CS 580 Client-Server Programming
Spring Semester, 2009
Doc 7 Threads & Server Types
16 Feb, 2009

References

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The Java Programming Language, 2nd Ed. Arnold & Gosling, Addison-Wesley, 1998

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Java 1.5.0 on-line documentation

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Programming Ruby, 2nd Ed, Thomas

Internetworking with TCP/IP, BSD Socket Version Vol. 3, Comer, Stevens, Prentice-Hall, 1993

Interrupt

The following program does not end
The interrupt just sets the interrupt flag!

```
public class NoInterruptThread extends Thread {
        public void run() {
                while ( true) {
                        System.out.println(  "From: " + getName()  );
                }
        }

        public static void main(String args[]) throws InterruptedException{
                NoInterruptThread focused  = new NoInterruptThread( );
                focused.setPriority( 2 );
                focused.start();
                Thread.currentThread().sleep( 5 ); // Let other thread run
                focused.interrupt();
                System.out.println( "End of main");
        }
}
```

Output

```
From: Thread-0        (repeated many times)
End of main
From: Thread-0        (repeated until program is killed)
```

Using Thread.interrupted

```
public class RepeatableNiceThread extends Thread {
	public void run() {
		while ( true ) {
			while ( !Thread.interrupted() )
				System.out.println(  "From: " + getName()  );

			System.out.println( "Clean up operations" );
		}
	}

	public static void main(String args[]) throws InterruptedException{
		RepeatableNiceThread  missManners  =
				new RepeatableNiceThread( );
		missManners.setPriority( 2 );
		missManners.start();
		Thread.currentThread().sleep( 5 );
		missManners.interrupt();
	}
}
```

Output

```
From: Thread-0
Clean up operations
From: Thread-0
From: Thread-0 (repeated)
```

Interrupt and sleep, join & wait

```
public class  NiceThread  extends Thread {
        public void run() {
                try {
                        System.out.println( "Thread started");
                        while ( !isInterrupted() ) {
                                sleep( 5 );
                                System.out.println(  "From: " + getName()  );
                        }
                        System.out.println( "Clean up operations" );
                } catch ( InterruptedException interrupted ) {
                        System.out.println( "In catch" );
                }
        }

        public static void main( String args[] )  {
                NiceThread  missManners  = new NiceThread( );
                missManners.setPriority( 6 );
                missManners.start();
                missManners.interrupt();
        }
}
```

Output

```
Thread started
From: Thread-0
From: Thread-0
In catch
```

Java interrupt ()

Sent to a thread to interrupt it

If thread is blocked on a call to wait, join or sleep

- InterruptedException is thrown &
- The interrupted status flag is cleared

if the thread is blocked on I/O operation on an interruptible channel (NIO)

- ClosedByInterruptException is thrown
- The interrupted status flag is set

If the thread is blocked by a selector (NIO)

- Interrupt status is set
- The thread returns from the selector call as normal

If none of the other conditions hold then the thread’s interrupt status is set

Details

If thread is blocked on a call to wait, join or sleep

- InterruptedException is thrown &
- The interrupted status flag is cleared

if the thread is blocked on I/O operation on an interruptible channel (NIO)

- ClosedByInterruptException is thrown
- The interrupted status flag is set

If the thread is blocked by a selector (NIO)

- Interrupt status is set
- The thread returns from the selector call as normal

If none of the other conditions hold then the thread’s interrupt status is set

Interrupt and Pre JDK 1.4 NIO operations

If a thread is blocked on a read/write to a:

Stream
Reader/Writer
Pre-JDK 1.4 style socket read/write

The interrupt does not interrupt the read/write operation!

The threads interrupt flag is set

Until the IO is complete the interrupt has no effect

This is one motivation for the NIO package

Safety - Mutual Access

Java Safety - Synchronize

A call to a synchronized method locks the object

Object remains locked until synchronized method is done

Any other thread's call to any synchronized method on the same object

will block until the object is unlocked

Java Safety - Synchronize

```
class SynchronizeExample {
    int[]  data;

    public String toString() {
        return "array length " + data.length + " array values " + data[0];
    }

    public synchronized void initialize( int size,  int  startValue){
        data  =  new  int[ size ];
        for  ( int  index  = 0; index < size;  index++ )
            data[ index ]  =  (int ) Math.sin( index * startValue );
    }

    public  void unSafeSetValue( int  newValue) {
        for  ( int  index  = 0; index < data.length;  index++ )
            data[ index ]  =  (int ) Math.sin( index * newValue );
    }

    public  synchronized void safeSetValue( int  newValue) {
        for  ( int  index  = 0; index < data.length;  index++ )
            data[ index ]  =  (int ) Math.sin( index * newValue );
    }
}
```

Synchronized Static Methods

Locks class

Blocks other synchronized class methods

```
class SynchronizeExample {
    int[]  data;

    public String toString() {
        return "array length " + data.length + " array values " + data[0];
    }

    public synchronized void initialize( int size,  int  startValue){
        data  =  new  int[ size ];
        for  ( int  index  = 0; index < size;  index++ )
            data[ index ]  =  (int ) Math.sin( index * startValue );
    }

    public  void unSafeSetValue( int  newValue) {
        for  ( int  index  = 0; index < data.length;  index++ )
            data[ index ]  =  (int ) Math.sin( index * newValue );
    }

    public  synchronized void safeSetValue( int  newValue) {
        for  ( int  index  = 0; index < data.length;  index++ )
            data[ index ]  =  (int ) Math.sin( index * newValue );
    }
}
```

Synchronized Statements

```
synchronized
( expression ) {
    statements
}
```

expression must evaluate to an object

That object is locked

```
class LockTest {
        public synchronized void enter() {
            System.out.println( "In enter");
        }
    }
```

```
class LockTest {
        public void enter() {
            synchronized ( this ) {
                System.out.println( "In enter");
            }
        }
    }
```

Lock for Block and Method

```
public class LockExample extends Thread {
	private Lock myLock;

	public LockExample( Lock aLock ) {
		myLock = aLock;
	}
	public void run()	{
		System.out.println( "Start run");
		myLock.enter();
		System.out.println( "End run");
	}
	public static void main( String args[] ) throws Exception {
		Lock aLock = new Lock();
		LockExample tester = new LockExample( aLock );

		synchronized ( aLock ) {
			System.out.println( "In Block");
			tester.start();
			System.out.println( "Before sleep");
			Thread.currentThread().sleep( 5000);
			System.out.println( "End Block");
		}
	}
}
```

```
class Lock {
	public synchronized void enter() {
		System.out.println( "In enter");
	}
}
```

Output

```
In Block
Start run
Before sleep
End Block
In enter
End run    (why is this at the end?)
```

Synchronized and Inheritance

```
class Top {
    public void synchronized left() {
        // do stuff
    }

    public void synchronized right() {
        // do stuff
    }
}

class Bottom extends Top {
    public void left() {
        // not synchronized
    }

    public void right() {
        // do stuff not synchronized
        super.right(); // synchronized here
        // do stuff not synchronized
    }
```

methods do not inherit synchronized

Ruby Synchronize

```
class Counter
  attr_reader :count
  def initialize
    @count = 0
    super
  end

  def tick
      @count += 1
  end
end



counter = Counter.new
tickA = Thread.new { 10000.times { counter.tick}}
tickB = Thread.new { 10000.times { counter.tick}}
tickA.join
tickB.join
puts counter.count -> 14451
```

```
require 'monitor'
class Counter < Monitor
  attr_reader :count
  def initialize
    @count = 0
    super
  end

  def tick
    synchronize do
      @count += 1
    end
  end
end

counter = Counter.new
tickA = Thread.new { 10000.times { counter.tick}}
tickB = Thread.new { 10000.times { counter.tick}}
tickA.join
tickB.join
puts counter.count -> 20000
```

Ruby Synchronize without inheritance

```
require 'monitor'

class Counter
  include MonitorMixin
  attr_reader :count
  def initialize
    @count = 0
    super
  end

  def tick
    synchronize do
      @count += 1
    end
  end
end
```

Ruby Synchronize examples from
Programming Ruby, 2nd Ed, Thomas, pp 142-144

Using Monitor directly

```
require 'monitor'

class Counter
  attr_reader :count
  def initialize
    @count = 0
    super
  end

  def tick
    @count += 1
  end
end

counter = Counter.new
lock = Monitor.new
tickA = Thread.new { 10000.times { lock.synchronize {counter.tick}}}
tickB = Thread.new { 10000.times { lock.synchronize {counter.tick}}}
tickA.join
tickB.join
puts counter.count -> 20000
```

wait and notify

public final void wait(timeout) throws InterruptedException

public final void wait(timeout, nanos) throws InterruptedException

public final void wait() throws InterruptedException

Causes a thread to wait until it is notified or the specified timeout expires.

Throws: IllegalMonitorStateException

If the current thread is not the owner of the Object's monitor.

Throws: InterruptedException

Another thread has interrupted this thread.

public final void notify()

public final void notifyAll()

Notifies threads waiting for a condition to change.

wait - How to use

The thread waiting for a condition should look like:

```
synchronized void waitingMethod()
    {
    while ( ! condition )
        wait();

    Now do what you need to do when condition is true
    }
```

Everything is executed in a synchronized method

The test condition is in loop not in an if statement

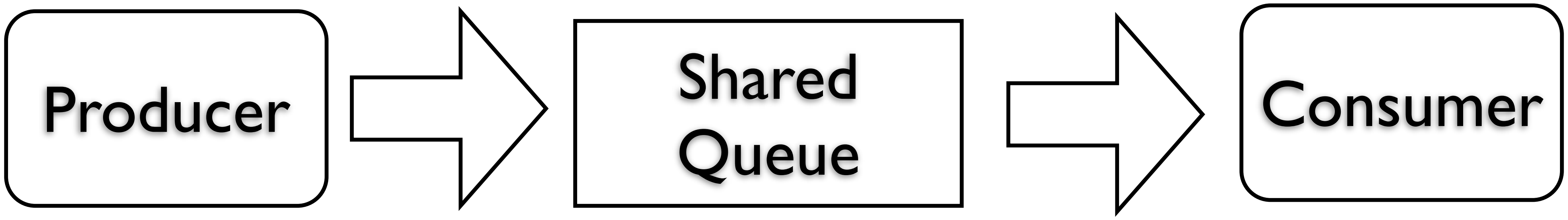
The wait suspends the thread it atomically releases the lock on the object

notify - How to Use

```
synchronized void changeMethod()
    {
    Change some value used in a condition test

    notify();
    }
```

wait and notify Example

When can Consumer read from queue?



wait and notify - Producer

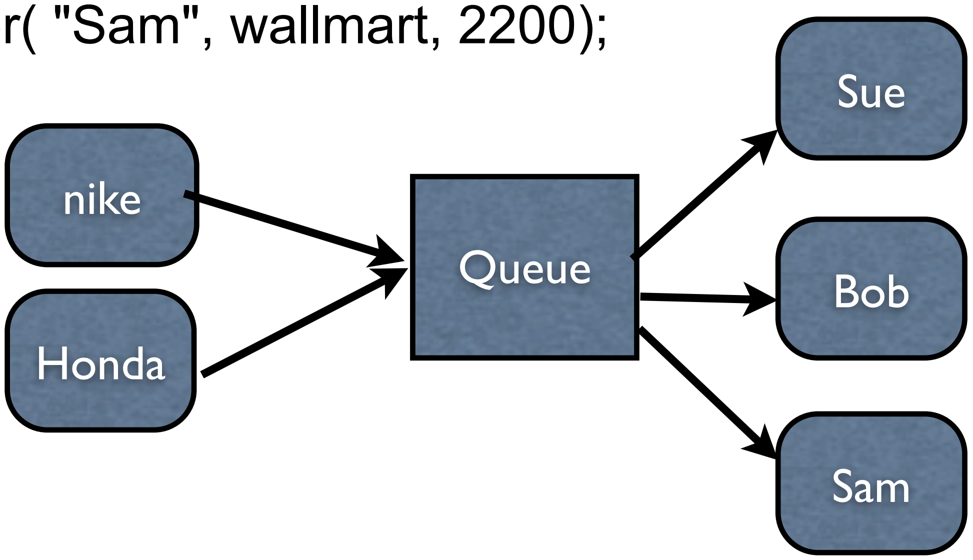
```
import java.util.concurrent.*;

public class Producer extends Thread {
    BlockingQueue<String> factory;
    int workSpeed;

    public Producer( String name, BlockingQueue<String> output, int speed ) {
        setName(name);
        factory = output;
        workSpeed = speed;
    }

    public void run() {
        try {
            int product = 0;
            while (true) {
                System.out.println( getName() + " produced " + product);
                factory.add( getName() + String.valueOf( product) );
                product++;
                sleep( workSpeed);
          }
        }
         catch ( InterruptedException workedToDeath ) {
            return;
        }
    }
}
```

wait and notify - Consumer

```
import java.util.concurrent.*;

class Consumer extends Thread {
    BlockingQueue<String> localMall;
    int sleepDuration;

    public Consumer( String name, BlockingQueue<String> input, int speed ) {
        setName(name);
        localMall = input;
        sleepDuration = speed;
    }

    public void run() {
        try {
            while (true) {
                System.out.println( getName() + " got " +  localMall.take());
                sleep( sleepDuration );
            }
        }
        catch ( InterruptedException endOfCreditCard ) {
            return;
        }
    }
}
```

wait and notify - Driver Program

```
import java.util.concurrent.*;
public class ProducerConsumerExample {
    public  static  void  main( String  args[] ) throws Exception {
        BlockingQueue<String> wallmart = new ArrayBlockingQueue(100, true);
        Producer nike = new Producer( "Nike", wallmart, 500 );
        Producer honda = new Producer( "Honda", wallmart, 1200 );
        Consumer valleyGirl = new Consumer( "Sue", wallmart, 400);
        Consumer valleyBoy = new Consumer( "Bob", wallmart, 900);
        Consumer dink = new Consumer( "Sam", wallmart, 2200);
        nike.start();
        honda.start();
        valleyGirl.start();
        valleyBoy.start();
        dink.start();
    }
}
```



Nike produced 0	Nike produced 2	Nike produced 4
Honda produced 0	Sue got Nike2	Sue got Nike4
Sue got Nike0	Honda produced 1	Honda produced
Bob got Honda0	Bob got Honda1	Bob got Honda2
Nike produced 1	Nike produced 3	Nike produced 5
Sam got Nike1	Sue got Nike3	Sue got Nike5

Java Blocking Queues

ArrayBlockingQueue
DelayQueue
LinkedBlockingQueue
PriorityBlockingQueue
SynchronousQueue

Ruby Producers & Consumers

```
require 'thread'

queue = Queue.new
consumers = (1..3).collect do |each|
  Thread.new("Consumer #{each}") do |name|
    begin
      product = queue.deq
      puts "#{name}: consumed #{product}"
      sleep(rand(0.05))
    end until product == :END_OF_WORK
  end
end

producers = (1..2).collect do |each|
  Thread.new("Producer #{each}") do |name|
    3.times do |k|
      sleep(0.1)
      queue.enq("Item #{k} from #{name}")
    end
  end
end

producers.each { |each| each.join }
consumers.size.times { queue.enq(:END_OF_WORK)}
consumers.each { |each| each.join }
```

Output

```
Consumer 1: consumed Item 0 from Producer 1
Consumer 2: consumed Item 0 from Producer 2
Consumer 3: consumed Item 1 from Producer 1
Consumer 2: consumed Item 1 from Producer 2
Consumer 3: consumed Item 2 from Producer 1
Consumer 1: consumed Item 2 from Producer 2
Consumer 1: consumed END_OF_WORK
Consumer 2: consumed END_OF_WORK
Consumer 3: consumed END_OF_WORK
```

Example from
Programming Ruby, 2nd Ed, Thomas, pp 743

Java ThreadPoolExecuter

```
import java.util.concurrent.*;

public class ThreadPoolExample extends Object
{
    public static void main(String[] args)
    {
        int corePoolSize = 2;
        int maximumPoolSize = 5;
        long keepAliveTime = 60 * 10;
        TimeUnit keepAliveUnit = TimeUnit.SECONDS;
        BlockingQueue<Runnable> surplusJobs = new LinkedBlockingQueue<Runnable>();
        ThreadPoolExecutor workers = new ThreadPoolExecutor(corePoolSize,
                maximumPoolSize, keepAliveTime, keepAliveUnit, surplusJobs);

        for (int k = 0;k< 5; k++)
            workers.execute( new SimpleThread(k + 5));
    }
}
```

Types of Servers

Connectionless(UDP) verse Connection-Oriented (TCP)

Iterative verses Concurrent

Stateless verse stateful

Iterative verses Concurrent Server

Iterative

Single process

Handles requests one at a time

Good for low volume & requests that are answered quickly

Iterative verses Concurrent Server

Concurrent

Handle multiple requests concurrently

Normally uses thread/processes

Needed for high volume & complex requests

Harder to implement than iterative

Must deal with currency

Sample Concurrent Server

```
require 'socket'
class DateServer
  def initialize(port)
    @port = port
  end

  def run()
    server = TCPServer.new( @port)
    puts("start " + @port.to_s)
    while (session = server.accept)
      Thread.new(session) do |connection|
        process_request_on(connection)
        connection.close
      end
    end
  end
```

```
def process_request_on(socket)
    request = canonical_form( socket.gets("\n") )
    now = Time.now
    answer = case request
      when 'time'
        now.strftime("%X")
      when 'date'
        now.strftime("%x")
      else
        "Invalid request"
    end
    socket.send(answer + "\n",0)
  end

  def canonical_form(string)
    string.lstrip.rstrip.downcase
  end
end
```

Can you spot the problem?

Single Thread Concurrent Server

One can implement a concurrent server using one thread/process

```
while (true) {
    check if any new connects (non-block accept)
    if new connection accept
    process a little on each current request
}
```

Stateless verses Stateful Servers

State information

Information maintained by server about ongoing interactions with clients

Consumes server resources

How long does one maintain the state?

Modes of Operation

Stateful servers sometimes have different modes of operation

Each mode has a set of legal commands

In Login mode only the commands password & username are acceptable

After successful login client-server connection in transaction mode

In transaction mode command X, Y Z are legal

These modes are also called server states or just states