Applying Thread Pools
Tasks and Execution Policies

• Executor tries to decouple task submission from execution policy
• But some tasks are incompatible with some execution policies
Dependent Tasks

- If Task B can’t run until Task A completes
  - Shouldn’t use Executors.newCachedThreadPool(), which creates threads on-demand
Thread-Confined Tasks

- If task expects to run in a thread-confined manner
- Probably need to use 
  Executors.newSingleThreadExecutor()
Time-Sensitive Tasks

• If task needs to be very responsive
  – e.g., UI update code
• Need to make sure no individual tasks gets starved
Tasks Using ThreadLocals

• ThreadLocal variables are associated with a thread
• Executors can reuse threads across tasks
  – Can also kill & create threads
Thread Starvation Deadlock

• When all executing threads are blocked waiting for tasks on the work queue.
public class ThreadDeadlock {
    ExecutorService exec = Executors.newSingleThreadExecutor();

    public class RenderPageTask implements Callable<String> {
        public String call() throws Exception {
            Future<String> header, footer;
            header = exec.submit(new LoadFileTask("header.html"));
            footer = exec.submit(new LoadFileTask("footer.html"));
            String page = renderBody();
            // Will deadlock -- task waiting for result of subtask
            return header.get() + page + footer.get();
        }
    }
}
Thread Pool Sizing

- Can avoid the starvation problem by sizing thread pool correctly
- Additionally, pool size should be larger than the average number of long-running tasks
- Otherwise, likely that all threads will eventually be running long-running tasks
Sizing Thread Pools

• For CPU-bound applications on N processor machine
  – N+1 threads often a good choice
  – Use Runtime.getRuntime().availableProcessors() to determine number of CPUs dynamically
Sizing Thread Pools

• For I/O-intensive or blocking tasks, compute or estimate the following quantities
  – \( N_{\text{cpu}} = \text{Number of CPUs} \)
  – \( W/C = \text{Waiting time / computing time} \)

• To keep the CPUs 100% busy, you’d need
  – \( N_{\text{threads}} = N_{\text{cpu}} \times (1+W/C) \)

• Note: Usually don’t want the CPUs to always be at 100% utilization
Configuring ThreadPoolExecutor

- ThreadPoolExecutor is the base implementation for the Executors returned by Executors factory methods

```java
public ThreadPoolExecutor(
    int corePoolSize,
    int maximumPoolSize,
    long keepAliveTime,
    TimeUnit unit,
    BlockingQueue<Runnable> workQueue,
    ThreadFactory threadFactory,
    RejectedExecutionHandler handler)
```
Creation & Teardown

- corePoolSize – target number of threads
- maximumPoolSize – max number of active threads
- keepAliveTime – threads idle for this long may be terminated
Queue Management

• Can supply a BlockingQueue to hold pending tasks that can’t be run immediately
• Three choices
  – Unbounded – e.g., unbounded LinkedBlockingQueue
  – Bounded – e.g., ArrayBlockingQueue
    • Saturation policy - What happens when the queue fills up?
  – Synchronous handoff – e.g., SynchronousQueue
    • If all threads are unavailable, rejects the task according to saturation policy
Queue Management

• Can use Queue to order when tasks start
  – LinkedListBlockingQueue - FIFO
  – PriorityBlockingQueue – ordered by Comparable or Comparator
Saturation Policy

• What happens when you submit a task to a full queue or to a shutdown executor?
• Specified by handler parameter
• Some impl’s defined in ThreadPoolExecutor:
  – AbortPolicy – throw RejectExecutionException
  – DiscardPolicy – silently discard task
  – DiscardOldestPolicy – discard task that would be run next & resubmit the new task
  – CallerRunsPolicy – execute task in calling thread
public class BoundedExecutor {
    private final Executor exec;    private final Semaphore semaphore;
    public BoundedExecutor(Executor exec, int bound) {
        this.exec = exec;    this.semaphore = new Semaphore(bound);
    }
    public void submitTask(final Runnable command) throws InterruptedException {
        semaphore.acquire();
        try {
            exec.execute(new Runnable() { public void run() {
                try {
                    command.run();
                } finally { semaphore.release();}
            } });
            } catch (RejectedExecutionException e) { semaphore.release(); } 
    }
}
Thread Factories

- Class that creates & returns new Threads for the executor’s thread pool
  ```java
  public interface ThreadFactory {
    Thread newThread(Runnable r);
  }
  ```
- Can implement this interface to customize
  - Exception handling
  - Functionality
  - Data fields
  - etc.
Extensions to ThreadPoolExecutor

- Override ThreadPoolExecutor to customize code
- **beforeExecute(Thread t, Runnable r)**
  - Method invoked prior to executing the given Runnable in the given thread
- **afterExecute(Runnable r, Throwable t)**
  - Method invoked upon completion of execution of the given Runnable
- **terminated()**
  - Method invoked when the Executor has terminated