Advanced Concurrency

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Excellent Reference on Concurrency

- Reference: “Java Concurrency in Practice” by Brian Goetz
Concurrency without Explicitly Threads

- You can write concurrent applications that don’t use explicit threads or synchronization
- Use built-in abstractions that support coordination and parallel execution
Synchronized Collections

- Achieve thread safety by allowing access to only one thread at a time
- Examples
  - Vector
  - Hashtable
  - **Synchronized wrapper classes** created by `Collections.synchronizedXxx`
- Example: synchronized set
  
  [http://docs.oracle.com/javase/8/docs/api/java/util/Collections.html#synchronizedSet](http://docs.oracle.com/javase/8/docs/api/java/util/Collections.html#synchronizedSet)

- Disadvantage of this approach: poor concurrency
Concurrent Collections

- Designed to allow concurrent access by multiple threads
  - Blocking only when they “conflict”
- Higher space overhead
  - Not much time overhead
- Many of the concurrent collections do not allow null keys or values
- Examples
  - **ConcurrentHashMap**
    - Replacement for synchronized hash-based Map implementations
  - **CopyOnWriteArrayList**
    - Replacement for synchronized List implementations (where traversal is the predominant operation)
Concurrent HashMap

- Allows simultaneous reads, and by default up to 16 simultaneous writers
  - Can increase the number of simultaneous writers

Special Methods

- V putIfAbsent(K key, V value)
  - Store the value only if the key has no mapping
  - Return old value (null if none)
- boolean remove(K key, V oldValue)
  - Remove mapping only if it has the specified value
- boolean replace(K key, V oldValue, V newValue)
  - Update the mapping only if it has the specified value
CopyOnWriteArrayList

- Suitable only if updates rare and iteration occurs often
- Iteration uses a snapshot of the array
- Iterators keep a reference to the backing array current at the beginning of the iteration
- When an update occurs a new array copy is created and published
- Important use case
  - Keeping track of listeners to an Observable
  - While iterating through list of listeners (delivering a notification), one of them might ask to be unsubscribed
Concurrent Skip Lists

- Skip Lists are a probabilistic alternative to balanced trees
  - Stores sorted list of items using layers of linked lists
- Invented in 1988 by Prof. Bill Pugh

Examples

- ConcurrentSkipListMap
  - [http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ConcurrentSkipListMap.html](http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ConcurrentSkipListMap.html)
- ConcurrentSkipListSet
  - [http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ConcurrentSkipListSet.html](http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ConcurrentSkipListSet.html)

- Above classes are concurrent replacements for a synchronized SortedMap or SortedSet (e.g., TreeMap, TreeSet wrapped with synchronizedMap)
Waiting for Something to Happen

• We briefly talk about join (waits for another thread to terminate)
• There are lots of ways to have a thread wait until things are right for it to do something
  • wait/notify were the way to do this before Java 5
  • But now we have new ways that are often better: blocking queues and synchronizers
# Blocking Queues

- **BlockingQueue**
  - [http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/BlockingQueue.html](http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/BlockingQueue.html)
  - BlockingQueue implementations are thread-safe
  - BlockingQueue implementations designed for use in producer-consumer queues
- BlockingQueue methods can handle operations that cannot be satisfied immediately. The options are:
  - Throwing an exception
  - Returning a special value (null or false)
  - Blocking the thread until the operation can succeed
    - E.g., waiting for space to become available
  - Blocking the thread for a given period of time before giving up

<table>
<thead>
<tr>
<th>Method</th>
<th>throws exception</th>
<th>returns special value</th>
<th>blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>insert</td>
<td>add(e)</td>
<td>offer(e)</td>
<td>put(e)</td>
</tr>
<tr>
<td>remove</td>
<td>remove()</td>
<td>poll()</td>
<td>take()</td>
</tr>
<tr>
<td>examine</td>
<td>element</td>
<td>peek()</td>
<td></td>
</tr>
</tbody>
</table>
Synchronizers

• Synchronizer
  • Any object that coordinates control flow of threads
  • They allow threads arriving at synchronizer to pass or to wait

• Examples
  • Semaphores
  • Latches
  • Barriers
  • Blocking queues can act as synchronizers
Semaphore

• Controls number of activities accessing a resource or performing an action
• Contains a count of the number of permits available
• You can acquire or release permits
  • acquire method - blocks if not enough permits are available
  • release method – returns permit to the semaphore
CountDownLatch

• Act as a gate that is open once a set of events have taken place
• Has a counter that can be decremented (never incremented)
• **countDown method** - decrements counter indicating event has taken place
• **await method** – wait for the counter to reach zero
  • Blocks until counter reaches zero
Barrier

- Allows set of threads to wait for each other to reach a common point
- await method – blocks until all threads have reached the barrier
- Example: CyclicBarrier

http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/CyclicBarrier.html
Atomic Classes

- java.util.concurrent.atomic
  - Toolkit of classes that support lock-free thread-safe programming on single variables

- AtomicInteger class
  - Encapsulates an integer
  - Supports atomic operations:
    - int getAndIncrement()
    - int decrementAndGet()
    - boolean compareAndSet(int expect, int update)

- There is an AtomicX class for every primitive type
- The atomic operations are very efficient
  - Most processors provide some kind of atomic compare and swap instruction
Executor

• An object that executes submitted Runnable tasks, rather than starting a thread for each task (e.g., new Thread(new(RunnableTask())).start()))

• You ask an executor to do it
  Executor executor = // create executor …
  executor.execute(new RunnableTask1());
  executor.execute(new RunnableTask2());

• An executor can be simple or complex
  • The execute method might just run the task
  • Or create and start thread
  • Or do something more complicated

• java.util.concurrent.Executors
  • Provides many factory and utility methods for executors
    • newFixedThreadPool(int nThreads)
    • newCachedThreadPool()
      • Creates threads as needed, reuses them
Why Thread Pools?

- Overhead to starting a thread
- Running 100,000 threads is a bad idea
  - Unless you have a monster machine