) and V( )

Linus Torvalds on semaphores

A Binary Semaphore is a Mutex

Except special properties

Wait() pattern

```
synchronized (obj) {
    while (<condition does not hold>)
        obj.wait();
    // Perform action appropriate to condition
}
```

Implementation Skeleton

```
public class Semaphore {
    private int permits;

    public Semaphore(int permits){
        this.permits = permits;
    }

    public void acquire() {

    }

    public void release() {

    }
}
```

Acquire Requirements

- Thread-safe
- Waits until a permit be available

Acquire Impl

```
public synchronized void acquire() {
    while(permits <= 0) {
        try {
            wait();
        } catch(InterruptedException e){}
    }
    --permit;
}
```

Release requirements

- Thread-safe
- Returns a permit
- Notify to one of waiting acquirers

Release Impl

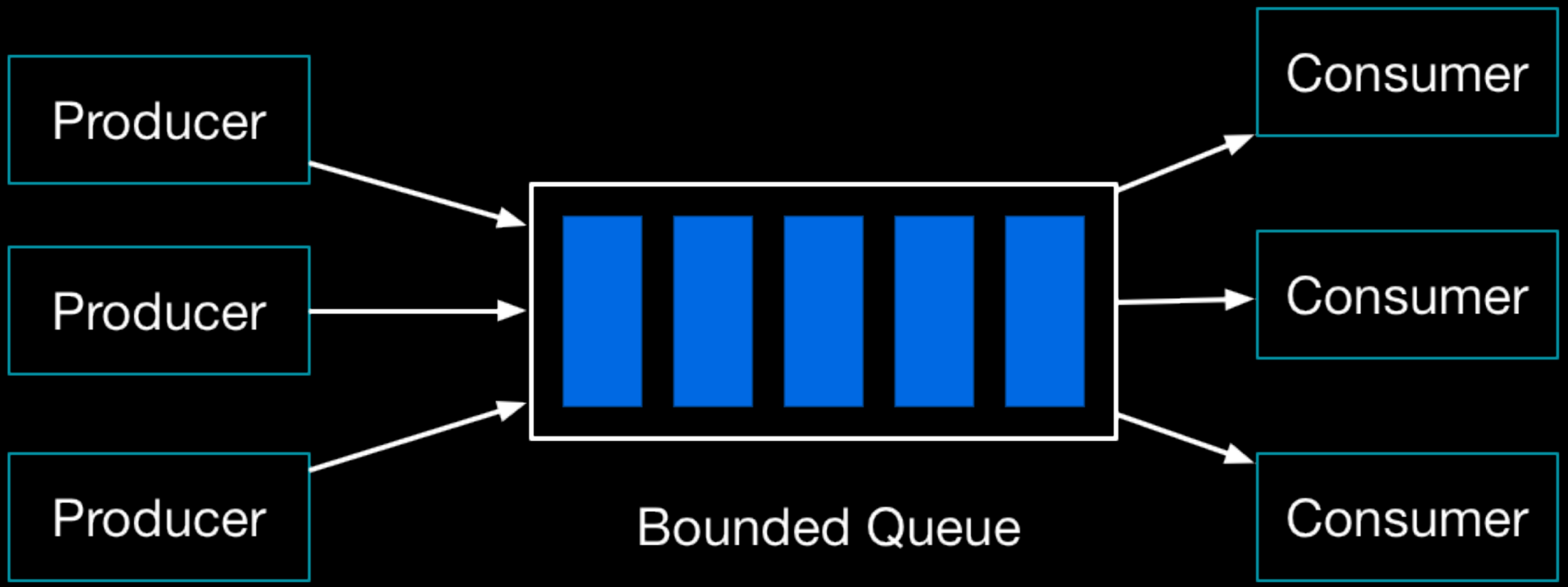
```
public synchronized void acquire() {
        ++permits;
        if(permits <= 1){
            notify();
        }
    }
```

```java
public class Semaphore {
    private int permits;

    public Semaphore(int permits){
        this.permits = permits;
    }

    public synchronized void acquire() {
        while(permits <= 0) {
            try {
                wait();
            } catch(InterruptedException e){ }
        }
        --permit;
    }

    public synchronized void acquire() {
        ++permits;
        if(permits <= 1){
            notify();
        }
    }
}
```

JDK Implementation

java.util.concurrent.Semaphore

Consumer-Producer



```
import java.util.concurrent.Semaphore;

class BoundedQueue<E> {
  private final Queue<E> elements = new LinkedList<E>()

  public BoundedQueue(int size) {

  }

  public synchronized void put(E e) {

  }

  public synchronized E take() {

  }
}
```

Initialization

```
import java.util.concurrent.Semaphore;

class BoundedQueue<E> {
  //Indicates number of empty slots
  private final Semaphore emptyCount;
  //Indicates number of filled slots
  private final Semaphore filledCount;

  public BoundedQueue(int size) {
    emptyCount = new Semaphore(size);
    filledCount = new Semaphore(0);
  }
}
```

Substitution

- `Acquire | Wait =>` means decrease
- `Release | Signal =>` means increase

Put Operation

1. Acquires an empty slot
2. Put element
3. Increase filled slots

```
class BoundedQueue<E> {
    public void put(E e) {
        emptyCount.acquire();
        synchronized(this) {
            elements.add(e);
        }
        filledCount.release();
    }
}
```

Take Operation

1. Acquire a filled slot
2. Take element
3. Increase empty slots

```
class BoundedQueue<E> {
  public E take() {
    filledCount.acquire();
    synchronized(this) {
        E e = elements.remove();
    }
    emptyCount.release();
    return e;
  }
}
```

```java
import java.util.concurrent.Semaphore;
import java.util.LinkedList;
import java.util.Queue;

class BoundedQueue<E> {
  private final Queue<E> elements = new LinkedList<E>();
  private final Semaphore emptyCount;
  private final Semaphore filledCount;

  public BoundedQueue(int size) throws InterruptedException {
    emptyCount = new Semaphore(size);
    filledCount = new Semaphore(0);
  }

  public void put(E e) throws InterruptedException {
    emptyCount.acquire();
    synchronized(this){
        elements.add(e);
    }
    filledCount.release();
  }

  public E take() throws InterruptedException {
    final E e;
    filledCount.acquire();
    synchronized(this){
      e = elements.remove();
    }
    emptyCount.release();
    return e;
  }
}
```

Revisited

- Semaphore allows # of concurrent executions
- Count indicates # of tokens or permits
- `Acquire|Wait` to take a permit
- `Release|Signal` to return a permit
- Mutex is a Semaphore with # of permits = 1
- Semaphore is not limited to the number of permits it was created with

Barrier

Group of executions must come together at a barrier point in order to proceeded

Example:

"Everyone meet at University at 7:00; once you get there, stay there until **all team members shows up**, and then we'll figure out what we're doing next."

JDK CyclicBarrier

java.util.concurrent.CyclicBarrier

`await()`: Waits until all parties have invoked await on this barrier.

```
class Solver {
final int N;
final float[][] data;
final CyclicBarrier barrier;

class Worker implements Runnable {
 int myRow;
 Worker(int row) { myRow = row; }
 public void run() {
   while (!done()) {
     processRow(myRow);

     try {
       barrier.await();
     } catch (InterruptedException ex) {
       return;
     } catch (BrokenBarrierException ex) {
       return;
     }
   }
 }
}

public Solver(float[][] matrix) {
 data = matrix;
 N = matrix.length;
 barrier = new CyclicBarrier(N,
                             new Runnable() {
                               public void run() {
                                 mergeRows(...);
                               }
                             });
 for (int i = 0; i < N; ++i)
   new Thread(new Worker(i)).start();

 waitUntilDone();
}
}
```

Cellular Automata

Game of Life

- Elements must be updated iteration by iteration
- All elements must be updated in iteration N before processing N+1

Solution

- Parition elements to groups
- Execute groups concurrently
- `await` at barrier then starts new iteration

```java
public class Barrier {
    private int elements;

    public Barrier(int elements) {
        this.elements = elements;
    }

    public synchronized void await() throws InterruptedException{
        --elements;
        if(elements == 0) {
            notifyAll();
        }else {
            while(elements > 0)
             wait();
        }
    }
}
```

Course Resources

1. Semaphore Implementation
2. Producer and Consumer