Overview of the `util.concurrent` package

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Outline

- Goals and structure
- Principal interfaces and implementations

  Sync: acquire/release protocols

  Channel: put/take protocols

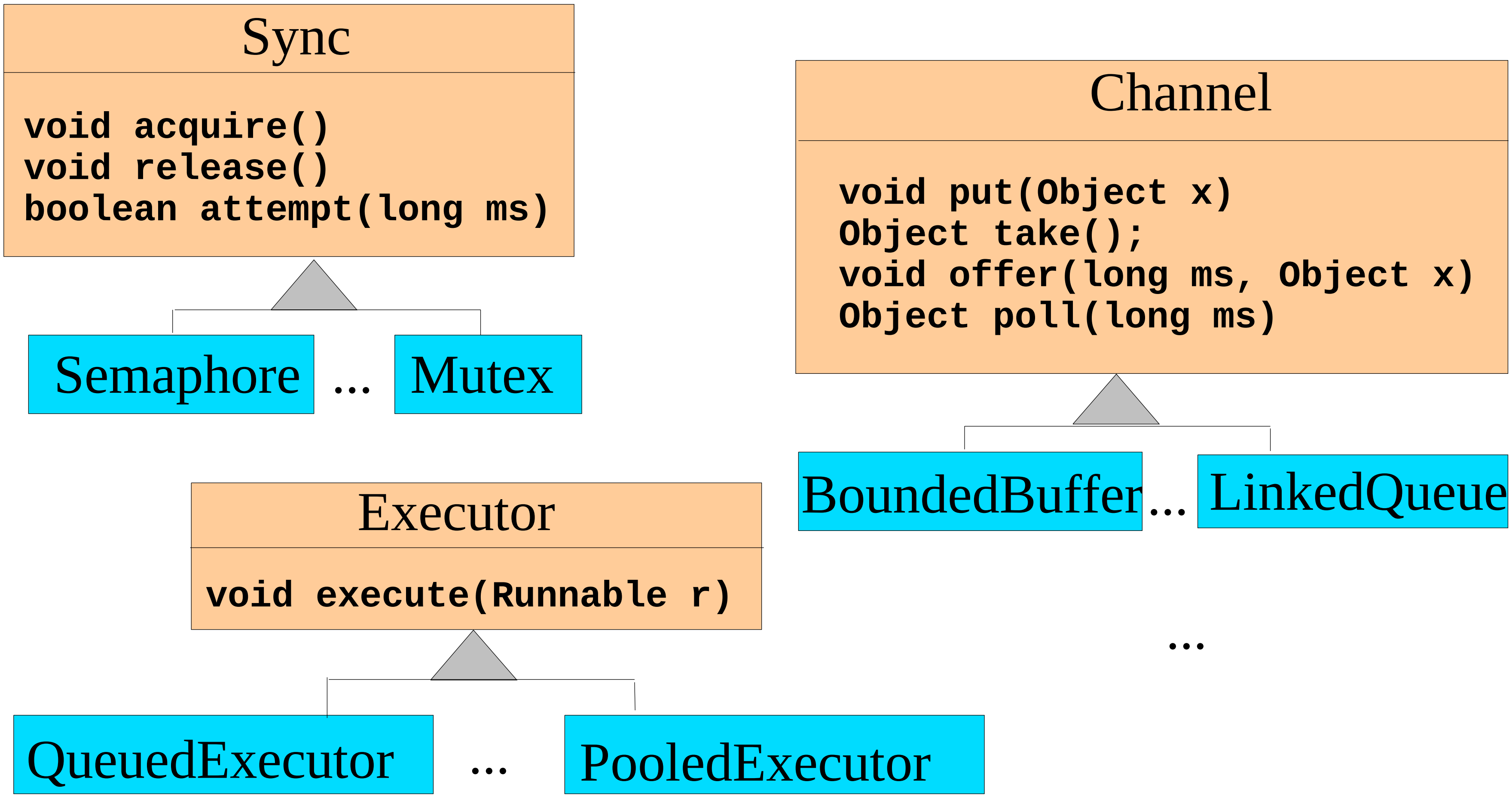
  Executor: executing Runnable tasks

  – Each has a few other associated interfaces and support classes
- Brief mentions of other classes and features

Goals

- A few simple interfaces
  - But cover most problems for which programmers would otherwise need to write tricky code
- High−quality implementations
  - correct, conservative, efficient, portable
- Possible basis for future standardization
  - Gain experience and collect feedback

Structure



classic interface + implementation design, with some opportunistic subclassing

Sync

- Main interface for acquire/release protocols
  - Used for custom locks, resource management, other common synchronization idioms
  - Coarse−grained interface
    - Doesn’t distinguish different lock semantics
- Implementations
  - Mutex, ReentrantLock, Latch, CountDown, Semaphore, WaiterPreferenceSemaphore, FIFOSemaphore, PrioritySemaphore
    - Also, utility implementations such as ObservableSync, LayeredSync that simplify composition and instrumentation

Exclusion Locks

```
try {
  lock.acquire();
  try {
    action();
  }
  finally {
    lock.release();
  }
}
catch (InterruptedException ie) { ... }
```

- Use when synchronized blocks don’t apply
  - Time−outs, back−offs
  - Assuring interruptibility
  - Hand−over−hand locking
  - Building Posix−style condvars

Exclusion Example

```
class ParticleUsingMutex {
  int x;  int y;
  final Random rng = new Random();
  final Mutex mutex = new Mutex();

  public void move() {
    try {
      mutex.acquire();
      try { x += rng.nextInt(2)-1; y += rng.nextInt(2)-1; }
      finally { mutex.release(); }
    }
    catch (InterruptedException ie) {
      Thread.currentThread().interrupt(); }
  }

  public void draw(Graphics g) {
    int lx, ly;
    try {
      mutex.acquire();
      try { lx = x; ly = y; }
      finally { mutex.release(); }
    }
    catch (InterruptedException ie) {
      Thread.currentThread().interrupt(); return; }
    g.drawRect(lx, ly, 10, 10);
  } }
```

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Backoff Example

```
class CellUsingBackoff {
  private long val;
  private final Mutex mutex = new Mutex();

  void swapVal(CellUsingBackoff other)
   throws InterruptedException {
    if (this == other) return; // alias check
    for (;;) {
      mutex.acquire();
      try {
        if (other.mutex.attempt(0)) {
          try {
            long t = val;
            val = other.val;
            other.val = t;
            return;
          }
          finally { other.mutex.release(); }
        }
      }
      finally { mutex.release(); };
      Thread.sleep(100); // heuristic retry interval
    }
  }
}
```

ReadWrite Locks

```
interface ReadWriteLock {
  Sync readLock();
  Sync writeLock();
}
```

- Manage a pair of locks
  - Used via same idioms as ordinary locks
- Can be useful for Collection classes
  - Semi−automated via SyncSet, SyncMap, ...
- Implementation classes vary in lock policy
  - WriterPreference, ReentrantWriterPreference, ReaderPreference, FIFO

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ReadWriteLock Example

- Sample wrapper class that can perform any **Runnable** inside a given read or write lock

```
class WithRWLock {
  final ReadWriteLock rw;
  public WithRWLock(ReadWriteLock l) { rw = l; }

  public void performRead(Runnable readCommand)
                      throws InterruptedException {
    rw.readLock().acquire();
    try     { readCommand.run();  }
    finally { rw.readlock().release(); }
  }

  public void performWrite(...) // similar
}
```

Latch

- A Latch is a condition starting out false, but once set true, remains true forever
  - Initialization flags
  - End−of−stream conditions
  - Thread termination
  - Event occurrence indicators
- A CountDown is similar but fires after a pre−set number of releases, not just one.
- Very simple but widely used classes
  - Replace error−prone constructions

Latch Example

```
class Worker implements Runnable {
  Latch startSignal;
  Worker(Latch l) { startSignal = l; }
  public void run() {
    startSignal.acquire();
    // ... doWork();
  }
}

class Driver { // ...
  void main() {
    Latch ss = new Latch();
    for (int i = 0; i < N; ++i) // make threads
      new Thread(new Worker(ss)).start();

    doSomethingElse(); // don't let run yet

    ss.release();       // now let all threads proceed
  }
 }
```

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Semaphores

- Conceptually serve as permit holders
  - Construct with initial number of permits (usually 0)
  - acquire waits if needed for a permit, then takes one
  - release adds a permit
- But no actual permits change hands.
  - Semaphore just maintains the current count.
- Applications
  - Locks: A semaphore can be used as Mutex
  - Isolating wait sets in buffers, resource controllers
  - Designs prone to missed signals
    - Semaphores ‘remember’ past signals

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Semaphore Example

```
class Pool {
  ArrayList items = new ArrayList();
  HashSet busy = new HashSet();
  final Semaphore available;

  public Pool(int n) {
    available = new Semaphore(n);
    // ... somehow initialize n items ...;
  }
  public Object getItem() throws InterruptedException {
    available.acquire();
    return doGet();
  }
  public void returnItem(Object x) {
    if (doReturn(x)) available.release();
  }

  synchronized Object doGet() {
    Object x = items.remove(items.size()-1);
    busy.add(x); // put in set to check returns
    return x;
  }
  synchronized boolean doReturn(Object x) {
    return busy.remove(x); //  true if was present
  }
 }
```

Barrier

- Interface for multiparty synchronization
  - Each party must wait for all others to hit barrier
- CyclicBarrier class
  - A resettable version of CountDown
  - Useful in iterative partitioning algorithms
- Rendezvous class
  - A barrier at which each party may exchange information with others
  - Behaves as simultaneous put and take of a synchronous channel
  - Useful in resource−exchange protocols

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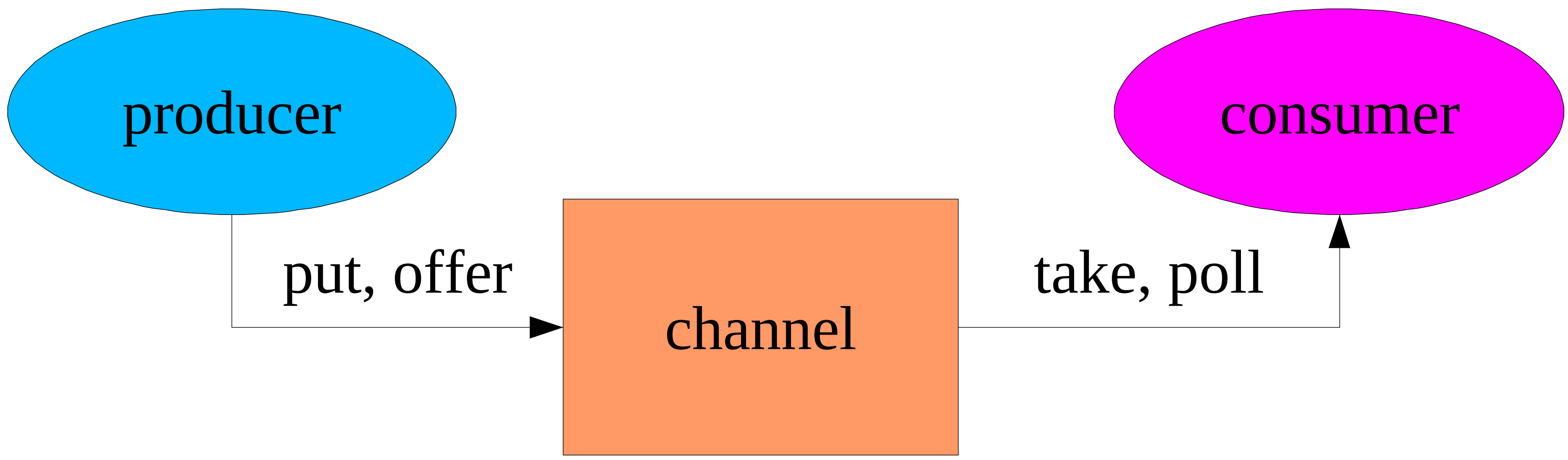
Channel

- Main interface for buffers, queues, etc.



- Implementations
  - LinkedQueue, BoundedLinkedQueue, BoundedBuffer, BoundedPriorityQueue, SynchronousChannel, Slot

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Channel Properties

- Defined as subinterface of **`Puttable`** and **`Takable`**
  - Allows type enforcement of producer vs consumer roles
- Support time−out methods **`offer`** and **`poll`**
  - Pure balking when timeout is zero
  - All methods can throw InterruptedException
- No interface requires a **`size`** method
  - But some implementations define them
  - **`BoundedChannel`** has **`capacity`** method

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Channel Example

```
class Service { // ...
  final Channel msgQ = new LinkedQueue();

  public void serve() throws InterruptedException {
    String status = doService();
    msgQ.put(status);
  }

  public Service() {  // start background thread
    Runnable logger = new Runnable() {
      public void run() {
        try {
          for(;;)
            System.out.println(msqQ.take());
        }
        catch(InterruptedException ie) {} }};
    new Thread(logger).start();
  }
}
```

Executor

- Main interface for Thread−like classes
  - Pools
  - Lightweight execution frameworks
  - Custom scheduling
- Need only support **`execute(Runnable r)`**
  - Analogous to **`Thread.start`**
- Implementations
  - PooledExecutor, ThreadedExecutor, QueuedExecutor, FJTaskRunnerGroup
  - Related ThreadFactory class allows most Executors to use threads with custom attributes

PooledExecutor

- A tunable worker thread pool, with controls for:
  - The kind of task queue (any Channel)
  - Maximum number of threads
  - Minimum number of threads
  - "Warm" versus on−demand threads
  - Keep−alive interval until idle threads die
    - to be later replaced by new ones if necessary
  - Saturation policy
    - block, drop, producer−runs, etc

PooledExecutor Example

```
class WebService {
  public static void main(String[] args) {
    PooledExecutor pool =
      new PooledExecutor(new BoundedBuffer(10), 20);
    pool.createThreads(4);
    try {
      ServerSocket socket = new ServerSocket(9999);
      for (;;) {
        final Socket connection = socket.accept();
        pool.execute(new Runnable() {
          public void run() {
            new Handler().process(connection);
          }});
      }
    }
    catch(Exception e) { } // die
  }
}

class Handler { void process(Socket s); }
```

Futures and Callables

- Callable is the argument and result carrying analog of Runnable

```
interface Callable {
  Object call(Object arg) throws Exception;
}
```

- FutureResult manages asynchronous execution of a Callable

```
class FutureResult { // ...
  // block caller until result is ready
  public Object get()
   throws InterruptedException, InvocationTargetException;

  public void set(Object result); // unblocks get

  // create Runnable that can be used with an Executor
  public Runnable setter(Callable function);
}
```

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FutureResult Example

```
class ImageRenderer { Image render(byte[] raw); }

class App { // ...
   Executor executor = ...;        // any executor
   ImageRenderer renderer = new ImageRenderer();

   public void display(byte[] rawimage) {
     try {
       FutureResult futureImage = new FutureResult();
       Runnable cmd = futureImage.setter(new Callable(){
         public Object call() {
           return renderer.render(rawImage);
         }});
       executor.execute(cmd);

       drawBorders(); // do other things while executing
       drawCaption();

       drawImage((Image)(futureImage.get())); // use future
     }
     catch (Exception ex) {
       cleanup();
       return;
     }
   }
}
```

Other classes

- CopyOnWriteArrayList
  - Supports lock−free traversal at expense of copying entire collection on each modification
  - Well−suited for most multicast applications
    - Package also includes COW versions of java.beans multicast−based classes
- SynchronizedDouble, SynchronizedInt, SynchronizedRef, etc
  - Analogs of java.lang.Double, etc that define atomic versions of mutative operators
    - for example, addTo, inc,
  - Plus utilities such as swap, commit

Future Plans

- Concurrent Data Structures
  - Collections useful under heavy thread contention
- Support for IO−intensive programs
  - Event−based IO
- Niche implementations
  - For example, SingleSourceQueue
- Minor incremental improvements
  - Making Executors easier to compose
- End−of−lifetime
  - JDK1.3 java.util.Timer obsoletes ClockDaemon