The Java Executors Utility Class

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Learning Objectives in this Lesson

• Understand the implementation of key methods in the Executors utility class

**Class Executors**

```java
java.lang.Object
    java.util.concurrent.Executors

public class Executors
    extends Object

Factory and utility methods for Executor, ExecutorService, ScheduledExecutorService, ThreadFactory, and Callable classes defined in this package. This class supports the following kinds of methods:
  • Methods that create and return an ExecutorService set up with commonly useful configuration settings.
  • Methods that create and return a ScheduledExecutorService set up with commonly useful configuration settings.
  • Methods that create and return a "wrapped" ExecutorService, that disables reconfiguration by making implementation-specific methods inaccessible.
  • Methods that create and return a ThreadFactory that sets newly created threads to a known state.
  • Methods that create and return a Callable out of other closure-like forms, so they can be used in execution methods requiring Callable.
```
The Java Executors Utility Class
The Java Executors Utility Class

• Executors is a Java utility class

```
public class Executors
extends Object

Factory and utility methods for Executor, ExecutorService,
ScheduledExecutorService, ThreadFactory, and Callable classes defined in
this package. This class supports the following kinds of methods:
• Methods that create and return an ExecutorService set up with
  commonly useful configuration settings.
• Methods that create and return a ScheduledExecutorService set up
  with commonly useful configuration settings.
• Methods that create and return a “wrapped” ExecutorService, that
  disables reconfiguration by making implementation-specific methods
  inaccessible.
• Methods that create and return a ThreadFactory that sets newly created
  threads to a known state.
• Methods that create and return a Callable out of other closure-like
  forms, so they can be used in execution methods requiring Callable.
```

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/Executors.html
The Java Executors Utility Class

- Executors is a Java utility class
- A utility class is a final class having only static methods, no non-static state, & a private constructor

```
public class Executors
extends java.lang.Object

java.util.concurrent.Executor
java.util.concurrent.ExecutorService
java.util.concurrent.ScheduledExecutorService
java.lang.ThreadFactory
java.util.concurrent.Callable
```

Factory and utility methods for Executor, ExecutorService, ScheduledExecutorService, ThreadFactory, and Callable classes defined in this package. This class supports the following kinds of methods:

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- Methods that create and return a Callable out of other closure-like forms, so they can be used in execution methods requiring Callable.

The Java Executors Utility Class

- It defines utility methods used by Executor framework classes

```java
newFixedThreadPool(int): ExecutorService
newWorkStealingPool(int): ExecutorService
newWorkStealingPool(): ExecutorService
newFixedThreadPool(int, ThreadFactory): ExecutorService
newSingleThreadExecutor(): ExecutorService
newSingleThreadExecutor(ThreadFactory): ExecutorService
newCachedThreadPool(): ExecutorService
newCachedThreadPool(ThreadFactory): ExecutorService
newSingleThreadScheduledExecutor(): ScheduledExecutorService
newSingleThreadScheduledExecutor(ThreadFactory): ScheduledExecutorService
newScheduledThreadPool(int): ScheduledExecutorService
newScheduledThreadPool(int, ThreadFactory): ScheduledExecutorService

defaultThreadFactory()
privilegedThreadFactory()
callable(Runnable, T): Callable<T>
callable(Runnable): Callable<Object>
callable(PrivilegedAction<?>): Callable<Object>
callable(PrivilegedExceptionAction<?>): Callable<Object>
privilegedCallable(Callable<T>): Callable<T>
privilegedCallableUsingCurrentClassLoader(Callable<T>): Callable<T>
```
The Java Executors Utility Class

- It defines utility methods used by Executor framework classes, e.g.
- `defaultThreadFactory()` sets new threads to a known state

```java
public class Executors {
    ...
    public static ThreadFactory defaultThreadFactory() {
        return new DefaultThreadFactory();
    }
}
```

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ThreadFactory.html
The Java Executors Utility Class

- It defines utility methods used by Executor framework classes, e.g.
  - `defaultThreadFactory()` sets new threads to a known state
  - The `defaultThreadFactory()` is used by these factory methods

```java
defaultThreadFactory()
Returns a default thread factory used to create new threads.

newCachedThreadPool()
Creates a thread pool that creates new threads as needed, but will reuse previously constructed threads when they are available.

newCachedThreadPool(ThreadFactory threadFactory)
Creates a thread pool that creates new threads as needed, but will reuse previously constructed threads when they are available, and uses the provided ThreadFactory to create new threads when needed.

newFixedThreadPool(int nThreads)
Creates a thread pool that reuses a fixed number of threads operating off a shared unbounded queue.

newFixedThreadPool(int nThreads, ThreadFactory threadFactory)
Creates a thread pool that reuses a fixed number of threads operating off a shared unbounded queue, using the provided ThreadFactory to create new threads when needed.

newScheduledThreadPool(int corePoolSize)
Creates a thread pool that can schedule commands to run after a given delay, or to execute periodically.

newScheduledThreadPool(int corePoolSize, ThreadFactory threadFactory)
Creates a thread pool that can schedule commands to run after a given delay, or to execute periodically.
```
## The Java Executors Utility Class

- It defines utility methods used by Executor framework classes, e.g.
  - `defaultThreadFactory()` sets new threads to a known state
  - User-defined `ThreadFactory` objects can be passed to other factory methods in Executors

<table>
<thead>
<tr>
<th>Method Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>defaultThreadFactory()</code></td>
<td>Returns a default thread factory used to create new threads.</td>
</tr>
<tr>
<td><code>newCachedThreadPool()</code></td>
<td>Creates a thread pool that creates new threads as needed, but will reuse previously constructed threads when they are available.</td>
</tr>
<tr>
<td><code>newFixedThreadPool(int nThreads)</code></td>
<td>Creates a thread pool that reuses a fixed number of threads operating off a shared unbounded queue.</td>
</tr>
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</tr>
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The Java Executors Utility Class

- It defines utility methods used by Executor framework classes, e.g.
  - `defaultThreadFactory()` sets new threads to a known state
  - User-defined ThreadFactory objects can be passed to other factory methods in Executors
    - e.g., enables apps to create custom thread subclasses, priorities, etc.

```java
defaultThreadFactory()
Returns a default thread factory used to create new threads.

newCachedThreadPool()
Creates a thread pool that creates new threads as needed, but will reuse previously constructed threads when they are available.

newCachedThreadPool(ThreadFactory threadFactory)
Creates a thread pool that creates new threads as needed, but will reuse previously constructed threads when they are available, and uses the provided ThreadFactory to create new threads when needed.

newFixedThreadPool(int nThreads)
Creates a thread pool that reuses a fixed number of threads operating off a shared unbounded queue.

newFixedThreadPool(int nThreads, ThreadFactory threadFactory)
Creates a thread pool that reuses a fixed number of threads operating off a shared unbounded queue, using the provided ThreadFactory to create new threads when needed.

newScheduledThreadPool(int corePoolSize)
Creates a thread pool that can schedule commands to run after a given delay, or to execute periodically.

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The Java Executors Utility Class

- It defines utility methods used by Executor framework classes, e.g.
  - `defaultThreadFactory()` sets new threads to a known state
  - User-defined `ThreadFactory` objects can be passed to other factory methods in Executors
  - Create a callable from a runnable

```java
class Executors {
    ...
    public static Callable<Object> callable(Runnable task) {
        ...
        return new RunnableAdapter<Object>(task, null);
    }
}
```
The Java Executors Utility Class

- It defines utility methods used by Executor framework classes, e.g.
  - defaultThreadFactory() sets new threads to a known state
  - User-defined ThreadFactory objects can be passed to other factory methods in Executors
  - Create a callable from a runnable

```java
public class Executors {
    ...
    public static Callable<Object> callable(Runnable task) {
        ...
        return new RunnableAdapter<Object>(task, null);
    }
}
```

```java
class RunnableAdapter<T> implements Callable<T> {
    final Runnable task; final T result;
    RunnableAdapter(Runnable t, T r) { task = t; result = r; }
    public T call() { task.run(); return result; }
}
```

See runtimeverification.com/monitor/annotated-java-8/java/util/concurrent/ExecutorsRunnableAdapter.html
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools.
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools

- It can also create a thread pool with just one thread!
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
- Create fixed-sized thread pools

```java
public class Executors {
    ...
    public static ExecutorService
        newFixedThreadPool(int nThreads, ThreadFactory threadFactory) {
        return new ThreadPoolExecutor
            (nThreads, nThreads,
             0L, TimeUnit.MILLISECONDS,
             new LinkedBlockingQueue
                <Runnable>(),
             threadFactory);
    }
}
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Uses ThreadPoolExecutor class

```java
public class Executors {

  ...  

  public static ExecutorService newFixedThreadPool(int nThreads,
                  ThreadFactory threadFactory) {
    return new ThreadPoolExecutor
              (nThreads, nThreads,
               0L, TimeUnit.MILLISECONDS,
               new LinkedBlockingQueue
                      <Runnable>(),
               threadFactory);
  }

  See earlier lesson on “Overview of Java ThreadPoolExecutor”
```
It also defines factory methods to make Executor thread pools, e.g.

- Create fixed-sized thread pools
  - Uses ThreadPoolExecutor class
  - Core pool size & maximum pool size are the same

```java
public class Executors {
    ...
    public static ExecutorService newFixedThreadPool(int nThreads,
        ThreadFactory threadFactory) {
        return new ThreadPoolExecutor(
            nThreads, nThreads,
            0L, TimeUnit.MILLISECONDS,
            new LinkedBlockingQueue<Runnable>(),
            threadFactory);
    }
}
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
    - Uses ThreadPoolExecutor class
    - Core pool size & maximum pool size are the same
    -Idle threads don’t timeout

```java
public class Executors {

  public static ExecutorService newFixedThreadPool(int nThreads,
                                                    ThreadFactory threadFactory) {
    return new ThreadPoolExecutor(
                                   nThreads, nThreads,
                                   0L, TimeUnit.MILLISECONDS,
                                   new LinkedBlockingQueue<Runnable>(),
                                   threadFactory);
  }
}
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
    - Uses ThreadPoolExecutor class
    - Core pool size & maximum pool size are the same
    - Idle threads don’t timeout
  - Threads can block on a shared unbounded queue

```java
public class Executors {
    ...
    public static ExecutorService
        newFixedThreadPool(int nThreads,
                            ThreadFactory threadFactory){
        return new ThreadPoolExecutor
                        (nThreads, nThreads,
                         0L, TimeUnit.MILLISECONDS,
                         new LinkedBlockingQueue
                                           <Runnable>(),
                         threadFactory);
    }
}
```

See [docs.oracle.com/javase/8/docs/api/java/util/concurrent/LinkedBlockingQueue.html](http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/LinkedBlockingQueue.html)
The Java Executors Utility Class

• It also defines factory methods to make Executor thread pools, e.g.
  • Create fixed-sized thread pools
    • Uses ThreadPoolExecutor class
    • Core pool size & maximum pool size are the same
    • Idle threads don’t timeout
    • Threads can block on a shared unbounded queue
  • Threads can be created via a custom ThreadFactory

```java
public class Executors {
    ...
    public static ExecutorService newFixedThreadPool(int nThreads,
        ThreadFactory threadFactory) {
        return new ThreadPoolExecutor(nThreads,
            nThreads,
            0L, TimeUnit.MILLISECONDS,
            new LinkedBlockingQueue<Runnable>(),
            threadFactory);
    }
}
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
    - Uses ThreadPoolExecutor class
    - Core pool size & maximum pool size are the same
    - Idle threads don’t timeout
    - Threads can block on a shared unbounded queue
    - Threads can be created via a custom ThreadFactory

```java
public class Executors {
    ...
    public static ExecutorService newFixedThreadPool(int nThreads) {
        return new ThreadPoolExecutor(nThreads,
                                        nThreads,
                                        0L,
                                        TimeUnit.MILLISECONDS,
                                        new LinkedBlockingQueue<>());
    }
}
```

A variant of `newFixedThreadPool()` uses `DefaultThreadFactory`
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools

```java
public class Executors {
    ...
    public static ExecutorService newCachedThreadPool(
        ThreadFactory threadFactory)
    {
        return new ThreadPoolExecutor(0,
            Integer.MAX_VALUE,
            60L,
            TimeUnit.SECONDS,
            new SynchronousQueue<>(),
            threadFactory);
    }
    ...
}
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
- Uses ThreadPoolExecutor class

```java
public class Executors {
    ...

    public static ExecutorService newCachedThreadPool(TreadFactory threadFactory) {
        return new ThreadPoolExecutor(0, Integer.MAX_VALUE,
                                       60L, TimeUnit.SECONDS,
                                       new SynchronousQueue<Runnable>(),
                                       threadFactory);
    }

    ...
}

See earlier lesson on “Overview of Java ThreadPoolExecutor”
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
  - Uses ThreadPoolExecutor class
  - New threads started as needed, but existing threads are reused

```java
public class Executors {
    ...

    public static ExecutorService newCachedThreadPool(
        ThreadFactory threadFactory) {
        return new ThreadPoolExecutor(
            0, Integer.MAX_VALUE,
            60L, TimeUnit.SECONDS,
            new SynchronousQueue<Runnable>(),
            threadFactory);
    }

    ...
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
    - Uses ThreadPoolExecutor class
    - New threads started as needed, but existing threads are reused
    - Terminate & remove threads from cache if unused for 60 seconds

```java
public class Executors {
    ...

    public static ExecutorService newCachedThreadPool(
        ThreadFactory threadFactory)
    {
        return new ThreadPoolExecutor
            (0, Integer.MAX_VALUE,
             60L, TimeUnit.SECONDS,
             new SynchronousQueue
                 <Runnable>(),
             threadFactory);
    }

    ...
```

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The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
    - Uses ThreadPoolExecutor class
    - New threads started as needed, but existing threads are reused
    - Terminate & remove threads from cache if unused for 60 seconds
  - `execute()` does a “rendezvous” with a new worker thread

```java
public class Executors {
    ...
    public static ExecutorService newCachedThreadPool(
            ThreadFactory threadFactory)
            return new ThreadPoolExecutor(0, Integer.MAX_VALUE,
                                           60L, TimeUnit.SECONDS,
                                           new SynchronousQueue<Runnable>(),
                                           threadFactory);
    }
    ...
```

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/SynchronousQueue.html
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
- Uses ThreadPoolExecutor class
- New threads started as needed, but existing threads are reused
- Terminate & remove threads from cache if unused for 60 seconds
- `execute()` does a “rendezvous” with a new worker thread
- Threads can be created via custom ThreadFactory

```java
class Executors {  
  ...
  public static ExecutorService newCachedThreadPool(  
      ThreadFactory threadFactory) {  
    return new ThreadPoolExecutor(0, Integer.MAX_VALUE,  
      60L, TimeUnit.SECONDS,  
      new SynchronousQueue<Runnable>(),  
      threadFactory);  
  }
  ...
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
    - Uses ThreadPoolExecutor class
    - New threads started as needed, but existing threads are reused
    - Terminate & remove threads from cache if unused for 60 seconds
    - execute() does a “rendezvous” with a new worker thread
  - Threads can be created via custom ThreadFactory

```java
public class Executors {
    ...

    public static ExecutorService newCachedThreadPool()
    {
        return new ThreadPoolExecutor
            (0, Integer.MAX_VALUE,
             60L, TimeUnit.SECONDS,
             new SynchronousQueue
             <Runnable>());
    }
    ...

    <<Java Class>>
    DefaultThreadFactory
    DefaultThreadFactory()
    newThread(Runnable)

    A variant of newCachedThreadPool() uses DefaultThreadFactory
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
  - Create work-stealing thread pools

```java
public class Executors {
    ...
    public static ExecutorService newWorkStealingPool
        (int parallelism) {
        return new ForkJoinPool
            (parallelism,
            ForkJoinPool.
                defaultForkJoin
                    WorkerThreadFactory,
            null,
            true);
    }
    ...
```
It also defines factory methods to make Executor thread pools, e.g.
- Create fixed-sized thread pools
- Create variable-sized thread pools
- Create work-stealing thread pools
- Implemented via ForkJoinPool

```java
public class Executors {
    ...
    public static ExecutorService newWorkStealingPool
        (int parallelism) {
            return new ForkJoinPool
                (parallelism,
                 ForkJoinPool.
                    defaultForkJoin
                        WorkerThreadFactory,
                    null,
                    true);
        }
    ...
}
```

See lessons on "Java ForkJoinPool"
• It also defines factory methods to make Executor thread pools, e.g.
  • Create fixed-sized thread pools
  • Create variable-sized thread pools
  • Create work-stealing thread pools
  • Implemented via ForkJoinPool
  • Set the target parallelism level

```java
public class Executors {
    ...
    public static ExecutorService newWorkStealingPool
        (int parallelism) {
        return new ForkJoinPool
            (parallelism,
             ForkJoinPool.
             defaultForkJoin
             .defaultForkJoin
             WorkerThreadFactory,
             null,
             true);
    }
    ...
```
The Java Executors Utility Class

- It also defines factory methods to make Executor thread pools, e.g.
  - Create fixed-sized thread pools
  - Create variable-sized thread pools
  - Create work-stealing thread pools
    - Implemented via ForkJoinPool
    - Set the target parallelism level
  - etc.

```java
public class Executors {
    ...
    public static ExecutorService newWorkStealingPool
            (int parallelism) {
        return new ForkJoinPool
                (parallelism,
                 ForkJoinPool.
                    defaultForkJoin
                        WorkerThreadFactory,
                    null,
                    true);
    }
    ...
}
```

See [docs.oracle.com/javase/8/docs/api/java/util/concurrent/ForkJoinPool.html#defaultForkJoinWorkerThreadFactory](docs.oracle.com/javase/8/docs/api/java/util/concurrent/ForkJoinPool.html#defaultForkJoinWorkerThreadFactory)
End of the Java Executors Utility Class