Threads

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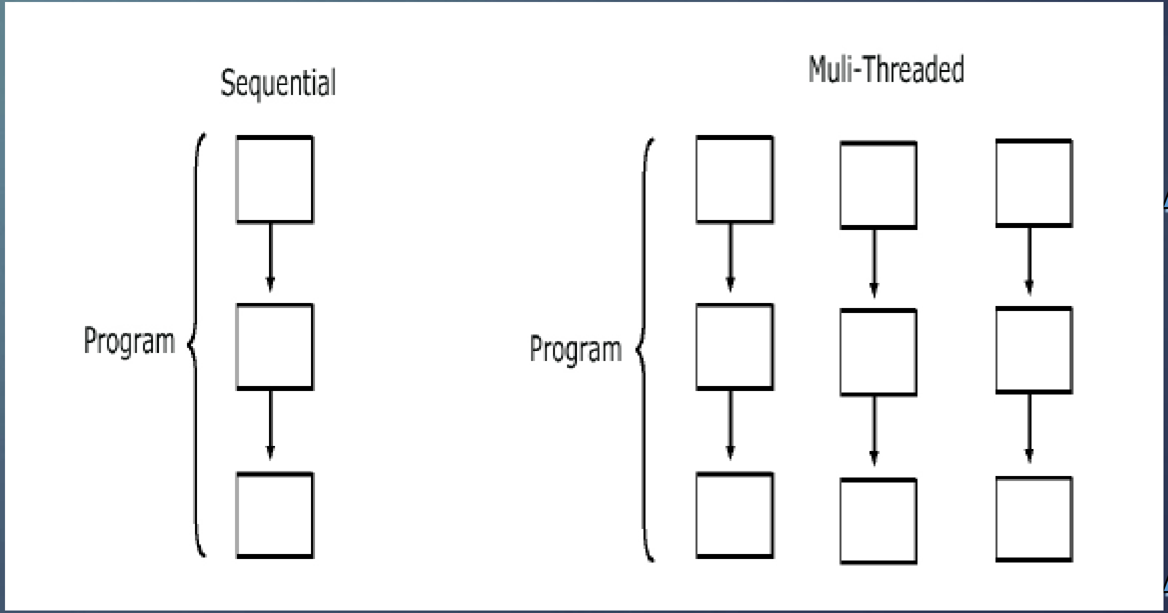
Why Threads

- Need to handle concurrent processes
- Definition
  - Single sequential flow of control within a program
- think of threads as processes executed by a program
- Example:
  - Operating System
  - HotJava web browser



Multi-threading in Java Platform

- We start with just one thread, called the main thread. This thread has the ability to create additional threads

- *When a new* thread is started , a new stack materializes and methods called from *that* thread run in a call stack that's separate from the main() call stack.

- That second new call stack runs concurrently with the main thread

- *A thread of execution* is an individual process (a "lightweight" process) that has its own call stack.
- *one thread per call stack—one call stack per thread*.

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The Main Thread

- Every java program has atleast one thread called main thread
- The current thread method of Thread class gets the current thread
- getName() and setName() method are used to get the name and set the name for the thread

```
class setname {
    public static void main(String args[])      {
        Thread thread = Thread.currentThread();
 System.out.println("Main thread's original name is " +
   thread.getName());
        thread.setName("The Main Thread");
        System.out.println("Main thread's name is now " +
            thread.getName());
    }
}
```

Making a Thread

- A thread a begins as an instance of java.lang.Thread.

```
public void run() {
    // your job code goes here
  }
```

- Put the code that needs to be run in a separate thread in a run() method.

- The run() method will call other methods, but the thread of execution of the new call stack always begins by invoking run()

Instantiate a thread

- Extend the java.lang.Thread class
  - Extend Thread when you have a more specialized version of a thread class.
  - The limitation with this approach is that if you extend Thread, *you can't extend anything else*.
- Implement the Runnable interface
  - design a class that implements the Runnable interface, leaves your class free to extend from some *other* class.

Extend the java.lang.Thread class

- To define code to run in a separate thread
  - Extend the Thread class.
  - Override the run() method.

```
    class MyThread extends Thread {
    public void run() {
    System.out.println("Starting My Thread");
    }
    }
public class Example_1 {
   public static void main (String args[]) {
    MyThread mt1=new MyThread();
    mt1.start();
    }
}
```

Implementing java.lang.Runnable

- Implementing the Runnable interface gives a way to extend from any class but still define behavior that will be run by a separate thread.

```
class ExRunnable implements Runnable {
public void run() {
System.out.println("Important job running in MyRunnable");
}
}
public class Example_3 {
public static void main (String [] args) {
ExRunnable r = new ExRunnable();
Thread t = new Thread(r);
t.start();
}
```

- Instantiate Runnable class and get an instance of thread - *give it the job*
- Thread class for the *thread-specific* code
- Thread objects is created by calling the Thread constructor that takes a Runnable argument. The Runnable object is the *target* of the thread.

Starting a Thread

- To launch a new call stack.
  - t.start();
- Prior to calling start() -it is in the *new* state as Thread *object*
  - A new thread of execution starts (with a new call stack).
  - The thread moves from the *new* state to the *runnable* state.
  - When the thread gets a chance to execute, its target run() method will run.

`void start()`

  - Creates a new thread and makes it runnable

`void run()`

  - The new thread begins its life inside this method

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Starting Multiple Thread

```
class NameRunnable implements Runnable {
public void run() {
for (int x = 1; x < 4; x++) {
System.out.println("Run by " + Thread.currentThread().getName());
   }
  }
 }
public class Example_5 {
public static void main (String [] args) {
NameRunnable nr = new NameRunnable(); // Make one Runnable
Thread one = new Thread(nr);
one.setName("ash");
Thread two = new Thread(nr);
two.setName("bash");
Thread three = new Thread(nr);
three.setName("clash");
one.start();
two.start();
three.start();
}
}
```

The Thread Scheduler

- The thread scheduler is the part of the JVM
- Any thread in the *runnable* state can be chosen by the scheduler to be the one and only *running* thread.
- **java.lang.Thread Class**
  - public static void sleep(long millis) throws InterruptedException
  - public static void yield()
  - public final void join()
  - public final void setPriority(int newPriority)
- **java.lang.Object Class**
  - public final void wait()
  - public final void notify()
  - public final void notifyAll()

Thread States

- **New**
  - When the Thread instance has been instantiated, but the start() method has not been invoked on the thread.
  - It is a live Thread object, but not yet a thread of execution.
  - At this point, thethread is considered *not alive*.

- **Runnable**
  - The state a thread is in when it's eligible to run,
  - Scheduler has not selected it to be the running thread.
  - A thread first enters the runnable state when the start() method is invoked
  - A thread can also return to the runnable state after either running or coming back from a blocked, waiting, or sleeping state.
  - When the thread is in the runnable state, it is considered *alive*.

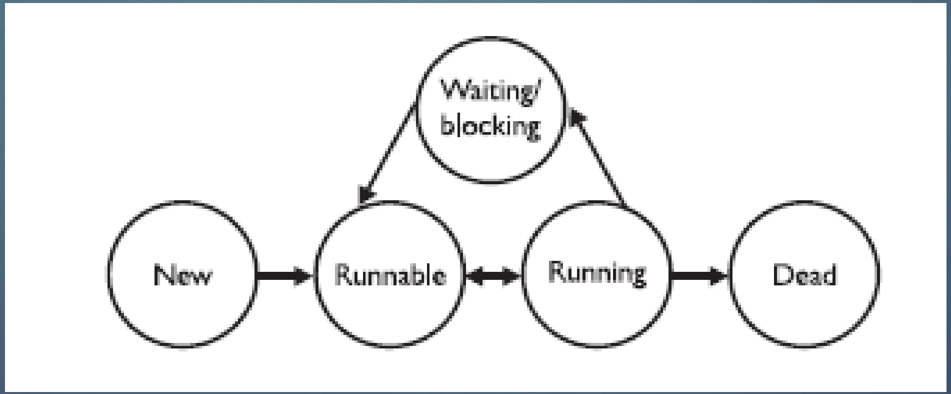
Thread States

- **Running**
  - This is the state a thread is in when the thread scheduler selects it from the runnable pool to be the currently executing process.
  - A thread can transition out of a running state for several reasons, including because "the thread scheduler felt like it."

- **Waiting/blocked/sleeping**
  - The thread is still alive, but is currently not eligible to run.
  - A thread may be *blocked* waiting for a resource
  - A thread may be *sleeping* because the thread's run code *tells* it to sleep for some period of time
  - *waiting*, because the thread's run code *causes* it to wait

Thread States

- **Dead**
- A thread is considered dead when its run() method completes.
- It may still be a viable Thread object, but it is no longer a separate thread of execution. Once a thread is dead, it can never be brought back to life
- A runtime exception will be thrown



Non Daemon Vs Daemon Thread

Non Daemon Thread/ User Threads	Daemon Thread
JVM wait until user threads to finish their work. It never exit until all user threads finish their work.	The JVM will't wait for daemon threads to finish their work. The JVM will exit as soon as all user threads finish their work.
JVM will not force to user threads for terminating, so JVM will wait for user threads to terminate themselves.	If all user threads have finished their work JVM will force the daemon threads to terminate
User threads are created by the application.	Mostly Daemon threads created by the JVM.
Mainly user threads are designed to do some specific task.	Daemon threads are design as to support the user threads.
User threads are foreground threads.	Daemon threads are background threads.
User threads are high priority threads.	Daemon threads are low priority threads.
Its life independent.	Its life depends on user threads.

Leave the running state

- **sleep()** is Guaranteed to cause the current thread to stop executing for at least the specified sleep duration (although it might be *interrupted* before its specified time).

- **yield()** Not guaranteed to do much of anything, although typically it will cause the currently running thread to move back to runnable so that a thread of the same priority can have a chance.

- **join()** Guaranteed to cause the current thread to stop executing until the thread it joins with the thread it calls wait on completes.

- The thread might leave the running state in the following scenarios
  - The thread's run() method completes..
  - A thread can't acquire the *lock* on the object whose method code it's attempting to run

The sleep() method

- The sleep() method is a static method of class Thread.
- "slows a thread down" by forcing it to go into a sleep mode before coming back to runnable

```
    try {
  Thread.sleep(5*60*1000); // Sleep for 5 minutes
  } catch (InterruptedException ex) { }
```

- sleep() code can be put anywhere,
- When the executing code hits a sleep() call, it puts the currently running thread to sleep.
- When a thread wakes up it simply goes back to the runnable state.
- Time specified in sleep() is the minimum duration in which the thread won't run, but it is not the exact duration in which the thread won't run.

Pausing a Thread-sleep()

- Sleep Method is used to pause the thread for a amount of time in milliseconds
- The thread will wait for that amount of time before continuing

```
class Example_4
{
    public static void main(String args[])
    {
        try {
            System.out.println("Hello");
            Thread.sleep(1000);
            System.out.println("from");
            Thread.sleep(1000);
            System.out.println("Java.");
            Thread.sleep(1000);
        } catch (InterruptedException e) {}
    }
}
```

The Join() Method

- The non-static join() method of class Thread lets one thread “join onto the end” of another thread.

- The thread class join method waits until a thread is finished executing or waiting for a thread to die before returning .

Joining Thread

```
public static void main(String[] args) {

       Thread t = new Thread( ) {

            public void run( ) {

                System.out.println("Reading");

                try {

                    System.in.read( );

                } catch (java.io.IOException ex) {

                   }

                System.out.println("Thread Finished.");
            }
        };
```

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Joining Thread

```
    System.out.println("Starting");

    t.start( );

    System.out.println("Joining");

    try {

        t.join( );

    } catch (InterruptedException ex) {

         ex.printStackTrace();

    }

    System.out.println("Main Finished.");

}
```

Thread Priorities

- Threads always run with some priority, represented usually as a number between 1 and 10
- The scheduled of JVMs use thread priorities in one important way:
- The lower-priority running thread usually will be bumped back to runnable and the highest-priority thread will be chosen to run.
- The running thread will be of equal or greater priority than the highest priority threads in the pool.
- The Thread class has three constants (static final variables) that define the range of thread priorities:
  - Thread.MIN_PRIORITY (1)
  - Thread.NORM_PRIORITY (5)
  - Thread.MAX_PRIORITY (10)

Setting a Thread’s Priority

A thread gets a default priority that is the priority of the thread of execution that creates it.

```
public class TestThreads {
public static void main (String [] args) {
MyThread t = new MyThread();
}
}
```

the thread referenced by *t* will have the same priority as the *main* thread,

since the main thread is executing the code that creates the MyThread instance.

set a thread’s priority directly by calling the setPriority() method on a Thread instance as follows:

```
FooRunnable r = new FooRunnable();
Thread t = new Thread(r);
t.setPriority(8);
t.start();
```

Thread.yield()

- yield() is *supposed* to make the currently running thread head back to runnable to allow other threads of the *same* priority to get their turn.

- yield() promotes graceful turn-taking among equal-priority threads.

- yield() method isn't guaranteed to do what it claims, and even if yield() *does* cause a thread to step out of running and back to runnable, *there's no guarantee the yielding thread won't just be chosen again over all the others!*

- yield() might—and often does—make a running thread give up its slot to another runnable thread of the same priority, there's no guarantee.

RACE CONDITION

- A race condition is a situation in which two or more threads or processes are reading or writing some shared data, and the final result depends on the timing of how the threads are scheduled. Race conditions can lead to unpredictable results and subtle program bugs. A thread can prevent this from happening by locking an object. When an object is locked by one thread and another thread tries to call a synchronized method on the same object, the second thread will block until the object is unlocked.

Synchronizing Code

- Threads can share resources.
- Sometimes it is desirable that only one thread at a time has access to a shared resource.
- Achieved by using the keyword: `synchronized`, Only *methods* can be synchronized, not variables.
- Protects access to code, not to data
  - Make data members private
  - Synchronize accessor methods
- 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.
- one thread can hold the lock and thereby have access to the shared resource.

Synchronizing Code

- A class can have both synchronized and no synchronized methods.
- If a class has both synchronized and nonsynchronized methods, *multiple threads can still access the nonsynchronized methods* of the class!
- *A thread can acquire more than one lock.*
- A thread can enter a synchronized method, thus acquiring a lock, and then immediately invoke a synchronized method on a different object, thus acquiring *that* lock as well.
- As the stack unwinds, locks are released again.

Thread Synchronization

```
class TwoStrings {

synchronized static void print(String str1, String str2) {

System.out.print(str1);

try {
Thread.sleep(500);
} catch (InterruptedException ie)
{
ie.printStackTrace();
}
System.out.println(str2);
}
}
```

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Thread Synchronization

```
class PrintStringsThread implements Runnable {

String str1, str2;

PrintStringsThread(String str1, String str2) {

    this.str1 = str1;
    this.str2 = str2;

 Thread thread = new Thread(this);
 thread.start();
}

public void run() {
 TwoStrings.print(str1, str2);


 }
}
```

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Thread Synchronization

```
public class Test {

public static void main(String args[])
{
new PrintStringsThread("Hello ", "there.");
 new PrintStringsThread("How are ", "you?");
 new PrintStringsThread("Thank you ","very much!");
 new PrintStringsThread("Bye ","Bye!");

}
}
```

Output- May be in Different Order

```
Hello there
How are you
Thank you very much
Bye,Bye
```

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Volatile

- Volatile keyword is used to modify the value of a variable by different threads.
- Used to make classes thread safe.
- The volatile keyword does not cache the value of the variable and always read the variable from the main memory.
- Use the volatile keyword with variables. Using volatile keyword with classes and methods is illegal.

Example

```
public class VolatileTest {
    private static volatile int MY_INT = 0;
    public static void main(String[] args)
    {
        new ChangeListener().start();
        new ChangeMaker().start();
    }

    static class ChangeListener extends Thread {
        @Override public void run()
        {
            int local_value = MY_INT;
            while (local_value < 5) {
                if (local_value != MY_INT) {
                System.out.println("Got Change for MY_INT : "+MY_INT);
                local_value = MY_INT;
                }
            }
        }
    }
```

```
static class ChangeMaker extends Thread {
        @Override public void run()
        {
            int local_value = MY_INT;
            while (MY_INT < 5) {
                System.out.println(
                        "Incrementing MY_INT to "+(local_value +
1));
                MY_INT = ++local_value;
                try {
                    Thread.sleep(500);
                }
                catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        }
    }
    }
```

Volatile Vs Synchronization

Volatile Keyword	Synchronization Keyword
Volatile keyword is a field modifier.	Synchronized keyword modifies code blocks and methods.
The thread cannot be blocked for waiting in case of volatile.	Threads can be blocked for waiting in case of synchronized.
It synchronizes the value of one variable at a time between thread memory and main memory.	It synchronizes the value of all variables between thread memory and main memory.
Volatile fields are not subject to compiler optimization.	Synchronize is subject to compiler optimization.

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Thread Interaction

- The java.lang.Object class has three methods—wait(), notify(), and notifyAll()—that help threads communicate
- wait(), notify(), *and* notifyAll() *must be called from within a synchronized context!*
- If many threads are waiting on the same object, only one will be chosen (in no guaranteed order) to proceed with its execution. If there are no threads waiting, then no particular action is take

Difference between Blocked-Waiting

- **Blocked**
- Thread is waiting to get a lock on the monitor.(or waiting for a blocking i/o method)
- Caused by the thread tried to execute some synchronized code. (or a blocking i/o method)
- Can move to ready only when the lock is available. (or the i/o operation is complete)

- **wait**
- Thread has been asked to wait. (by means of wait method)
- The thread already acquired the lock and executed some synchronized code before coming across a wait call.
- Can move to ready only when it gets notified (by means of notify or notifyAll)

notifyAll()

- This notifies all waiting threads and they start competing to get the lock. As the lock is used and released by each thread, all of them will get into action without a need for further notification.
- Object can have many threads waiting on it, and using notify() will affect only one of them.
- Which one exactly is not specified and depends on the JVM implementation,
- never rely on a particular thread In cases in which there might be a lot more waiting, the best way to do this is by using notifyAll().

Producer Consumer Problem

- In computing, the producer-consumer problem (also known as the bounded-buffer problem) is a classic example of a multi-process synchronization problem. The problem describes two processes, the producer and the consumer, which share a common, fixed-size buffer used as a queue.
- The producer's job is to generate data, put it into the buffer, and start again.
- At the same time, the consumer is consuming the data (i.e. removing it from the buffer), one piece at a time.

Problem

To make sure that the producer won't try to add data into the buffer if it's full and that the consumer won't try to remove data from an empty buffer.

Producer Consumer Problem

Solution

- The producer is to either go to sleep or discard data if the buffer is full. The next time the consumer removes an item from the buffer, it notifies the producer, who starts to fill the buffer again. In the same way, the consumer can go to sleep if it finds the buffer to be empty. The next time the producer puts data into the buffer, it wakes up the sleeping consumer.
- An inadequate solution could result in a deadlock where both processes are waiting to be awakened.

Producer Consumer Example

```
import java.util.LinkedList;

public class Threadexample {
    public static void main(String[] args)
        throws InterruptedException
    {
        // Object of a class that has both produce()
        // and consume() methods
        final PC pc = new PC();

        // Create producer thread
        Thread t1 = new Thread(new Runnable() {
            @Override
            public void run()
            {
                try {
                    pc.produce();
                }
                catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        });
```

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Producer Consumer Example

```
// Create consumer thread
        Thread t2 = new Thread(new Runnable() {
            @Override
            public void run()
            {
                try {
                    pc.consume();
                }
                catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        });
```

Producer Consumer Example

```
// Start both threads
    t1.start();
    t2.start();

    // t1 finishes before t2
    t1.join();
    t2.join();
  }

  // This class has a list, producer (adds items to list
  // and consumer (removes items).
```

Producer Consumer Example

```
// This class has a list, producer (adds items to list
    // and consumer (removes items).
    public static class PC {

        // Create a list shared by producer and consumer
        // Size of list is 2.
        LinkedList<Integer> list = new LinkedList<>();
        int capacity = 2;
```

Producer Consumer Example

```
// Function called by producer thread
    public void produce() throws InterruptedException
    {
        int value = 0;
        while (true) {
            synchronized (this)
            {
                // producer thread waits while list
                // is full
                while (list.size() == capacity)
                    wait();

                System.out.println("Producer produced-"
                                   + value);
// to insert the jobs in the list
                list.add(value++);

                // notifies the consumer thread that
                // now it can start consuming
                notify();
// makes the working of program easier
// to  understand
                Thread.sleep(1000);
            }
        }
    }
```

Producer Consumer Example

```
// Function called by consumer thread
        public void consume() throws
InterruptedException
        {
            while (true) {
                synchronized (this)
                {
                    // consumer thread waits while list
                    // is empty
                    while (list.size() == 0)
                        wait();

                    // to retrieve the first job in the list
int val = list.removeFirst();

                    System.out.println("Consumer consumed-"
                                       + val);

                    // Wake up producer thread
                    notify();

                    // and sleep
                    Thread.sleep(1000);
                }
            }
        } }
}
```

Notify -Example

```
class Computations extends Thread
{
  private int num;
  private boolean isComplete;
  private int result;

  public Computations(int num)  {
   this.num = num;
  }
  public synchronized void run()    {
   result = num * 2;
   isComplete=true;
   notify();
  }
```

Notify -Example

```
public synchronized int getResult() {
     while(!isComplete)
     {
          try
          {
               wait();
          }
          catch(InterruptedException e)
          {
               e.printStackTrace();
          }
     }
     return result;
   }

}
```

Notify -Example

```
public class ThrNotifyWait {

    public static void main(String[] args) {

        Computations[] comp = new Computations[4];

        for(int i =0;i<4 ;i++)
        {
        comp[i] = new Computations(i);
        comp[i].start();
        }

        for(Computations c :comp)
            System.out.println(c.getResult());

    }

}
```

Concurrency

- Java platform always has a strong support for concurrent programming and multithreading.
- earlier days the support was in the form of calling native constructs itself in the application layer.
- Before java 1.5, multithreading applications were created using thread group, thread pool or custom thread pool.
- Entire thread management was the responsibility of the programmer keeping in mind the following points.
  - Thread synchronization
  - Thread waiting
  - Thread joining
  - Thread locking
  - Thread notification
  - Handling dead lock
- Disadvantage
  - Handle those primitive construct calls efficiently. Otherwise the application will not run properly and unexpected results will be generated.

Thread Pool

- A thread pool is a group of pre-instantiated, idle threads which stand ready to be given work.
- Preferred over instantiating new threads for each task when there is a large number of short tasks to be done rather than a small number of long ones.
- Prevents having to incur the overhead of creating a thread a large number of times.

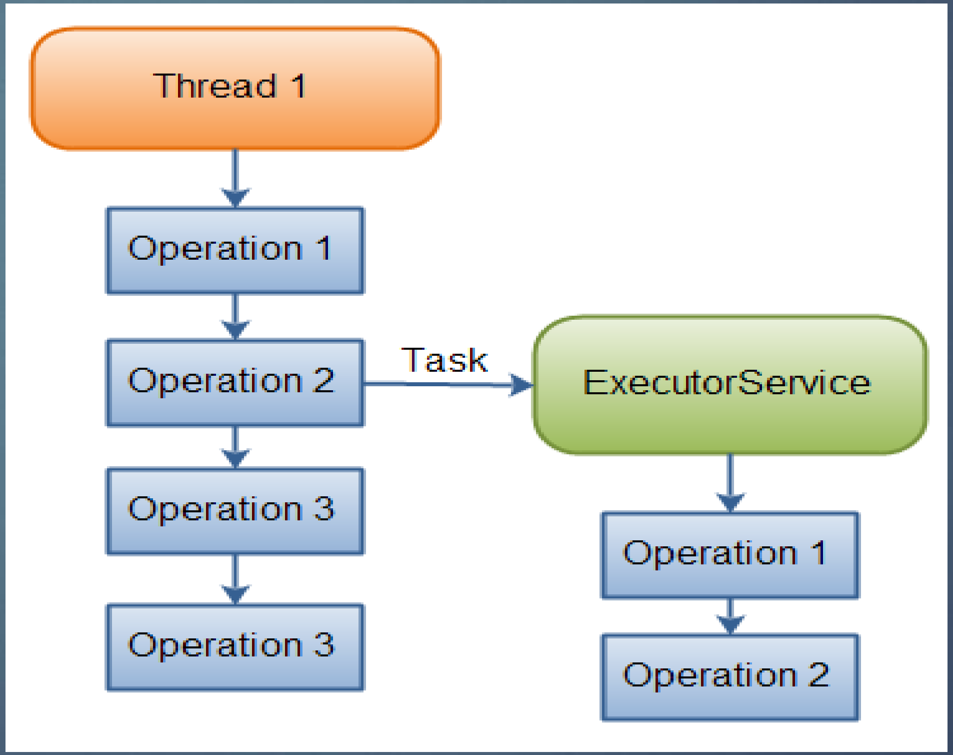
Executor Framework

- Introduced in Java 1.5 .
- Part of java concurrency package.
- Abstraction layer over the actual implementation of java multithreading.
  - hides the critical parts of concurrent execution and the programmer only concentrates on the business logic implementation.
- First concurrent utility framework in java ,used for standardizing invocation, scheduling, execution and control of asynchronous tasks in parallel threads.
- Executor implementation thread pools which consists of worker threads.

Executor Framework

- Parallel works are considered as tasks instead of simple threads.
- Application deals simply with instances of Runnable (which is basically collections of tasks or parallel works) and then it is passed to an **Executor** to process.
- The **ExecutorService** interface extends the simplistic Executor interface.
- The Java Executor framework has life cycle methods to manage the entire concurrent execution flow.

Executor Framework



Creating Thread Pool

This class java.util.concurrent.Executors provides the following factory methods to create thread Pool:

- newFixedThreadPool() creates and executor with the *fixed thread pool.*
- The newCachedThreadPool() creates an executor with an expandable thread pool. This executor is suitable for applications that launch many short-lived tasks.
- The newSingleThreadExecutor() creates an executor that executes a single task at a time.

Executor Interfaces

The java.util.concurrent package defines the following executor interfaces:

- Executor, a simple interface that supports launching new tasks.
- ExecutorService, a subinterface of Executor, which adds features that help manage the lifecycle, both of the individual tasks and of the executor itself.

The Executor Interface

- Provides a single method, execute, designed to be a drop-in replacement for a common thread-creation idiom.
- If r is a Runnable object, and e is an Executor object you can replace

  (new Thread(r)).start();   with e.execute(r);

The ExecutorService Interface

- Supplements execute with a similar(), but more versatile submit method.
- submit() accepts Runnable objects, but also accepts Callable objects, which allow the task to return a value.
- submit() returns a Future object, which is used to retrieve the Callable return value and to manage the status of both Callable and Runnable tasks.
- Provides methods for submitting large collections of Callable objects.
  - invokeAny() method takes a collection of Callable objects, or subinterfaces of Callable.
  - The invokeAll() method invokes all of the Callable objects passed as parameter,returns a list of Future objects .

Shutdown Pool

- ExecutorService provides() a number of methods for managing the shutdown of the executor. To support immediate shutdown, tasks should handle interrupts correctly.
  - shutdown() method will not shut down immediately
  - Will no longer accept new tasks.
  - once all threads have finished current tasks, the ExecutorService shuts down.
  - All tasks submitted to the ExecutorService before shutdown() is called, are executed.
  - to shut down the ExecutorService immediately, call shutdownNow() method.

Modifier and Type	Method and Description
Boolean	**awaitTermination(long timeout, TimeUnit unit)**Blocks until all tasks have completed execution after a shutdown request, or the timeout occurs, or the current thread is interrupted, whichever happens first.
<T> **List<Future<T>>**	**invokeAll Collection<? extends Callable<T>> tasks)**Executes the given tasks, returning a list of Futures holding their status and results when all complete.
<T> List Future	**invokeAll Collection<? extends Callable<T>> tasks, long timeout, TimeUnit** Executes the given tasks, returning a list of Futures holding their status and results when all complete or the timeout expires, whichever happens first.
<T> T	**invokeAny(Collection<? extends Callable<T>> tasks)**Executes the given tasks, returning the result of one that has completed successfully (i.e., without throwing an exception), if any do.
<T> T	**invokeAny(Collection<? extends Callable<T>> tasks, long timeout, TimeUnit unit)**Executes the given tasks, returning the result of one that has completed successfully (i.e., without throwing an exception), if any do before the given timeout elapses.
Boolean	**isShutdown()**Returns true if this executor has been shut down.
	isTerminated() Returns true if all tasks have completed following shut down.
Void	**shutdown()**Initiates an orderly shutdown in which previously submitted tasks are executed, but no new tasks will be accepted.
List Runnable	**shutdownNow()**Attempts to stop all actively executing tasks, halts the processing of waiting tasks, and returns a list of the tasks that were awaiting execution.
<T> **Future<T>**	**submit Callable<T> task)**Submits a value-returning task for execution and returns a Future representing the pending results of the task.
Future	**submit Runnable task)**Submits a Runnable task for execution and returns a Future representing that task.
<T> **Future<T>**	**submit Runnable task, T result)**Submits a Runnable task for execution and returns a Future representing that task.

Callable and Future Interfaces

- Callable has just one method call() which holds all the code needs to executed asynchronously.
- In Runnable interface, there was no way to return the result of computation or throw checked exception but with Callable you can both return a value and can throw checked exception.
- You can use get() method of Future to retrieve result once computation is done. You can check if computation is finished or not by using isDone() method.
- You can cancel the computation by using Future.cancel() method.
- get() is a blocking call and it blocks until computation is completed.
- overloaded get() method with timeout: for definite blocking.

CountDownLatch

- CountDownLatch is used to make sure that a task waits for other threads before it starts.

How CountDownLatch works?

- When we create an object of CountDownLatch, we specify the number of threads it should wait for, all such thread are required to do count down by calling CountDownLatch.countDown() once they are completed or ready to the job. As soon as count reaches zero, the waiting task starts running.

Example

```
import java.util.concurrent.CountDownLatch;

public class CountDownLatchDemo
{
    public static void main(String args[])
                throws InterruptedException
    {
        // Let us create task that is going to
        // wait for four threads before it starts
        CountDownLatch latch = new CountDownLatch(4);

        // Let us create four worker
        // threads and start them.
        Worker first = new Worker(1000, latch,
                                  "WORKER-1");
        Worker second = new Worker(2000, latch,
                                  "WORKER-2");
        Worker third = new Worker(3000, latch,
                                  "WORKER-3");
        Worker fourth = new Worker(4000, latch,
                                  "WORKER-4");
    first.start();
        second.start();
        third.start();
        fourth.start();

        // The main task waits for four threads
        latch.await();

        // Main thread has started
        System.out.println(Thread.currentThread().getName() +
                             " has finished");
    }
}
```

Example

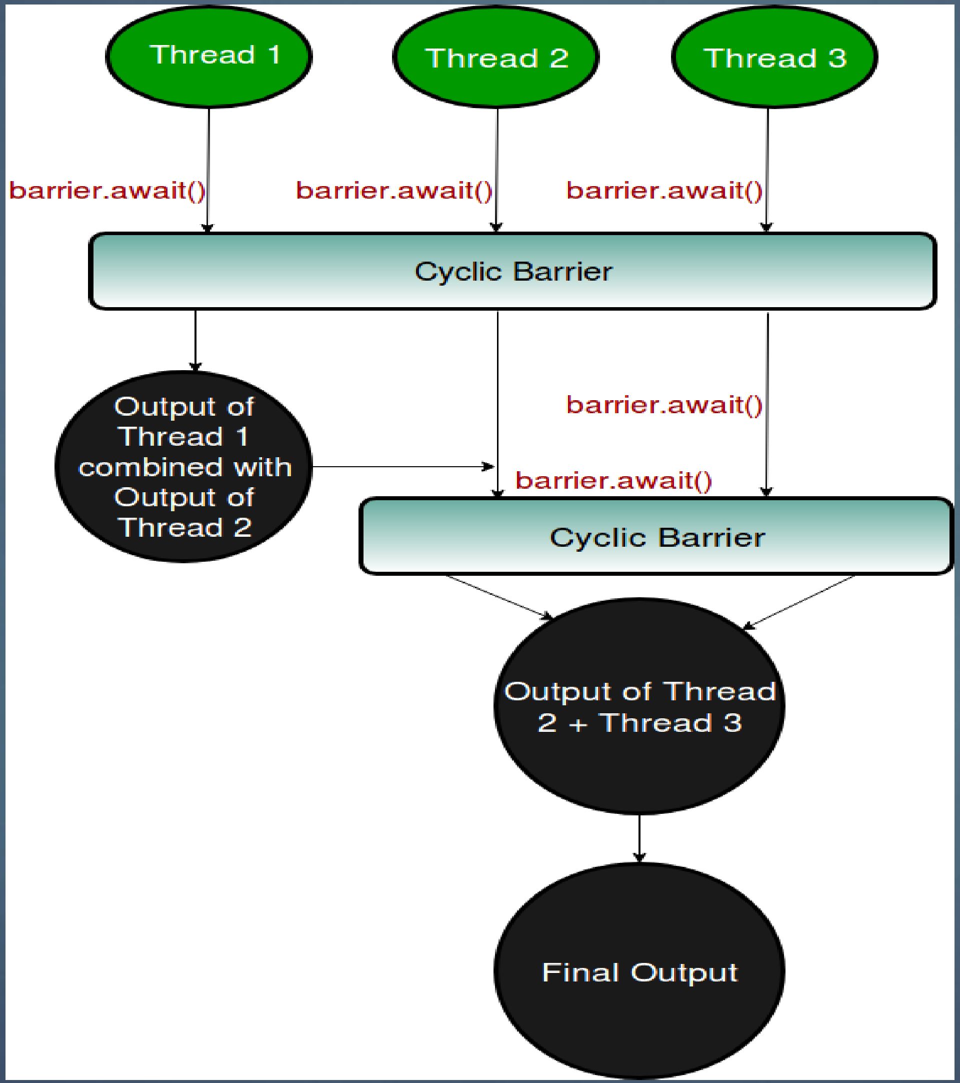
```
class Worker extends Thread
{
    private int delay;
    private CountDownLatch latch;

    public Worker(int delay, CountDownLatch latch,
                                    String name)
    {
        super(name);
        this.delay = delay;
        this.latch = latch;
    }
```

```
@Override
    public void run()
    {
        try
        {
            Thread.sleep(delay);
            latch.countDown();
            System.out.println(Thread.currentThread().getName()
                            + " finished");
        }
        catch (InterruptedException e)
        {
            e.printStackTrace();
        }
    }
}
```

CyclicBarrier

- The cyclic barrier is a concurrent utility mechanism of synchronization that allows a set of threads to all wait for each other to reach a common barrier point.
- It is useful in Java programs that involve a fixed-sized party of threads that must wait for each other. The word cyclic is used for its reused purpose.
- It means that the barrier can be re-used when all waiting threads are released. The point is the barrier that ensures all the threads complete their execution before reaching here.
- Therefore, the mechanism is known as the cyclic barrier.
- In short, cyclic barrier preserves a count of threads.

Working of CyclicBarrier



Methods of CyclicBarrier Class

Method	Description
await()	It returns the arrival index of the current thread.
await(long timeout, TimeUnit unit)	Waits until all parties (threads) have invoked await on this barrier, or the specified waiting time elapses.
getNumberWaiting()	The method is used to return the number of parties currently waiting at the barrier (blocked in await() method). The method is widely used for debugging and assertions.
getParties()	The method returns an integer value that denotes the number of parties required to trip this barrier.
isBroken()	The method returns a boolean value if one or more parties broke out of this barrier due to interruption or timeout since construction or the last reset or a barrier action failed due to an exception. Else, returns false.
reset()	The method is used to reset the barrier to its initial state. The method throws BrokenBarrierException if any parties are currently waiting at the barrier.

ThreadFactory Interface

- ThreadFactory is another choice to create new threads.
- This interface provides a factory method**(newThread(Runnable))** that creates and returns new threads when called.
- This factory method takes a Runnable object as an argument and creates a new thread using it.

Why use ThreadFactory?

- We can give the threads more meaningful custom names. It helps in analyzing their purposes and how they work.
- We can have the statistics about the created threads like the count of threads and other details. We can restrict the creation of new threads based on the statistics.
- We can set the daemon status of threads.
- We can set the thread priority.
- We can have all the features confined in one class.

Default Thread Factory

- Implemented by the **Executors.defaultThreadFactory()** static method.
- Used by many classes (such as ScheduledThreadPoolExecutor, ThreadPoolExecutor etc.) when they are not given any custom ThreadFactory.
- This default ThreadFactory creates all the new threads in the same ThreadGroup(A ThreadGroup represents a group of threads).
- All the created new threads are non-daemon with priority set to the smallest of Thread.NORM_PRIORITY and the maximum priority permitted in the ThreadGroup.
- The threads created by this default ThreadFactory are given names in the form of pool-N-thread-M (As examples, pool-1-thread-1, pool-1-thread-2, pool-2-thread-1 etc.) where N is the sequence number of this factory, and M is the sequence number of the threads created by this factory.

FutureTask

- FutureTask is a concrete implementation of the Future, Runnable, and RunnableFuture interfaces and therefore can be submitted to an ExecutorService instance for execution.
- FutureTask call get() waits for the task to complete or error out.
- Behaviour of the parameterless get() method depends on the state of the task. If tasks are not completed, get() method blocks until the task is completed. Once the task complete, it returns the result or throws an ExecutionException.
- An overloaded variant of get() allows passing a timeout parameter to limit the amount of time the thread waits for a result.

Example

```
class MyCallable implements Callable<String> {

    private long waitTime;

    public MyCallable(int timeInMillis) {
        this.waitTime = timeInMillis;
    }

    @Override
    public String call() throws Exception {
        Thread.sleep(waitTime);
        // return the thread name executing this callable task
        return Thread.currentThread().getName();
    }

}
```

Example

```
public class FutureTaskExampleTwo {

	public static void main(String[] args) {
		MyCallable callable1 = new MyCallable(1000);
		MyCallable callable2 = new MyCallable(2000);

		FutureTask<String> futureTask1 = new FutureTask<String>(callable1);
		FutureTask<String> futureTask2 = new FutureTask<String>(callable2);

		ExecutorService executor = Executors.newFixedThreadPool(2);
		executor.execute(futureTask1);
		executor.execute(futureTask2);

		while (true) {
			try {
				if (futureTask1.isDone() && futureTask2.isDone()) {
					System.out.println("Done");
					// shut down executor service
					executor.shutdown();
					return;
				}
if (!futureTask1.isDone()) {
					// wait indefinitely for future task to complete
					System.out.println("FutureTask1 output=" +
futureTask1.get());
				}

				System.out.println("Waiting for FutureTask2 to complete");
				String s = futureTask2.get(200L, TimeUnit.MILLISECONDS);
				if (s != null) {
					System.out.println("FutureTask2 output=" + s);
				}
			} catch (InterruptedException | ExecutionException e) {
				e.printStackTrace();
			} catch (TimeoutException e) {
				// do nothing
			}
		}

	}

}
```

SUJATABATRA

Semaphore

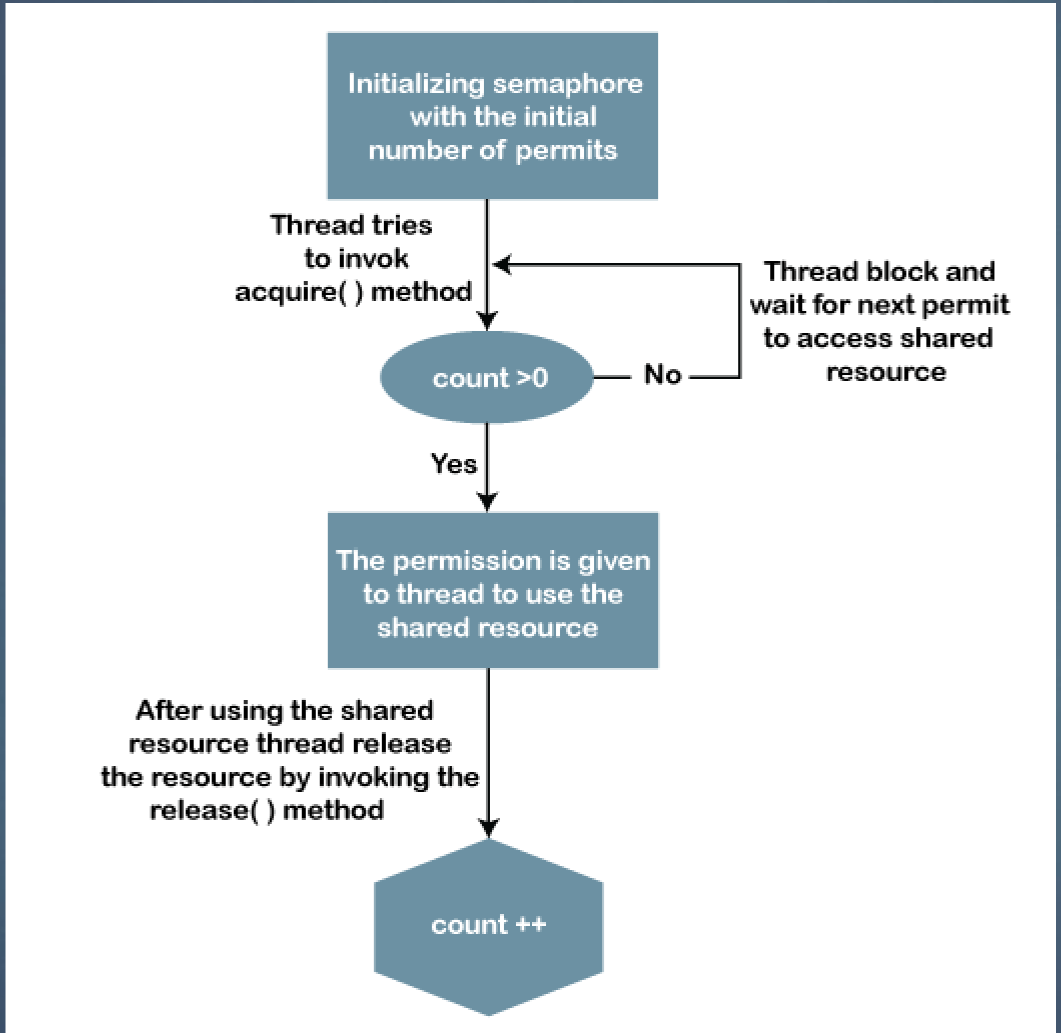
- A Semaphore is used to limit the number of threads that want to access a shared resource.
- It is a non-negative variable that is shared among the threads known as a counter. It sets the limit of the threads. A mechanism in which a thread is waiting on a semaphore can be signaled by other threads.
  - If counter > 0, access to shared resources is provided.
  - If counter = 0, access to shared resources is denied.
- In short, the counter keeps tracking the number of permissions it has given to a shared resource. Therefore, semaphore grants permission to threads to share a resource.

Working of Semaphore

Semaphore controls over the shared resource through a counter variable. The counter is a non-negative value. It contains a value either greater than 0 or equal to 0.

- If counter > 0, the thread gets permission to access the shared resource and the counter value is decremented by 1.
- Else, the thread will be blocked until a permit can be acquired.
- When the execution of the thread is completed then there is no need for the resource and the thread releases it. After releasing the resource, the counter value incremented by 1.
- If another thread is waiting for acquiring a resource, the thread will acquire a permit at that time.
- If counter = 0, the thread does not get permission to access the shared resource.

Working of Semaphore



Initializing semaphore with the initial number of permits
Thread tries to invok acquire( ) method
Thread block and wait for next permit to access shared resource
count >0
No
Yes
The permission is given to thread to use the shared resource
After using the shared resource thread release the resource by invoking the release( ) method
count ++

Working of Semaphore in Java

S U J A T A B A T R A

Semaphore class

- **Semaphore class** is used to implement the semaphore mechanism.
- It belongs to the **java.util.concurrent** package.
- The Semaphore class provides two constructors:
  - Semaphore(int permits)
  - Semaphore(int permits, boolean fair)
- permits: The value of permits may be negative. In such a case, the release must occur before any acquires will be granted.
- fair: If we set the value to true, the semaphore guarantees FIFO to the threads in the order they are requested, false By default, all the threads that are waiting for the resource grants permit in an undefined order.

Methods of Semaphore Class

- **acquire() Method**: The method acquire the permits from the semaphore, blocking until one is available, or the thread is interrupted. It reduces the number of available permits by 1.
- If there is no permit is available for the current thread, the thread becomes disabled for the thread scheduling purposes. The current thread goes in the inactive state until one of two things happens:
- If the other thread invokes the release() method to release the resource then the current thread gets permits.
- If the other thread interrupts the current thread.
- It throws InterruptedException if the current thread is interrupted. The method does not return any value.

Syntax:

public void acquire() throws InterruptedException

Methods of Semaphore Class

- **release() Method**: It releases a permit and returns it to the semaphore. It increments the number of available permits by 1. If a thread tries to acquire a permit, the semaphore grants permission to acquire the resource that was just released by other threads. Further, that thread is considered for thread scheduling purposes.

Syntax:

```
public void release()
```

Methods of Semaphore Class

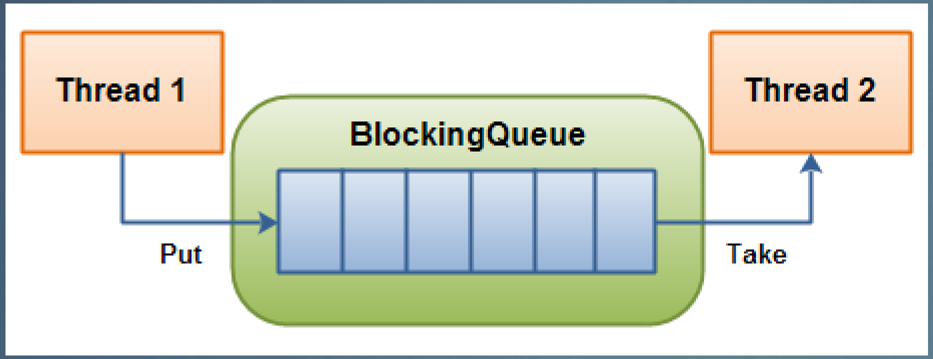
- **availablePermits() Method**: The method returns the number of permits available in semaphore for granting the resource. Usually, it is used for debugging and testing purposes.

Syntax:

public int availablePermits()

Blocking Queue

- A BlockingQueue is used to have on thread produce objects, which another thread consumes.



Blocking Queue

- The producing thread will keep producing new objects and insert them into the queue, until the queue reaches some upper bound on what it can contain.
- If the blocking queue reaches its upper limit, the producing thread is blocked while trying to insert the new object.
- It remains blocked until a consuming thread takes an object out of the queue.
- The consuming thread keeps taking objects out of the blocking queue, and processes them.
- If the consuming thread tries to take an object out of an empty queue, the consuming thread is blocked until a producing thread puts an object into the queue.

Blocking Queue Methods

	Throws Exception	Special Value	Blocks	Times Out
Insert	add(o)	offer(o)	put(o)	offer(o, timeout, timeunit)
Remove	remove(o)	poll()	take()	poll(timeout, timeunit)
Examine	element()	peek()		

SUJATABATRA

- Throws Exception:
  - If the attempted operation is not possible immediately, an exception is thrown.
- Special Value:
  - If the attempted operation is not possible immediately, a special value is returned (often true / false).
- Blocks:
  - If the attempted operation is not possible immedidately, the method call blocks until it is.
- Times Out:
  - If the attempted operation is not possible immedidately, the method call blocks until it is, but waits no longer than the given timeout. Returns a special value telling whether the operation succeeded or not (typically true / false).

Note: It is not possible to insert null into a BlockingQueue. If you try to insert null, the BlockingQueue will throw a NullPointerException.

Blocking Queue Implementation Classes

- ArrayBlockingQueue
  - ArrayBlockingQueue is a bounded, blocking queue that stores the elements internally in an array. That it is bounded means that it cannot store unlimited amounts of elements. There is an upper bound on the number of elements it can store at the same time. You set the upper bound at instantiation time, and after that it cannot be changed.
- DelayQueue
  - The DelayQueue blocks the elements internally until a certain delay has expired.
- LinkedBlockingQueue
  - The LinkedBlockingQueue keeps the elements internally in a linked structure (linked nodes). This linked structure can optionally have an upper bound if desired. If no upper bound is specified, Integer.MAX_VALUE is used as the upper bound.
  - The LinkedBlockingQueue stores the elements internally in FIFO (First In, First Out) order. The head of the queue is the element which has been in queue the longest time, and the tail of the queue is the element which has been in the queue the shortest time.
- PriorityBlockingQueue
  - The PriorityBlockingQueue is an unbounded concurrent queue.
  - All elements inserted into the PriorityBlockingQueue must implement the java.lang.Comparable interface. The elements thus order themselves according to whatever priority you decide in your Comparable implementation.
- SynchronousQueue
  - The SynchronousQueue is a queue that can only contain a single element internally. A thread inseting an element into the queue is blocked until another thread takes that element from the queue. Likewise, if a thread tries to take an element and no element is currently present, that thread is blocked until a thread insert an element into the queue.

CompletableFuture

- CompletableFuture is used for asynchronous programming in Java. Asynchronous programming is a means of writing non-blocking code by running a task on a separate thread than the main application thread and notifying the main thread about its progress, completion or failure.

- This way, your main thread does not block/wait for the completion of the task and it can execute other tasks in parallel.

- Having this kind of parallelism greatly improves the performance of your programs.

Future vs CompletableFuture

- CompletableFuture is an extension to Java's Future API which was introduced in Java 5.
- A Future is used as a reference to the result of an asynchronous computation. It provides an isDone() method to check whether the computation is done or not, and a get() method to retrieve the result of the computation when it is done.

Limitations of Future

- It cannot be manually completed
- You cannot perform further action on a Future's result without blocking
- Multiple Futures cannot be chained together
- You can not combine multiple Futures together
- No Exception Handling

CompletableFuture

- CompletableFuture implements **Future and CompletionStage interfaces** and provides a huge set of convenience methods for creating, chaining and combining multiple Futures. It also has a very comprehensive exception handling support.

CompletableFuture

- Use no-arg constructor to create CompletableFuture

```
CompletableFuture<String> completableFuture = new CompletableFuture<String>();
```

Methods of CompletableFuture

- get(): Blocks for this future to complete, and then returns its result.

Example : String result = completableFuture.get()

- complete(): manually complete a Future.

Example : completableFuture.complete("Future's Result")

Methods of CompletableFuture

- If you want to run some background task asynchronously and don't want to return anything from the task, then you can use **CompletableFuture.runAsync()** method. It takes a Runnable object and returns CompletableFuture<Void>.

Example:

```
CompletableFuture<Void> future = CompletableFuture.runAsync(new Runnable() {
    @Override
    public void run() {
        // Simulate a long-running Job
        try {
            TimeUnit.SECONDS.sleep(1);
        } catch (InterruptedException e) {
            throw new IllegalStateException(e);
        }
        System.out.println("I'll run in a separate thread than the main thread.");
    }
});
// Block and wait for the future to complete
future.get()
```

Methods of CompletableFuture

- Run a task asynchronously and return the result using **supplyAsync()**

Example

```
CompletableFuture<String> future = CompletableFuture.supplyAsync(new Supplier<String>() {
    @Override
    public String get() {
        try {
            TimeUnit.SECONDS.sleep(1);
        } catch (InterruptedException e) {
            throw new IllegalStateException(e);
        }
        return "Result of the asynchronous computation";
    }
});

// Block and get the result of the Future
String result = future.get();
System.out.println(result);
```

Transforming and acting on a CompletableFuture

- **thenApply():** use thenApply() method to process and transform the result of a CompletableFuture when it arrives. It takes a Function<T,R> as an argument.

Example:

```
CompletableFuture<String> whatsYourNameFuture = CompletableFuture.supplyAsync(() -> {
  try {
     TimeUnit.SECONDS.sleep(1);
  } catch (InterruptedException e) {
     throw new IllegalStateException(e);
  }
  return "Rajeev";
});
// Attach a callback to the Future using thenApply()
CompletableFuture<String> greetingFuture = whatsYourNameFuture.thenApply(name -> {
  return "Hello " + name;
});

// Block and get the result of the future.
System.out.println(greetingFuture.get()); // Hello Rajeev
```

Transforming and acting on a CompletableFuture

- **thenAccept() and thenRun()** : run some piece of code after the completion of the Future, then you can use thenAccept() and thenRun() methods. These methods are consumers and are often used as the last callback in the callback chain.

Example:

```
// thenAccept() example
CompletableFuture.supplyAsync(() -> {
    return ProductService.getProductDetail(productId);
}).thenAccept(product -> {
    System.out.println("Got product detail from remote service " + product.getName())
});
```

Transforming and acting on a CompletableFuture

- thenRun() :While thenAccept() has access to the result of the CompletableFuture on which it is attached, thenRun() doesn't even have access to the Future's result. It takes a Runnable and returns CompletableFuture<Void>

Example:

```
// thenRun() example
CompletableFuture.supplyAsync(() -> {
   // Run some computation
}).thenRun(() -> {
   // Computation Finished.
});
```

Combining two CompletableFutures together

- **thenCombine()** is used when you want two Futures to run independently and do something after both are complete.

Example:

```
CompletableFuture<Double> weightInKgFuture =
CompletableFuture.supplyAsync(() -> {
    try {
        TimeUnit.SECONDS.sleep(1);
    } catch (InterruptedException e) {
       throw new IllegalStateException(e);
    }
    return 65.0;
});
```

```
CompletableFuture<Double> heightInCmFuture
= CompletableFuture.supplyAsync(() -> {
    try {
        TimeUnit.SECONDS.sleep(1);
    } catch (InterruptedException e) {
       throw new IllegalStateException(e);
    }
    return 177.8;
});
```

```
System.out.println("Calculating BMI.");
CompletableFuture<Double> combinedFuture = weightInKgFuture
        .thenCombine(heightInCmFuture, (weightInKg, heightInCm) -> {
    Double heightInMeter = heightInCm/100;
    return weightInKg/(heightInMeter*heightInMeter);
});

System.out.println("Your BMI is - " + combinedFuture.get());
```

CompletableFuture Exception Handling

- **exceptionally()** callback gives you a chance to recover from errors generated from the original Future. You can log the exception here and return a default value.

Example:

```
Integer age = -1;

CompletableFuture<String> maturityFuture = CompletableFuture.supplyAsync(() -> {
   if(age < 0) {
      throw new IllegalArgumentException("Age can not be negative");
   }
   if(age > 18) {
      return "Adult";
   } else {
      return "Child";
   }
}).exceptionally(ex -> {
   System.out.println("Oops! We have an exception - " + ex.getMessage());
   return "Unknown!";
});

System.out.println("Maturity : " + maturityFuture.get());
```

CompletableFuture Exception Handling

- **handle()** to recover from exceptions. It is called whether or not an exception occurs.

Example:

```
Integer age = -1;

CompletableFuture<String> maturityFuture = CompletableFuture.supplyAsync(() -> {
    if(age < 0) {
        throw new IllegalArgumentException("Age can not be negative");
    }
    if(age > 18) {
        return "Adult";
    } else {
        return "Child";
    }
}).handle((res, ex) -> {
    if(ex != null) {
        System.out.println("Oops! We have an exception - " + ex.getMessage());
        return "Unknown!";
    }
    return res;
});
System.out.println("Maturity : " + maturityFuture.get());
```

Note : If an exception occurs, then the res argument will be null, otherwise, the ex argument will be null.

SUJATABATRA

Syslog

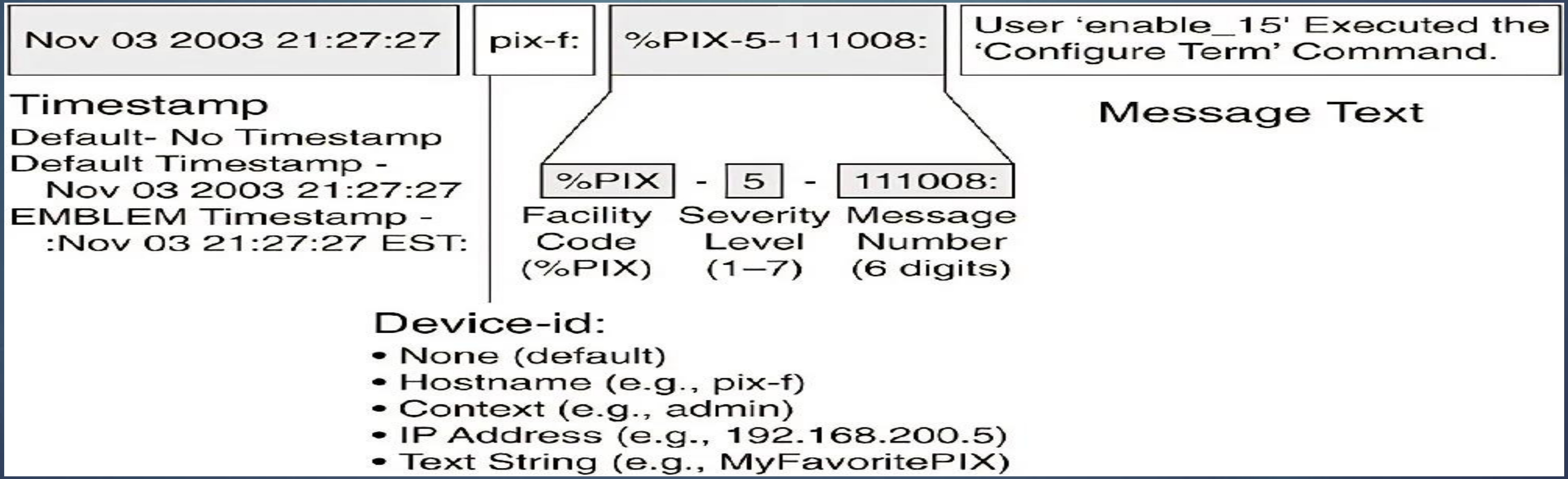
- Syslog is a standard for sending and receiving notification messages–in a particular format–from various network devices.
- The messages include : time stamps, event messages, severity, host IP addresses, diagnostics and more.
- Its built-in severity level, it can communicate a range between level 0, an Emergency, level 5, a Warning, System Unstable, critical and level 6 and 7 which are Informational and Debugging.

Syslog

- Syslog was designed to monitor network devices and systems to send out notification messages if there are any issues with functioning–it also sends out alerts for pre-notified events and monitors suspicious activity via the change log/event log of participating network devices.

Syslog

- The Syslog protocol was initially written by Eric Allman and is defined in RFC 3164. The messages are sent across IP networks to the event message collectors or syslog servers. Syslog uses the User Datagram Protocol (UDP), port 514, to communicate. Although, syslog servers do not send back an acknowledgment of receipt of the messages. Since 2009, syslog has been standardized by the IETF in RFC 5424.


Nov 03 2003 21:27:27
pix-f:
%PIX-5-111008:
User 'enable_15' Executed the 'Configure Term' Command.
Timestamp
Default- No Timestamp
Default Timestamp - Nov 03 2003 21:27:27
EMBLEM Timestamp - :Nov 03 21:27:27 EST:
%PIX - 5 - 111008:
Facility Code (%PIX)
Severity Level (1—7)
Message Number (6 digits)
Message Text
Device-id:
• None (default)
• Hostname (e.g., pix-f)
• Context (e.g., admin)
• IP Address (e.g., 192.168.200.5)
• Text String (e.g., MyFavoritePIX)

SUJATA BATRA

Benefits of Logging

- Reduce the number of trouble tickets
- Reduce downtime
- Decrease the volume of business interruptions
- Promote preventative troubleshooting

Without logging, it can become a nightmare to search for a single transaction that may have been processed on any of your servers. With centralized logging, you get a correlated view of all of the log data. In contrast, reviewing each log file separately can become quite time-consuming. This is why using Syslog to forward local log messages to a remote log analytics server has become the standard for logging solutions.

Component of Syslog

- **A Syslog listener**–The listener gathers and processes syslog data sent over UDP port 514. Although, there is no acknowledgment receipt and messages aren't guaranteed to arrive.

- **A database**–Syslog servers need databases to store the massive amounts of data for quick access.

- **Management and filtering software**–Since there can be enormous amounts of data, it can take excessive amounts of time to find specific log entries. The syslog server needs help to automate the work, as well as to filter to view specified log messages. To illustrate, it can extract messages based on specific parameters such as a critical event or device name. You can also use the filter to avoid seeing certain types of entries through the Negative Filter rule. If you wanted, you could show all of the critical log messages from a firewall.