SLIIT
Discover Your Future

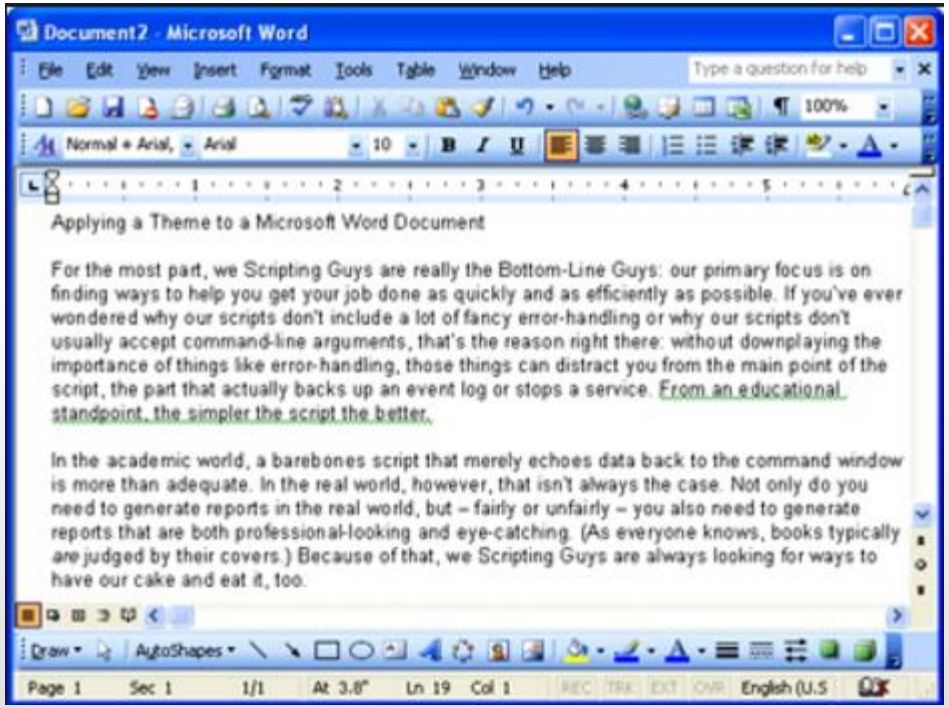
IT2030 - Object Oriented Programming

Lecture 09

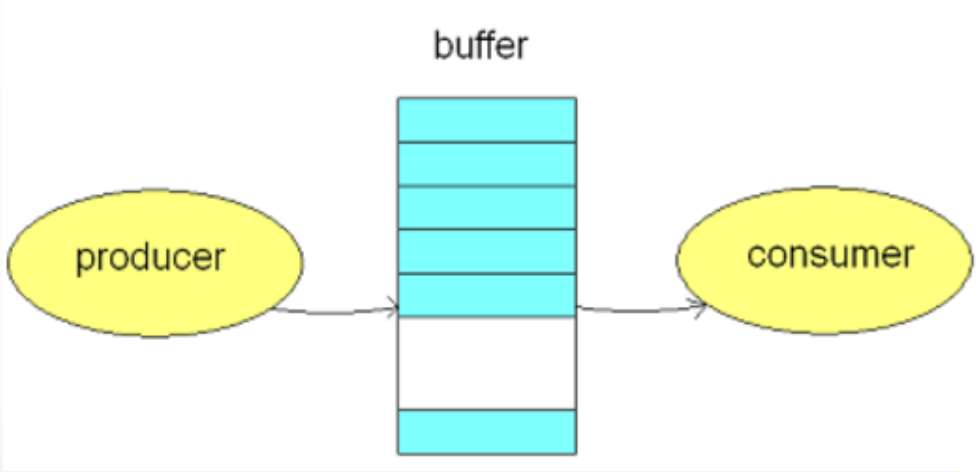
Threads

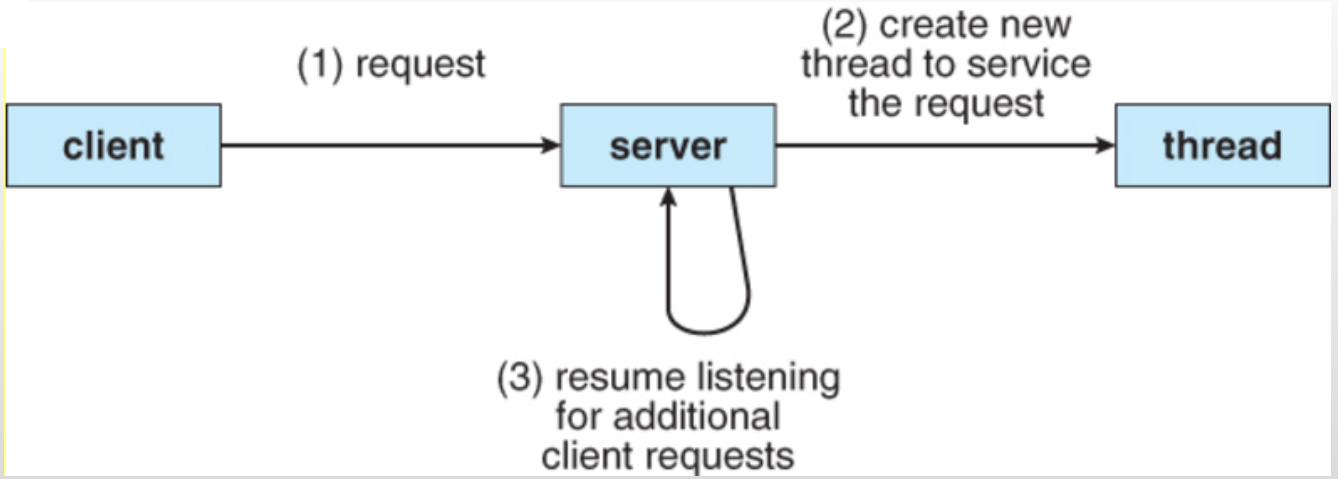
What is a Thread?

Examples:-



Other Scenarios Threads can be Applied



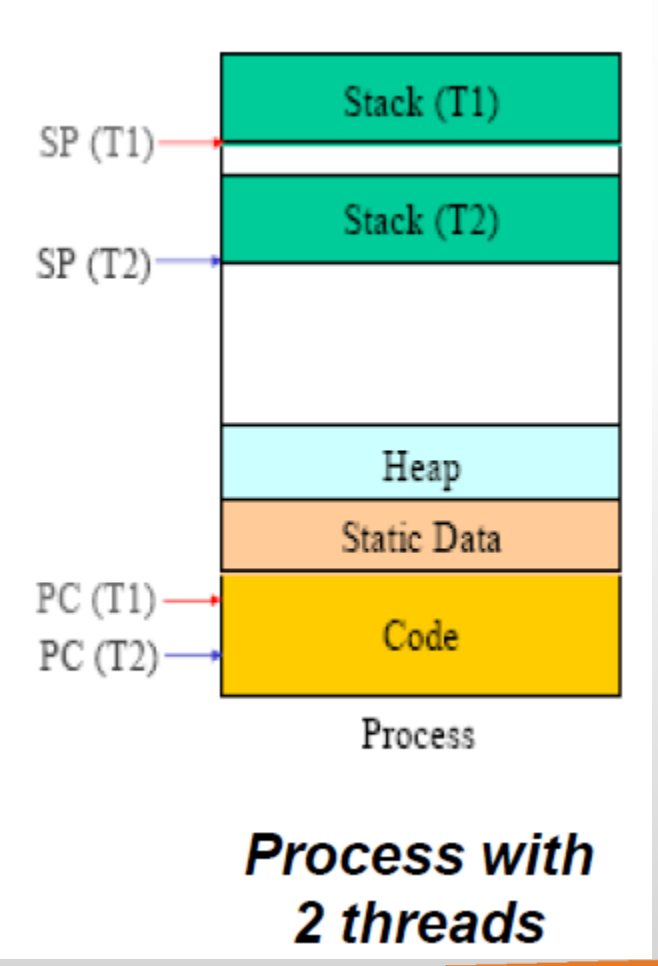


Thread Vs. Process

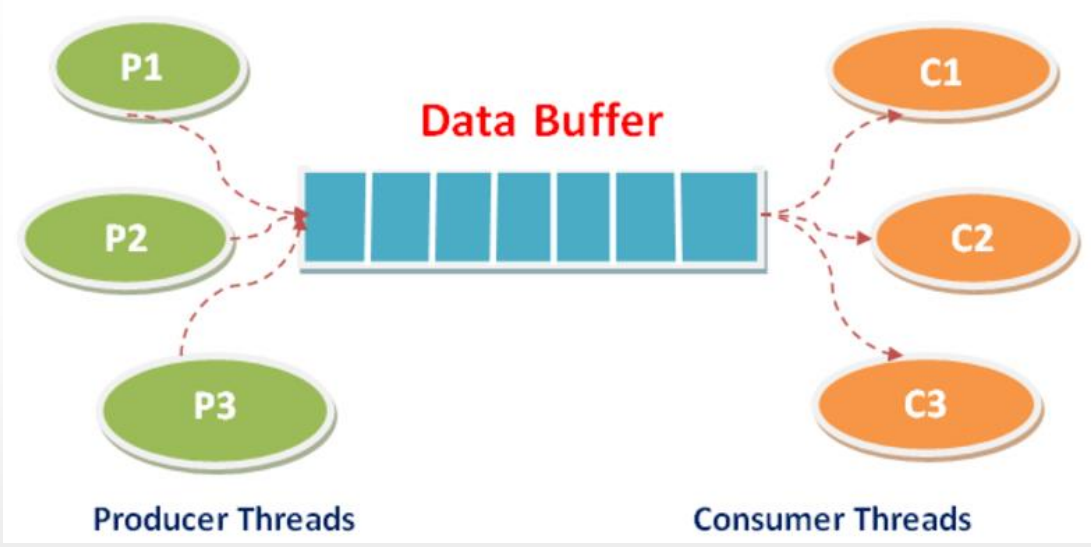
- **Threads** are easier to create than **processes** since they don't require a separate address space.
- Threads are considered lightweight because they use far less resources than processes.
- Processes are typically independent, while threads exist as subsets of a process
- Processes have separate address spaces, whereas threads share their address space
- **Context switching** between threads in the same process is typically faster than **context switching** between processes.

Thread Vs. Process

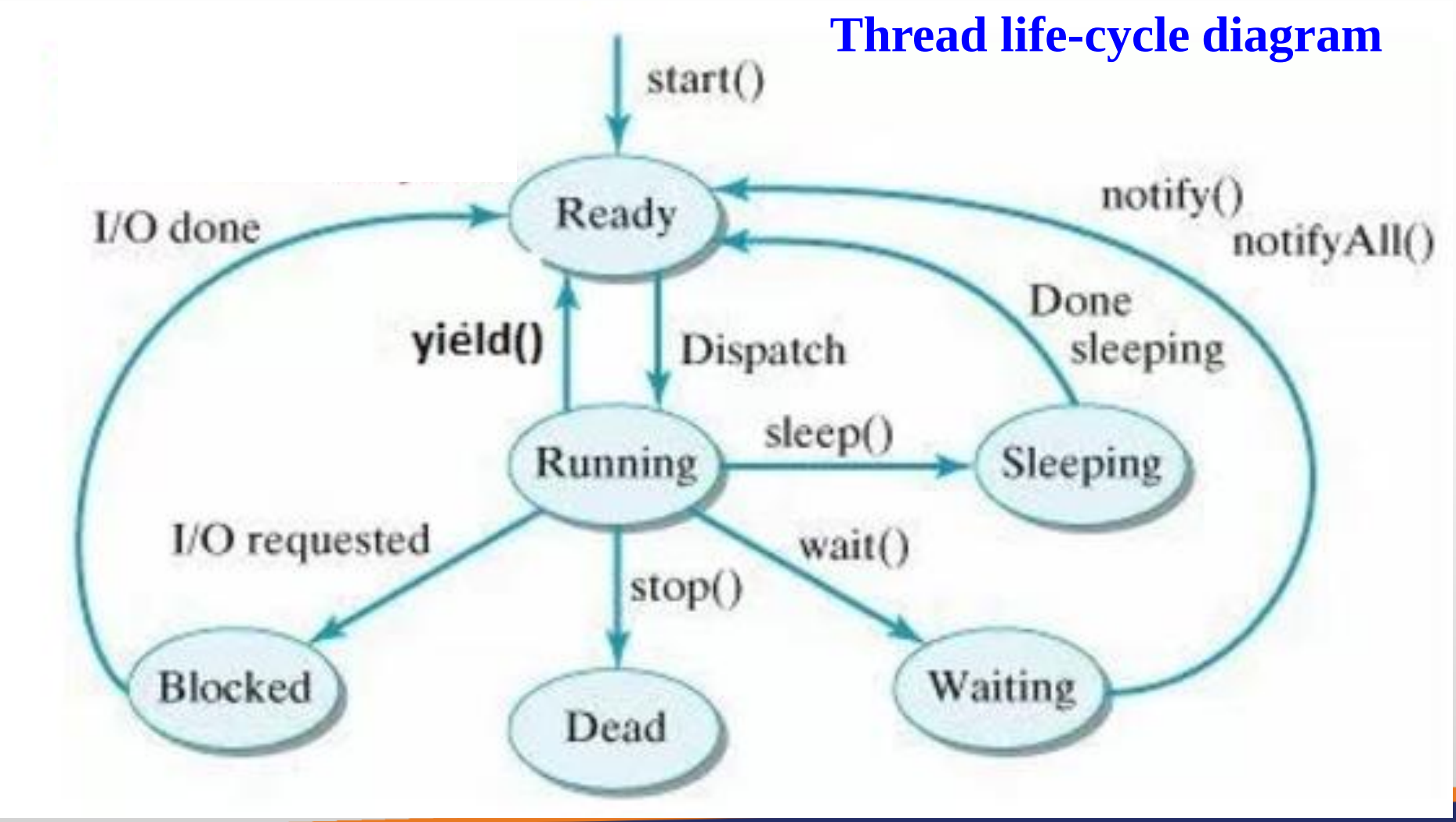
- A **Thread** in execution works with
  - thread ID
  - Registers (program counter and working register set)
  - Stack (for procedure call parameters, local variables etc.)
- A thread *shares* with other threads a process's (to which it belongs to)
  - Code section
  - Data section (static + heap)
  - Permissions
  - Other resources (e.g. files)



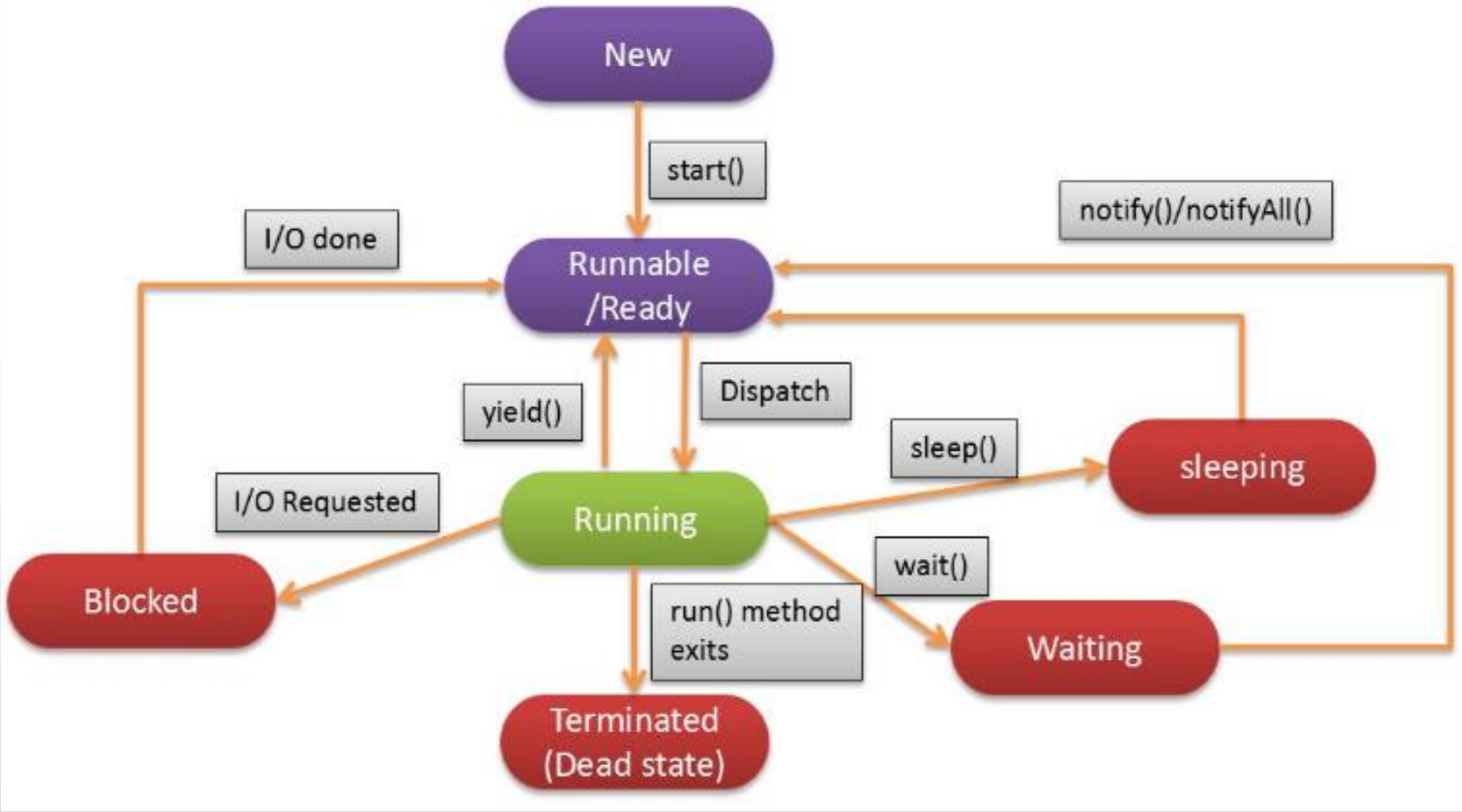
Multi-threaded Environment



Thread Life Cycle



Thread States



Thread Implementation

Extends Thread class

Test.java | ThreadImpl.java

```
public class ThreadImpl extends Thread{

    /**
     * Thread execution scenario implementation
     * @param args
     */
    public static void main(String[] args) {
        ThreadImpl threadImpl = new ThreadImpl();
        threadImpl.start();
        for (int i = 0; i < 10; i++) {
            System.out.println("Main Thread " + i);
        }

    }

    /**
     * New thread implementation
     */
    public void run(){
        for (int i = 0; i < 10; i++) {
            System.out.println("New Thread " + i);
        }
    }
}
```

Console

<terminated> ThreadIm

```
Main Thread 0
New Thread 0
Main Thread 1
New Thread 1
Main Thread 2
New Thread 2
New Thread 3
Main Thread 3
New Thread 4
Main Thread 4
New Thread 5
Main Thread 5
Main Thread 6
Main Thread 7
New Thread 6
Main Thread 8
Main Thread 9
New Thread 7
New Thread 8
New Thread 9
```

Implements Runnable Interface

Test.java | ThreadImpl.java

```
public class ThreadImpl implements Runnable{

    /**
     * Thread execution scenario implementation
     * @param args
     */
    public static void main(String[] args) {

        Thread thread = new Thread(new ThreadImpl());
        thread.start();
        for (int i = 0; i < 10; i++) {
            System.out.println("Main Thread " + i);
        }
    }

    /**
     * New thread implementation
     */
    public void run(){
        for (int i = 0; i < 10; i++) {
            System.out.println("New Thread " + i);
        }
    }
}
```

Console

<terminated> ThreadI

```
Main Thread 0
New Thread 0
Main Thread 1
New Thread 1
New Thread 2
New Thread 3
Main Thread 2
Main Thread 3
Main Thread 4
Main Thread 5
New Thread 4
Main Thread 6
Main Thread 7
Main Thread 8
Main Thread 9
New Thread 5
New Thread 6
New Thread 7
New Thread 8
New Thread 9
```

Thread Synchronization

Threads are not synchronized

est.java | ThreadImpl.java | Sample.java

```
/**
 * Sample Implementation using Threads
 * @author Udara
 */
class Sample {

    public void displayOutput(Sample sample) {

        try {
            for (int i = 0; i < 10; i++) {
                Thread.sleep(1000);
                System.out.println(Thread.currentThread().getName());
            }
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
}
```

- When Thread sleeps it throws InterruptedException
- When Thread sleep it keeps the lock with it

Threads are not synchronized

st.java | ThreadImpl.java | Sample.java

```
public class ThreadImpl extends Thread{

    Sample sample;
    String name;
    public static final String THREAD0 = "Thread 0";
    public static final String THREAD1 = "Thread 1";

    public ThreadImpl(Sample sample, String name) {
        this.sample = sample;
        this.name = name;
    }

    /**
     * Thread execution scenario implementation
     * @param args
     */
    public static void main(String[] args) {

        Sample sample = new Sample();
        ThreadImpl threadImpl1 = new ThreadImpl(sample,THREAD0);
        ThreadImpl threadImpl2 = new ThreadImpl(sample,THREAD1);
        threadImpl1.start();
        threadImpl2.start();
    }

    /**
     * New thread implementation
     */
    public void run(){
        sample.displayOutput(sample);
    }
}
```

Console

```
<terminated> T
Thread-0
Thread-1
Thread-0
Thread-1
Thread-1
Thread-0
Thread-0
Thread-1
Thread-0
Thread-1
Thread-0
Thread-1
Thread-0
Thread-1
Thread-0
Thread-1
Thread-0
Thread-1
Thread-0
Thread-1
```

Locks

- A *lock* (also called a *monitor*) is used to synchronize access to a shared resource
- A lock can be associated with a shared resource
- Threads gain access to a shared resource by first acquiring the lock associated with the resource
- At any given time, at most one thread can hold the lock and thereby have access to the shared resource
- Only one thread at a time can access the shared resource guarded by the *object lock*

- A thread must *acquire* the object lock associated with a shared resource, before it can *enter* the shared resource.
- The runtime system ensures that no other thread can enter a shared resource if another thread already holds the object lock associated with it.
- If a thread cannot immediately acquire the object lock, it is *blocked*, i.e., it must wait for the lock to become available
- When a thread *exits* a shared resource, the runtime system ensures that the object lock is also released.
- If another thread is waiting for this object lock, it can try to acquire the lock in order to gain access to the shared resource

Thread Synchronized Method

```
/**
 * Sample Implementation using Threads
 * @author Udara
 */
class Sample {

    public synchronized void displayOutput(Sample sample) {

        try {
            for (int i = 0; i < 10; i++) {
                Thread.sleep(1000);
                System.out.println(Thread.currentThread().getName());
            }
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
}
```

Thread Synchronization

Test.java | ThreadImpl.java | Sample.java

```
public class ThreadImpl extends Thread{

    Sample sample;
    String name;
    public static final String THREAD0 = "Thread 0";
    public static final String THREAD1 = "Thread 1";

    public ThreadImpl(Sample sample, String name) {
        this.sample = sample;
        this.name = name;
    }

    /**
     * Thread execution scenario implementation
     * @param args
     */
    public static void main(String[] args) {

        Sample sample = new Sample();
        ThreadImpl threadImpl1 = new ThreadImpl(sample,THREAD0);
        ThreadImpl threadImpl2 = new ThreadImpl(sample,THREAD1);
        threadImpl1.start();
        threadImpl2.start();
    }

    /**
     * New thread implementation
     */
    public void run(){
        sample.displayOutput(sample);
    }
}
```

Console

```
<terminated>
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
```

Thread Synchronization block

```
/**
 * Sample Implementation using Threads
 * @author Udara
 *
 */
class Sample {

    public  void displayOutput(Sample sample) {

        synchronized (sample) {
            try {
                for (int i = 0; i < 10; i++) {
                    Thread.sleep(1000);
                    System.out.println(Thread.currentThread().getName());
                }
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
        }
    }
}
```

Thread Synchronization block

ThreadImpl.java | Sample.java

```
public class ThreadImpl extends Thread{

    Sample sample;
    String name;
    public static final String THREAD0 = "Thread 0";
    public static final String THREAD1 = "Thread 1";

    public ThreadImpl(Sample sample, String name) {
        this.sample = sample;
        this.name = name;
    }

    /**
     * Thread execution scenario implementation
     * @param args
     */
    public static void main(String[] args) {

        Sample sample = new Sample();
        ThreadImpl threadImpl1 = new ThreadImpl(sample,THREAD0);
        ThreadImpl threadImpl2 = new ThreadImpl(sample,THREAD1);
        threadImpl1.start();
        threadImpl2.start();
    }

    /**
     * New thread implementation
     */
    public void run(){
        sample.displayOutput(sample);
    }
}
```

Console

<terminated> T

```
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-0
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
Thread-1
```

Thread Synchronization block with lock change

est.java | ThreadImpl.java | Sample.java

```
/**
 * Sample Implementation using Threads
 * @author Udara
 */
class Sample {

    public  void displayOutput(Sample sample) {

        synchronized (new Sample()) {
            try {
                for (int i = 0; i < 10; i++) {
                    Thread.sleep(1000);
                    System.out.println(Thread.currentThread().getName());
                }
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
        }
    }
}
```

Each Thread get separate object to lock. So method not synchronized

Thread Synchronization block with lock change

est.java | ThreadImpl.java | Sample.java

```
public class ThreadImpl extends Thread{

    Sample sample;
    String name;
    public static final String THREAD0 = "Thread 0";
    public static final String THREAD1 = "Thread 1";

    public ThreadImpl(Sample sample, String name) {
        this.sample = sample;
        this.name = name;
    }

    /**
     * Thread execution scenario implementation
     * @param args
     */
    public static void main(String[] args) {

        Sample sample = new Sample();
        ThreadImpl threadImpl1 = new ThreadImpl(sample,THREAD0);
        ThreadImpl threadImpl2 = new ThreadImpl(sample,THREAD1);
        threadImpl1.start();
        threadImpl2.start();
    }

    /**
     * New thread implementation
     */
    public void run(){
        sample.displayOutput(sample);
    }
}
```

Console

```
<terminated>
Thread-1
Thread-0
Thread-1
Thread-0
Thread-0
Thread-1
Thread-1
Thread-0
Thread-1
Thread-0
Thread-0
Thread-1
Thread-0
Thread-1
Thread-1
Thread-0
Thread-1
Thread-0
Thread-1
Thread-0
```

Synchronized block importance

```
public class Singleton {

    private Singleton() {
    }

    private static Singleton instance;

    public static Singleton getInstance() {

        if (instance == null) {
            instance = new Singleton();
            System.out.println("Instance Created "
                    + Thread.currentThread().getName());
        }
        return instance;
    }
}
```

```
public class ThreadSafeSingleton {

    private ThreadSafeSingleton() {
    }

    private static ThreadSafeSingleton instance;

    public static ThreadSafeSingleton getInstance() {

        if (instance == null) {
            synchronized (ThreadSafeSingleton.class) {
                if (instance == null) {
                    instance = new ThreadSafeSingleton();
                    System.out.println("Thread Safe Instance created "
                            + Thread.currentThread().getName());
                }
            }
        }
        return instance;
    }
}
```

SingletonTest.java | Test.java | ThreadImpl.java | Sample.java

```
public class SingletonTest implements Runnable{

    /**
     * @param args
     */
    public static void main(String[] args) {

        new Thread(new SingletonTest()).start();

        for (int i = 0; i < 10; i++) {
            Singleton.getInstance();
            ThreadSafeSingleton.getInstance();
        }
    }

    public void run(){
        for (int i = 0; i < 10; i++) {
            Singleton.getInstance();
            ThreadSafeSingleton.getInstance();
        }
    }
}
```

Console

```
<terminated> SingletonTest [Java Application] C:\Program Files\Java\jre7\bin\
Instance Created Thread-0
Instance Created main
Thread Safe Instance created Thread-0
```

Thread Join method

- The join() method waits for a thread to die.
- It causes the currently running threads to stop executing until the thread it joins with completes its task.
- This **method** waits until the **thread** on which it is called terminates.

ThreadJoin.java

```
public class ThreadJoin extends Thread{

    public void run() {
        Thread t = Thread.currentThread();
        System.out.println("Started executing " + t.getName());

        for (int i = 0; i < 10; i++) {
            System.out.println(t.getName() + i);
        }
        System.out.println("Finished executing " + t.getName());
    }

    public static void main(String args[]) throws Exception {

        Thread t = new Thread(new ThreadJoin(),"New Thread ");
        t.start();
        System.out.println("Started executing main thread");

        // waits for main thread to die and allow execute the other thread
        t.join();

        for (int i = 0; i < 10; i++) {
            System.out.println(Thread.currentThread().getName() + i);
        }
        System.out.println("Finished executing " + Thread.currentThread().getName());
    }
}
```

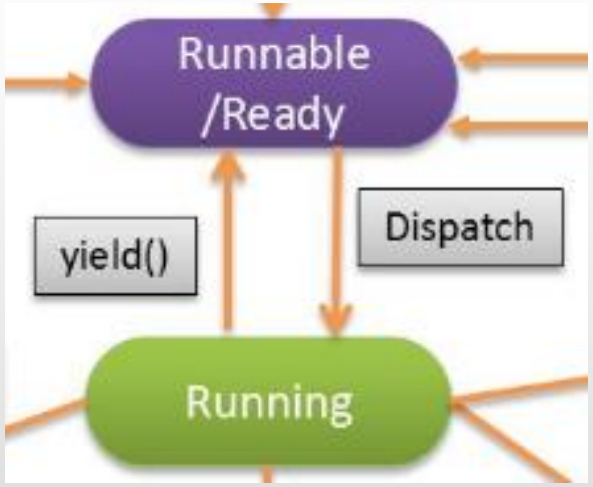
Console

```
<terminated> ThreadJoin [Java Application] C
Started executing main thread
Started executing New Thread
New Thread 0
New Thread 1
New Thread 2
New Thread 3
New Thread 4
New Thread 5
New Thread 6
New Thread 7
New Thread 8
New Thread 9
Finished executing New Thread
main0
main1
main2
main3
main4
main5
main6
main7
main8
main9
Finished executing main
```

Thread Yield method

- Yield() is used to give the other threads of the same priority a chance to execute

- This causes current running thread to move to runnable state. [running state to ready state]



ThreadYield.java

```
public class ThreadYield extends Thread{

    public void run() {
        Thread t = Thread.currentThread();
        System.out.println("Started executing " + t.getName());

        for (int i = 0; i < 10; i++) {
            System.out.println(t.getName() + i);
        }
        System.out.println("Finished executing " + t.getName());
    }

    public static void main(String args[]) throws Exception {

        Thread t = new Thread(new ThreadYield(),"New Thread ");
        t.start();
        System.out.println("Started executing main thread");
        /*
         *  temporarily stop executing main thread and give chance to
         *  newly created thread.
         */
        t.yield();

        for (int i = 0; i < 10; i++) {
            System.out.println(Thread.currentThread().getName() + i);
        }
        System.out.println("Finished executing " + Thread.currentThread().getName());
    }
}
```

Console

```
<terminated> ThreadYield [Java Application]
Started executing main thread
Started executing New Thread
New Thread 0
main0
New Thread 1
New Thread 2
New Thread 3
New Thread 4
main1
main2
main3
main4
main5
main6
main7
main8
main9
Finished executing main
New Thread 5
New Thread 6
New Thread 7
New Thread 8
New Thread 9
Finished executing New Thread
```

Thread wait and notify

- Once thread executes wait() method it releases the lock and state changed from **Runnable** to **waiting state**.
- Other thread can acquire the lock and continue execution.
- Once notify() method get executed the waited thread move to ready state and resume its execution.
- notifyAll() This wakes up all the threads that called wait() on the same object.

Thread wait and notify

```
class Thread1 extends Thread {

    ThreadNotifyTest object;

    public Thread1(ThreadNotifyTest object, String name) {
        super(object, name);
        this.object = object;
    }

    public void run() {
        synchronized (object) {
            try {
                System.out.println("Started "
                        + Thread.currentThread().getName() + " wait");
                object.wait();
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
            for (int i = 0; i < 10; i++) {
                System.out.println(Thread.currentThread().getName() + " " + i);
            }
        }
    }
}
```

- Thread wait() method throw an InturruptedException
- But it releases the lock

Thread wait and notify

```
class Thread2 extends Thread {

    ThreadNotifyTest object;

    public Thread2(ThreadNotifyTest object, String name) {
        super(object, name);
        this.object = object;
    }

    public void run() {
        synchronized (object) {
            System.out.println(Thread.currentThread().getName()
                    + " notify Thread");
            object.notify();
        }
    }
}
```

Thread wait and notify

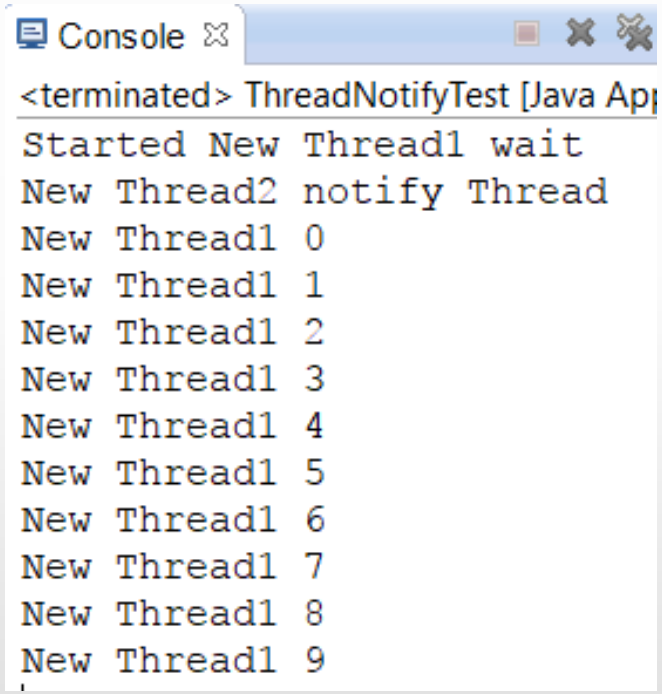
```
public class ThreadNotifyTest extends Thread {

    public static void main(String args[]) throws Exception {

        ThreadNotifyTest threadNotify = new ThreadNotifyTest();
        Thread1 t1 = new Thread1(threadNotify, "New Thread1");
        Thread2 t2 = new Thread2(threadNotify, "New Thread2");

        t1.start();
        t2.start();
    }
}
```

Response



Example for notifyAll with multi-threaded scenario

```
class Thread1 extends Thread {

    ThreadNotifyTest object;

    public Thread1(ThreadNotifyTest object, String name) {
        super(object, name);
        this.object = object;
    }

    public void run() {
        synchronized (object) {
            try {
                System.out.println("Started "
                        + Thread.currentThread().getName() + " wait");
                object.wait();
                System.out.println("Started "
                        + Thread.currentThread().getName() + " notified");
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
            for (int i = 0; i < 10; i++) {
                System.out.println(Thread.currentThread().getName() + " " + i);
            }
        }
    }
}
```

Example for notifyAll with multi-threaded scenario

```
class Thread2 extends Thread {

    ThreadNotifyTest object;

    public Thread2(ThreadNotifyTest object, String name) {
        super(object, name);
        this.object = object;
    }

    public void run() {
        synchronized (object) {
            try {
                System.out.println("Started "
                        + Thread.currentThread().getName() + " wait");
                object.wait();
                System.out.println("Started "
                        + Thread.currentThread().getName() + " notified");
            } catch (InterruptedException e) {
                e.printStackTrace();
            }
            for (int i = 0; i < 10; i++) {
                System.out.println(Thread.currentThread().getName() + " " + i);
            }
        }
    }
}
```

Thread notifyAll() method

```
class Thread3 extends Thread {

    ThreadNotifyTest object;

    public Thread3(ThreadNotifyTest object, String name) {
        super(object, name);
        this.object = object;
    }

    public void run() {
        synchronized (object) {
            System.out.println("notifyAll Thread executed");
            object.notifyAll();
        }
    }
}
```

This method awake all threads which are waiting with the same objects

Output of notifyAll Scenario

```
public class ThreadNotifyTest extends Thread {

    public static void main(String args[]) throws Exception {

        ThreadNotifyTest threadNotify = new ThreadNotifyTest();
        Thread1 t1 = new Thread1(threadNotify, "New Thread1");
        Thread2 t2 = new Thread2(threadNotify, "New Thread2");
        Thread3 t3 = new Thread3(threadNotify, "New Thread3");
        t1.start();
        t2.start();
        t3.start();
    }
}
```

Console

<terminated> ThreadNotifyTest [Java Applic

```
Started New Thread1 wait
Started New Thread2 wait
notifyAll Thread executed
Started New Thread2 notified
New Thread2 0
New Thread2 1
New Thread2 2
New Thread2 3
New Thread2 4
New Thread2 5
New Thread2 6
New Thread2 7
New Thread2 8
New Thread2 9
Started New Thread1 notified
New Thread1 0
New Thread1 1
New Thread1 2
New Thread1 3
New Thread1 4
New Thread1 5
New Thread1 6
New Thread1 7
New Thread1 8
New Thread1 9
```

Thread Priority

```
System.out.println(Thread.MIN_PRIORITY);
```
=> 1

```
System.out.println(Thread.NORM_PRIORITY);
```
=> 5

```
System.out.println(Thread.MAX_PRIORITY);
```
=> 10

```
public class ThreadPriority {

    public static void main(String[] args) {

        System.out.println(Thread.MIN_PRIORITY);

        System.out.println(Thread.NORM_PRIORITY);

        System.out.println(Thread.MAX_PRIORITY);

        System.out.println("Existing thread priority = "
                + Thread.currentThread().getPriority());

    }
}
```

```
<terminated> ThreadPriority [Java Applicatic
1
5
10
Existing thread priority = 5
```

Daemon Threads

- Daemon Threads are "backgroung threads".
  - That **provides service to other threads**, e.g. **The garbage collection thread.**
- The Java VM will not exit if non-daemon threads are executing
- The Java VM will exit if only Daemon threads are executing
- Daemon thread die when the Java VM exits.

Daemon Thread Example

- Since newly created thread is daemon thread when main thread completes its execution JavaVM will not wait until Daemon thread completes its execution.
- So it exit and Daemon thread automatically Die

Daemon Thread Example

DeamonThread.java | DeamonThreadTest.java

```
public class DeamonThread extends Thread {

    public static void main(String[] args) {

        System.out.println("Entering main Method");

        DeamonThread t = new DeamonThread();
        t.setDaemon(true);
        t.start();
        try {
            Thread.sleep(3000);
        } catch (InterruptedException x) {
        }

        System.out.println("Leaving main method");
    }

    public void run() {

        System.out.println("Entering run method");
        try {
            System.out.println("In run Method: currentThread() is"
                    + Thread.currentThread().getName());

            while (true) {
                try {
                    Thread.sleep(500);
                    System.out.println("In run method: woke up again");
                } catch (InterruptedException x) {
                    x.printStackTrace();
                }
            }
        } finally {
            System.out.println("Leaving run Method");
        }
    }
}
```

Console

```
<terminated> DeamonThread [Java Applicati
Entering main Method
Entering run method
In run Method: currentThread()
In run method: woke up again
In run method: woke up again
In run method: woke up again
In run method: woke up again
In run method: woke up again
Leaving main method
```

Commonly used methods for Thread class

1. **public void run():** is used to perform action for a thread.
2. **public void start():** starts the execution of the thread.JVM calls the run() method on the thread.
3. **public void sleep(long miliseconds):** Causes the currently executing thread to sleep (temporarily cease execution) for the specified number of milliseconds.
4. **public void join():** waits for a thread to die.
5. **public void join(long miliseconds):** waits for a thread to die for the specified miliseconds.
6. **public int getPriority():** returns the priority of the thread.
7. **public int setPriority(int priority):** changes the priority of the thread.
8. **public String getName():** returns the name of the thread.
9. **public void setName(String name):** changes the name of the thread.
10. **public Thread currentThread():** returns the reference of currently executing thread.
11. **public int getId():** returns the id of the thread.

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12. **public Thread.State getState():** returns the state of the thread.
13. **public boolean isAlive():** tests if the thread is alive.
14. **public void yield():** causes the currently executing thread object to temporarily pause and allow other threads to execute.
15. **public void suspend():** is used to suspend the thread(depricated).
16. **public void resume():** is used to resume the suspended thread(depricated).
17. **public void stop():** is used to stop the thread(depricated).
18. **public boolean isDaemon():** tests if the thread is a daemon thread.
19. **public void setDaemon(boolean b):** marks the thread as daemon or user thread.
20. **public void interrupt():** interrupts the thread.
21. **public boolean isInterrupted():** tests if the thread has been interrupted.
22. **public static boolean interrupted():** tests if the current thread has been interrupted.

Thank you!