Multithreading in Java

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- Multithreading in java is a process of executing multiple threads simultaneously.
- Thread is basically a lightweight sub-process, a smallest unit of processing.
- Multiprocessing and multithreading, both are used to achieve multitasking.
- But we use multithreading than multiprocessing because threads share a common memory area. They don't allocate separate memory area so saves memory, and context-switching between the threads takes less time than process.
- Java Multithreading is mostly used in games, animation etc.

Advantages of Java Multithreading

- 1) It **doesn't block the user** because threads are independent and we can perform multiple operations at same time.
- 2) we **can perform many operations together so it saves time**.
- 3) Threads are **independent** so it doesn't affect other threads if exception occur in a single thread.

Multitasking

- Multitasking is a process of executing multiple tasks simultaneously. We use multitasking to utilize the CPU. Multitasking can be achieved by two ways:
- Process-based Multitasking(Multiprocessing)
- Thread-based Multitasking(Multithreading)

1) Process-based Multitasking (Multiprocessing)

- Each process have its own address in memory i.e. each process allocates separate memory area.
- Process is heavyweight.
- Cost of communication between the process is high.
- Switching from one process to another require some time for saving and loading registers, memory maps, updating lists etc.

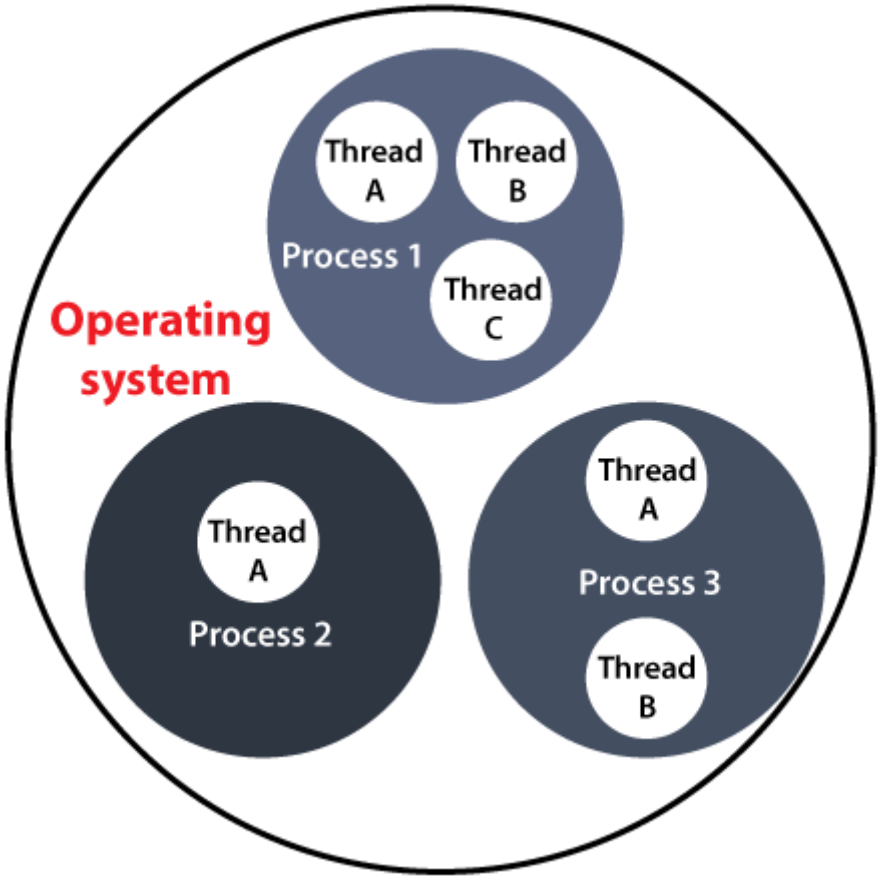
2) Thread-based Multitasking (Multithreading)

- Threads share the same address space.
- Thread is lightweight.
- Cost of communication between the thread is low.

What is Thread in java?

- A thread is a lightweight sub process, a smallest unit of processing. It is a separate path of execution.
- Threads are independent, if there occurs exception in one thread, it doesn't affect other threads. It shares a common memory area.
- ***Note: At a time one thread is executed only.***

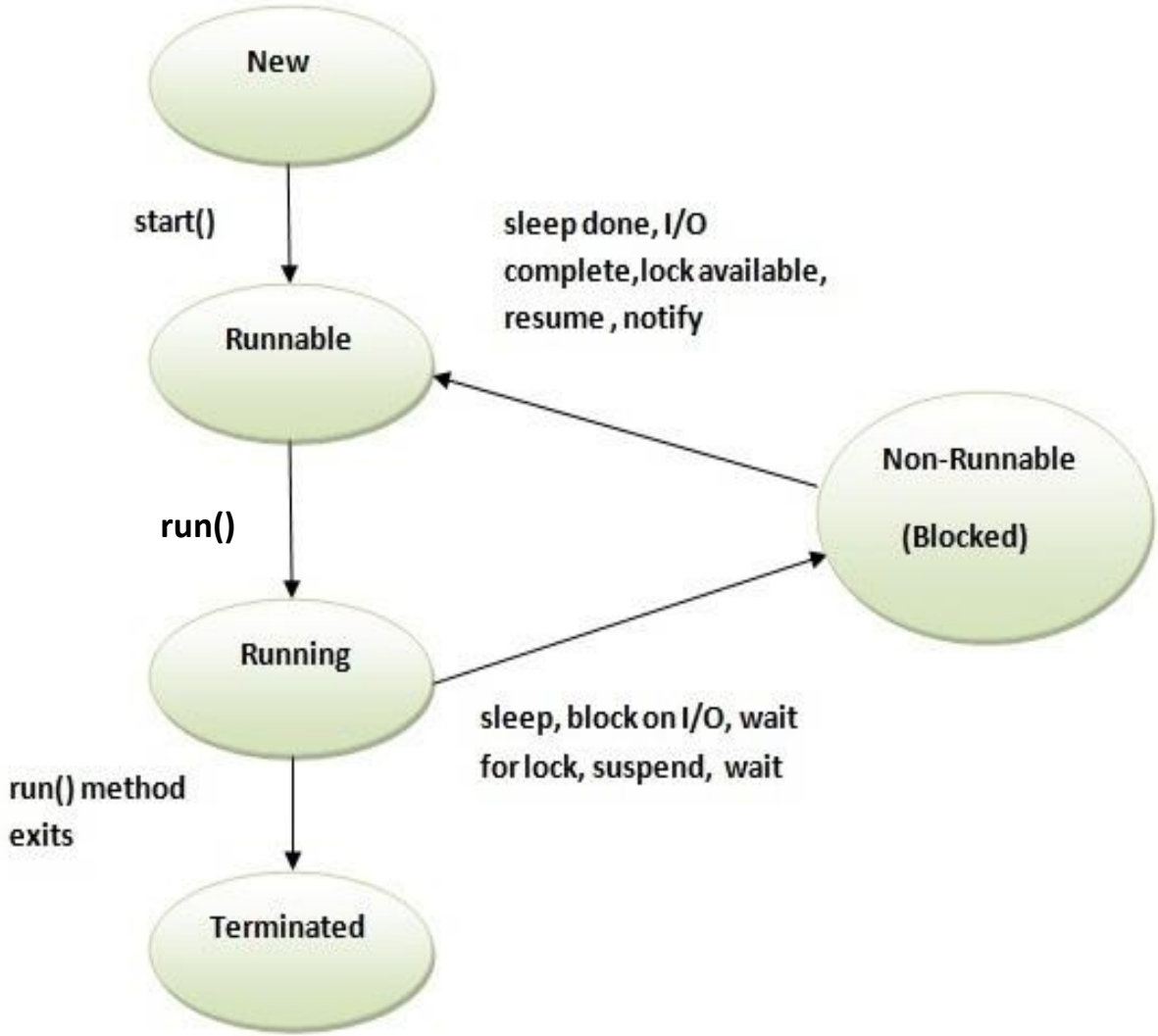
Threads in Process1



Life cycle of a Thread (Thread States)

- A thread can be in one of the five states.
- The life cycle of the thread in java is controlled by JVM. The java thread states are as follows:
- New(Born)
- Runnable(Ready)
- Running
- Blocked(Waiting)
- Terminated

Thread Life Cycle



1) **New**

The thread is in new state if you create an instance of Thread class but before the invocation of start() method.

2) **Runnable**

The thread is in runnable state after invocation of start() method, but the thread scheduler has not selected it to be the running thread.

3) **Running**

The thread is in running state if the thread scheduler has selected it.

4) **Non-Runnable (Blocked)**

This is the state when the thread is still alive, but is currently not eligible to run.

5) **Terminated**

A thread is in terminated or dead state when its run() method exits.

How to create thread ?

- There are two ways to create a thread:

1. By extending Thread class
2. By implementing Runnable interface.

1) Java Thread Example by extending Thread class

```
class Multi extends Thread
{
public void run()
{
System.out.println("thread is running...");
}
public static void main(String args[])
{
Multi t1=new Multi();
t1.start();
 }
}
```

Output: thread is running...

2) Java Thread Example by implementing Runnable interface

```
class Multi3 implements Runnable
{
public void run()
{
System.out.println("thread is running...");
}
public static void main(String args[])
{
Multi3 m1=new Multi3();
Thread t1 =new Thread(m1);
t1.start();
 }
}
```

Output: thread is running...

Thread Scheduler in Java

- **Thread scheduler** in java is the part of the JVM that decides which thread should run.
- There is no guarantee that which runnable thread will be chosen to run by the thread scheduler.
- Only one thread at a time can run in a single process.
- The thread scheduler mainly uses preemptive or time slicing(Round-Robin) scheduling to schedule the threads.

Sleep method in java

- The sleep() method of Thread class is used to sleep a thread for the specified amount of time(milli seconds).

➢ Syntax of sleep() method in java

- The Thread class provides two methods for sleeping a thread:

- public static void sleep(long milliseconds)throws InterruptedException

Example of sleep method in java

```
class TestSleepMethod1 extends Thread{
 public void run(){
  for(int i=1;i<5;i++){
    try{
Thread.sleep(500);
}
catch(InterruptedException e)
{System.out.println(e);}
    System.out.println(i);
  }
 }
 public static void main(String args[]){
  TestSleepMethod1 t1=new TestSleepMethod1();
  TestSleepMethod1 t2=new TestSleepMethod1();

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

```
1
1
2
2
3
3
4
4
```

Can we start a thread two times?

```
public class TestThreadTwice1 extends Thread
{
 public void run(){
   System.out.println("running...");
 }
 public static void main(String args[])
{
  TestThreadTwice1 t1=new TestThreadTwice1();
  t1.start();
  t1.start();
 }
}
```

```
running
Exception in thread "main" java.lang.IllegalThreadStateException
```

What if we call run() method directly instead start() method?

```
class TestCallRun2 extends Thread{
 public void run(){
  for(int i=1;i<5;i++){
    try{Thread.sleep(500);}
catch(InterruptedException e)
{System.out.println(e);}
    System.out.println(i);
  }
 }
 public static void main(String args[]){
  TestCallRun2 t1=new TestCallRun2();
  TestCallRun2 t2=new TestCallRun2();

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

```
1
2
3
4
5
1
2
3
4
5
```

no context-switching between t1 and t2 .
They are treated as normal object not thread object.

The join() method

- The join() method waits for a thread to die. In other words, it causes the currently running threads to stop executing until the thread it joins with completes its task.
- Syntax

public void join()throws InterruptedException

public void join(long milliseconds)throws InterruptedException

Example of join() method

```
class TestJoinMethod1 extends Thread{
 public void run(){
  for(int i=1;i<=5;i++){
   try{
    Thread.sleep(500);
   }catch(Exception e){System.out.println(e);}
  System.out.println(i);
  }
 }
public static void main(String args[]){
 TestJoinMethod1 t1=new TestJoinMethod1();
 TestJoinMethod1 t2=new TestJoinMethod1();
 TestJoinMethod1 t3=new TestJoinMethod1();
 t1.start();
 try{
  t1.join();
 }catch(Exception e){System.out.println(e);}

 t2.start();
 t3.start();
 }
}
```

```
1
2
3
4
5
1
1
2
2
3
3
4
4
5
5
```

getName(),setName(String) and getId() method:

```
class TestJoinMethod3 extends Thread{
  public void run(){
   System.out.println("running...");
  }
 public static void main(String args[]){
  TestJoinMethod3 t1=new TestJoinMethod3();
  TestJoinMethod3 t2=new TestJoinMethod3();
  System.out.println("Name of t1:"+t1.getName());
  System.out.println("Name of t2:"+t2.getName());
  System.out.println("id of t1:"+t1.getId());
  t1.start();
  t2.start();
  t1.setName("RVR");
  System.out.println("After changing name of t1:"+t1.getName());
 }
}
```

```
Name of t1:Thread-0 Name of t2:Thread-1 id of t1:8
running...
After changing name of t1:RVR
running...
```

The currentThread() method returns a reference to the currently executing thread object.

```
class TestJoinMethod4 extends Thread{
 public void run(){
  System.out.println(Thread.currentThread().getName());
 }
 }
 public static void main(String args[]){
  TestJoinMethod4 t1=new TestJoinMethod4();
  TestJoinMethod4 t2=new TestJoinMethod4();

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

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

Priority of a Thread (Thread Priority)

- Each thread have a priority.
- Priorities are represented by a number between 1 and 10.
- In most cases, thread scheduler schedules the threads according to their priority (known as preemptive scheduling).
- But it is not guaranteed because it depends on JVM specification that which scheduling it chooses.

3 constants defined in Thread class:

1. public static int MIN_PRIORITY (1)
2. public static int NORM_PRIORITY (5)
3. public static int MAX_PRIORITY (10)

- Default priority of a thread is 5 (NORM_PRIORITY).
- The value of MIN_PRIORITY is 1.
- The value of MAX_PRIORITY is 10.

Example: priority of a Thread:

```
class TestMultiPriority1 extends Thread{
 public void run(){
   System.out.println("running thread name is:"+Thread.currentThread().getN
ame());
   System.out.println("running thread priority is:"+Thread.currentThread().get
Priority());


  }
 public static void main(String args[]){
  TestMultiPriority1 m1=new TestMultiPriority1();
  TestMultiPriority1 m2=new TestMultiPriority1();
  m1.setPriority(Thread.MIN_PRIORITY);
  m2.setPriority(Thread.MAX_PRIORITY);
  m1.start();
  m2.start();

 }
}
```

```
running thread name is:Thread-0
running thread priority is:10
running thread name is:Thread-1
running thread priority is:1
```

Daemon Thread in Java

- **Daemon thread in java** is a service provider thread that provides services to the user thread. Its life depend on the mercy of user threads i.e. when all the user threads dies, JVM terminates this thread automatically.
- There are many java daemon threads running automatically e.g. gc, finalizer etc.

Points to remember for Daemon Thread in Java

- It provides services to user threads for background supporting tasks. It has no role in life than to serve user threads.
- Its life depends on user threads.
- It is a low priority thread.

Methods for Java Daemon thread by Thread class

No.	Method	Description
1)	public void setDaemon(boolean status)	is used to mark the current thread as daemon thread or user thread.
2)	public boolean isDaemon()	is used to check that current thread is daemon or not.

Simple example of Daemon thread in java

```
public class TestDaemonThread1 extends Thread{
 public void run(){
  if(Thread.currentThread().isDaemon()){//checking for daemon thread
   System.out.println("daemon thread work");
  }
  else{
  System.out.println("user thread work");
 }
 }
 public static void main(String[] args){
  TestDaemonThread1 t1=new TestDaemonThread1();//creating thread
  TestDaemonThread1 t2=new TestDaemonThread1();
  TestDaemonThread1 t3=new TestDaemonThread1();

  t1.setDaemon(true);//now t1 is daemon thread

  t1.start();//starting threads
  t2.start();
  t3.start();
 }
}
```

```
daemon thread work
user thread work
user thread work
```

If you want to make a user thread as Daemon, it must not be started otherwise it will throw IllegalThreadStateException.

```
class TestDaemonThread2 extends Thread{
 public void run(){
  System.out.println("Name: "+Thread.currentThread().getName());
  System.out.println("Daemon: "+Thread.currentThread().isDaemon());

 }
   public static void main(String[] args){
  TestDaemonThread2 t1=new TestDaemonThread2();
  TestDaemonThread2 t2=new TestDaemonThread2();
  t1.start();
  t1.setDaemon(true);//will throw exception here
  t2.start();
 }
}
```

exception in thread main: java.lang.IllegalThreadStateException

Java Thread Pool

- **Java Thread pool** represents a group of worker threads that are waiting for the job and reuse many times.

➢ Advantage of Java Thread Pool

- **Better performance** It saves time because there is no need to create new thread.
- **Real time usage** It is used in Servlet and JSP where container creates a thread pool to process the request.

Synchronization in Java

- Synchronization in java is the capability *to control the access of multiple threads to any shared resource*.
- Java Synchronization is better option where we want to allow only one thread to access the shared resource.

Why use Synchronization?

- The synchronization is mainly used to
- To prevent thread interference.
- To prevent consistency problem.
- Types of Synchronization
- There are two types of synchronization
- Process Synchronization
- Thread Synchronization

Thread Synchronization

- There are two types of thread synchronization mutual exclusive and inter-thread communication.
- Mutual Exclusive
  - Synchronized method.
  - Synchronized block.
  - static synchronization.
- Cooperation (Inter-thread communication in java)

Mutual Exclusive

- Mutual Exclusive helps keep threads from interfering with one another while sharing data. This can be done by three ways in java:
- by synchronized method
- by synchronized block
- by static synchronization

Concept of Lock in Java

- Synchronization is built around an internal entity known as the lock or monitor. Every object has an lock associated with it. By convention, a thread that needs consistent access to an object's fields has to acquire the object's lock before accessing them, and then release the lock when it's done with them.
- From Java 5 the package java.util.concurrent.locks contains several lock implementations.

Understanding the problem without Synchronization

```
Class Table{

void printTable(int n){//method not synchronized
  for(int i=1;i<=5;i++){
    System.out.println(n*i);
    try{
     Thread.sleep(400);
    }catch(Exception e){System.out.println(e);}
  }
 }
}
class MyThread1 extends Thread{
Table t;
MyThread1(Table t){
this.t=t;
}
public void run(){
t.printTable(5);
}
 }
```

```
class MyThread2 extends Thread{
Table t;
MyThread2(Table t){
this.t=t;
}
public void run(){
t.printTable(100);
}
}

class TestSynchronization1{
public static void main(String args[]){
Table obj = new Table();//only one object
MyThread1 t1=new MyThread1(obj);
MyThread2 t2=new MyThread2(obj);
t1.start();
t2.start();
}
}
```

```
5
100
10
200
15
300
20
400
25
500
```

Java synchronized method

- If you declare any method as synchronized, it is known as synchronized method.
- Synchronized method is used to lock an object for any shared resource.
- When a thread invokes a synchronized method, it automatically acquires the lock for that object and releases it when the thread completes its task.

example of java synchronized method

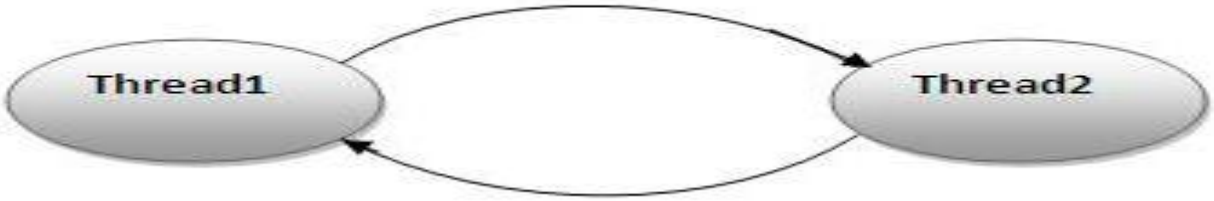
```
class Table{
 synchronized void printTable(int n){//synch
ronized method
   for(int i=1;i<=5;i++){
     System.out.println(n*i);
     try{
      Thread.sleep(400);
     }catch(Exception e){System.out.println(e)
;}
   }

 }
}

class MyThread1 extends Thread{
Table t;
MyThread1(Table t){
this.t=t;
}
public void run(){
t.printTable(5);
}
}
```

```
class MyThread2 extends Thread{
Table t;
MyThread2(Table t){
this.t=t;
}
public void run(){
t.printTable(100);
}
}

public class TestSynchronization2{
public static void main(String args[]){
Table obj = new Table();//only one object

MyThread1 t1=new MyThread1(obj);
MyThread2 t2=new MyThread2(obj);
t1.start();
t2.start();
}
}
```

```
5 10 15 20 25 100 200 300 400 500
```

Deadlock in java

- Deadlock in java is a part of multithreading.
- Deadlock can occur in a situation when a thread is waiting for an object lock, that is acquired by another thread and second thread is waiting for an object lock that is acquired by first thread.
- Since, both threads are waiting for each other to release the lock, the condition is called deadlock.



Example of Deadlock in java

```
public class TestDeadlockExample1 {
  public static void main(String[] args) {
    final String resource1 = "ratan jaiswal";
    final String resource2 = "vimal jaiswal";
    // t1 tries to lock resource1 then resource2
    Thread t1 = new Thread() {
      public void run() {
        synchronized (resource1) {
          System.out.println("Thread 1: locked resource 1");

          try { Thread.sleep(100);} catch (Exception e) {}

          synchronized (resource2) {
            System.out.println("Thread 1: locked resource 2");
          }
        }
      }
    };

    // t2 tries to lock resource2 then resource1
    Thread t2 = new Thread() {
      public void run() {
        synchronized (resource2) {
          System.out.println("Thread 2: locked resource 2");

          try { Thread.sleep(100);} catch (Exception e) {}

          synchronized (resource1) {
            System.out.println("Thread 2: locked resource 1");
          }
        }
      }
    };


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

Thread 1: locked resource 1
Thread 2: locked resource 2

Inter-thread communication in Java

- **Inter-thread communication** or **Co-operation** is all about allowing synchronized threads to communicate with each other.
- Cooperation (Inter-thread communication) is a mechanism in which a thread is paused running in its critical section and another thread is allowed to enter (or lock) in the same critical section to be executed.
- It is implemented by following methods of **Object class**:
- wait()
- notify()
- notifyAll()

1) wait() method

- Causes current thread to release the lock and wait until either another thread invokes the notify() method or the notifyAll() method for this object, or a specified amount of time has elapsed.
- The current thread must own this object's monitor, so it must be called from the synchronized method only otherwise it will throw exception.

Method	Description
public final void wait()throws InterruptedException	waits until object is notified.
public final void wait(long timeout)throws InterruptedException	waits for the specified amount of time.

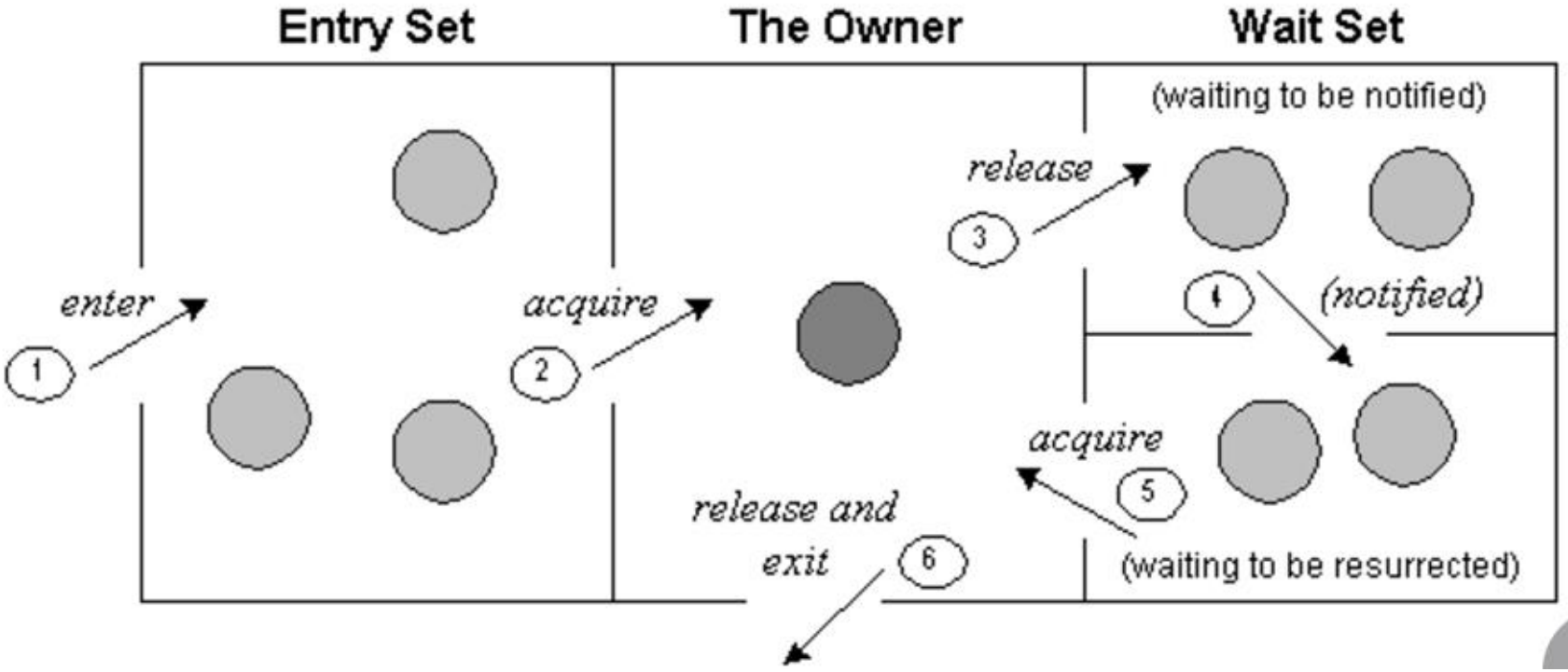
2) notify() method

- Wakes up a single thread that is waiting on this object's monitor. If any threads are waiting on this object, one of them is chosen to be awakened. The choice is arbitrary and occurs at the discretion of the implementation. Syntax:
- public final void notify()

3) notifyAll() method

- Wakes up all threads that are waiting on this object's monitor.
- Syntax:
- public final void notifyAll()

Understanding the process of inter-thread communication



The point to point explanation of the above diagram is as follows:

- Threads enter to acquire lock.
- Lock is acquired by on thread.
- Now thread goes to waiting state if you call wait() method on the object. Otherwise it releases the lock and exits.
- If you call notify() or notifyAll() method, thread moves to the notified state (runnable state).
- Now thread is available to acquire lock.
- After completion of the task, thread releases the lock and exits the monitor state of the object.

Example of Inter thread communication

```
class Customer{
int amount=10000;

synchronized void withdraw(int amount){
System.out.println("going to withdraw...");
if(this.amount<amount){
System.out.println("Less balance; waiting for deposit...");
try{wait();}catch(Exception e){}
}
this.amount-=amount;
System.out.println("withdraw completed...");
}
synchronized void deposit(int amount){
System.out.println("going to deposit...");
this.amount+=amount;
System.out.println("deposit completed... ");

notify();
}
}

class Test{
public static void main(String args[]){
final Customer c=new Customer();
new Thread(){
public void run(){c.withdraw(15000);}
}.start();
new Thread(){
public void run(){c.deposit(10000);}
}.start();

}}
```

going to withdraw...
Less balance; waiting for deposit... going to deposit...

deposit completed...
withdraw completed