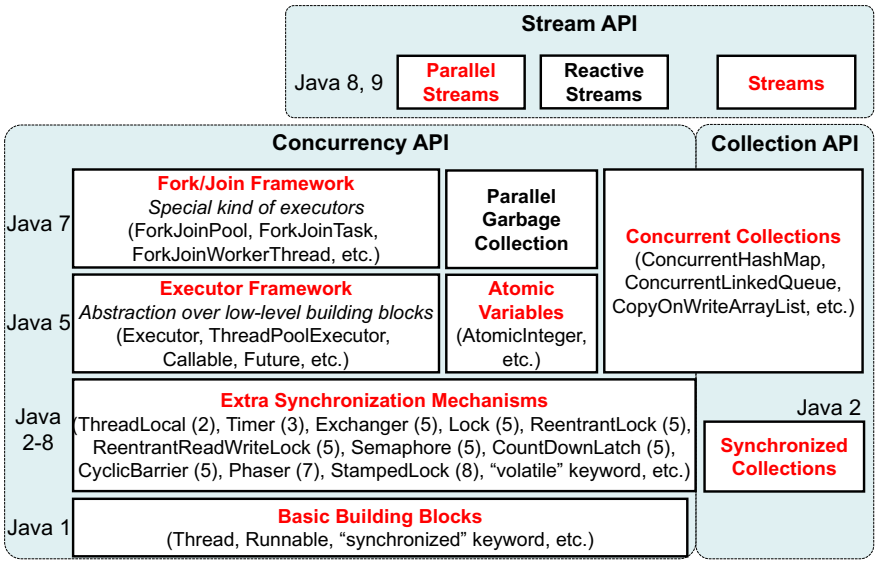
Executor Framework

Concurrency API in Java



Executor Framework

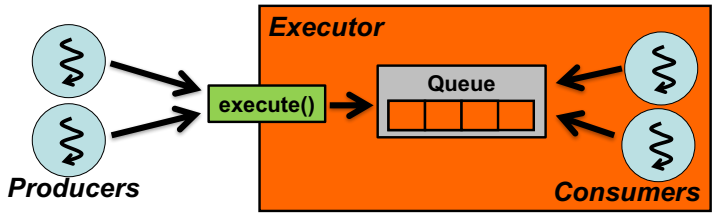
- An abstraction layer atop low-level concurrency primitives
  - Focuses on task execution on threads
  - Decouples task execution (on threads) from task submission (to threads) to make task execution configurable.
  - Introduced in Java 5 (2004)
  - Further enhanced in subsequent versions
  - Implemented in `java.util.concurrent`.

Tasks, Threads and Executor

- Tasks
  - Logical units of work
    - e.g., prime number generation, file caching, file crawling, file indexing, access counting
- Threads
  - Mechanism to run tasks *concurrently*.
- Executor
  - Is the primary abstraction for task execution
    - `Thread` is not anymore.

Executor

- `public interface Executor{ void execute(Runnable command); }`
- `Runnable`'s `run()` implements a task.
- Follows the Producer-Consumer design pattern.
  - Producers: submit tasks
  - Consumers: execute tasks
- Provides the easiest way to implement producers and consumers
- Makes task execution configurable.

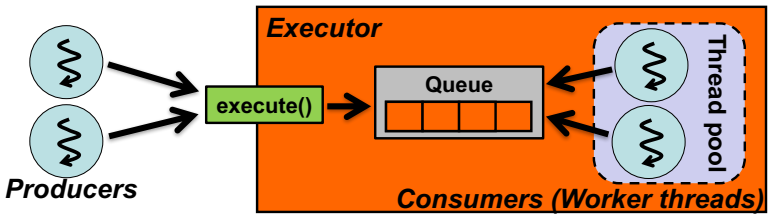


Task Execution Policies

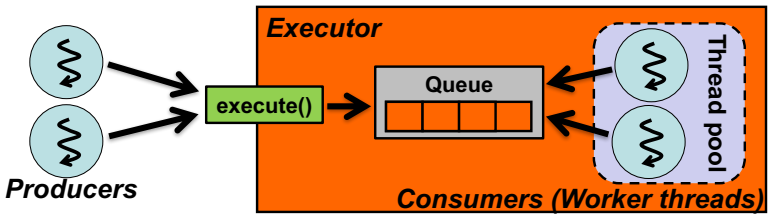
- The Executor framework allows you to specify and customize the *execution policy* for tasks.
  - "What, where, when and how" of task execution.
    - In what thread will tasks be executed?
    - In what order should tasks be executed (FIFO, LIFO, priority-based ordering)?
    - How many tasks may execute concurrently.
    - How many tasks may be queued pending execution?
    - If a task has to be rejected because an application is overloaded, which task should be selected as the victim? How should the application be notified?
    - What actions should be taken before or after executing a task?

Thread Pool

- A key component for task execution.
- A set of pre-created "worker" threads that will be used for future task execution
- Each worker thread
  - Gets and executes a task if it is available in the queue.
  - Goes to the Waiting state until a producer submits the next task.



- Benefits of using a thread pool
  - Can eliminate runtime overhead to create threads
  - Can bound the maximum number of threads (i.e., the max amount of resource utilization)

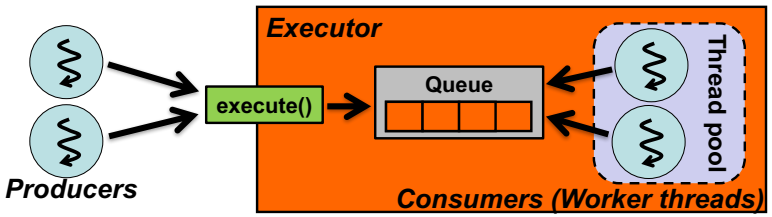


Executors

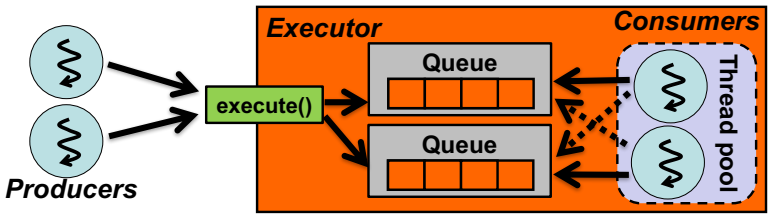
- A utility class for `Executor` objects
- Defines static factory methods to create thread pools.
  - `static ExecutorService newFixedThreadPool(int n)`
    - Fixed-size thread pool.
  -
```
ExecutorService executor = Executors.newFixedThreadPool(2);
executor.execute( new PrimeNumberGenerator(1L, 500000L) );
executor.execute( new PrimeNumberGenerator(500001L, 1000000L) );
```
  -
```
Thread t1, t2;
t1 = new Thread( new PrimeNumberGenerator(1L, 500000L) );
t2 = new Thread(new PrimeNumberGenerator(500001L, 1000000L) );
t1.start();
t2.start();
```


- Defines static factory methods to create thread pools.
  - `static ExecutorService newFixedThreadPool(int n)`
    - Fixed-size thread pool.
  - `static ScheduledExecutorService newScheduledThreadPool(int n)`
    - Fixed-size thread pool that supports delayed and periodic task execution.
  - `static ExecutorService newSingleThreadExecutor()`
    - A pool that operates only one thread.
  - `static ScheduledExecutorService newSingleThreadScheduledExecutor()`
    - A single-threaded pool that supports delayed and periodic task execution.

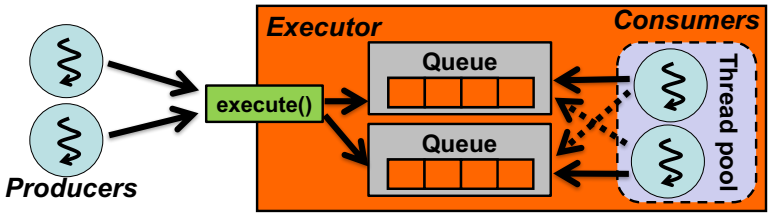
- `static ExecutorService newCachedThreadPool()`
  - Variable-size (not fixed-size) thread pool.
    - Uses previously created "idle" threads if they are available.
    - Creates a new thread if no idle threads are available.
    - Idle threads are terminated and removed from the pool after they are not used for 60 seconds.
  - Pros: Intends to minimize the number of tasks in the queue.
  - Cons: No cap for the number of threads in the pool.
  - Useful to handle a number of *short-lived* (lightweight) tasks



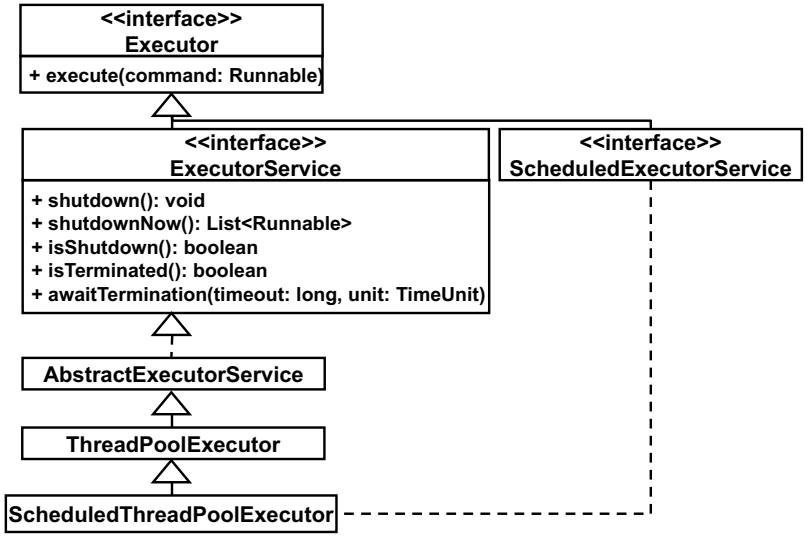
- `static ExecutorService newWorkStealingPool(int parallelism)`
  - Variable-size (not fixed-size) thread pool with a cap for the number of threads.
    - `parallelism` specifies the cap for the number of threads.
  - Each worker thread
    - Has its own "primary" queue and gets the next task from the queue.
    - "Steals" a task from another queue if no tasks are available in its primary queue.
    - Dies after being idle for some time.
  - Pros:
    - Each queue requires less thread synchronization.
    - Each queue operates to minimize the number of tasks.
    - The number of worker threads can be bounded.
  - Cons: N/A



- `static ExecutorService newWorkStealingPool()`
  - Obtains the number of available CPU cores by calling `availableProcessors()` and invokes the previous version of `newWorkStealingPool()`

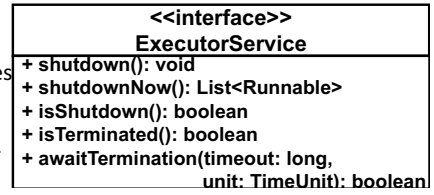


ExecutorService

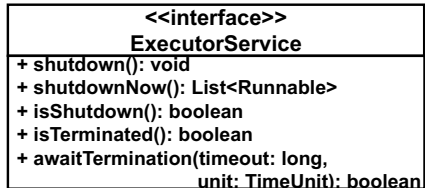


Termination of `Executor`

- Methods to terminate an executor
  - **`shutdown()`**
    - Rejects new tasks to get in
      - Throws a `RejectedExecutionException`
    - Allows previously submitted tasks to complete
      - Tasks being executed
      - Tasks in the queue
  - **`shutdownNow()`**
    - Rejects new tasks to get in
    - Removes all tasks from the queue and returns them
    - Tries to stop the tasks that are being executed.
      - Call `interrupt()` on each worker thread
    - A task can be stopped if it checks `Thread.interrupted()` or catches `InterruptedException` to exit `run()`.
      - Otherwise, it may not be stopped.



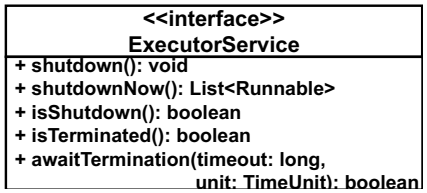
- 3 states of an executor
  - Running
  - Shutting down
    - Once `shutdown()` or `shutdownNow()` is called.
    - `isShutdown()` returns true.
  - Terminated
    - Once all tasks have been completed or stopped.
    - `isTerminated()` returns true.



- Use **`awaitTermination()`** if you want to wait for an executor to be terminated.
  - It blocks until the pool is terminated or the timeout occurs.
  - It returns true if the pool is terminated or false otherwise.

```
executor.shutdown();
executor.awaitTermination(Long.MAX_VALUE, TimeUnit.SECONDS);
doSomething();
```

```
executor.shutdown();
if(!executor.awaitTermination(60, TimeUnit.SECONDS)){
    shotdownNow();
}
if(!executor.awaitTermination(60, TimeUnit.SECONDS)){
    doErrorHandling();
}
```




```
Runnable r1, r2;
r1 = new PrimeNumberGenerator(1L, 500000L);
r2 = new PrimeNumberGenerator(500001L, 1000000L);
ExecutorService executor = Executors.newFixedThreadPool(2);
executor.execute(r1);
executor.execute(r2);
executor.shutdown();
executor.awaitTermination(...);
r1.getPrimes().forEach(...);
r2.getPrimes().forEach(...);
```