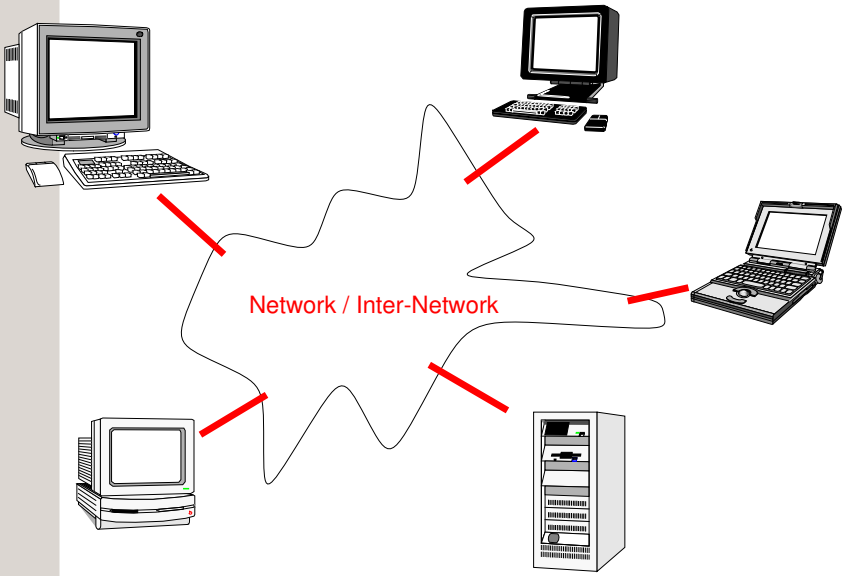
31 Network Programming



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31.1 Host Addressing: InetAddress

- IP addresses:
  - DNS form: www4.informatik.uni-erlangen.de
  - "dotted quad" form: 131.188.34.42
- **`java.net.InetAddress`** contains IP address
- **`InetAddress`** has no public constructor, create instances with
  - **`getLocalHost()`**
  - **`getByName(String hostname)`**
  - **`getAllByName(String hostname)`**
- convert **`InetAddress`** instance to different format
  - **`byte[] getAddress()`**: bytes of IP address
  - **`String getHostAddress()`**: "dotted quad" IP address as String
  - **`String getHostName()`**: host name (DNS form)

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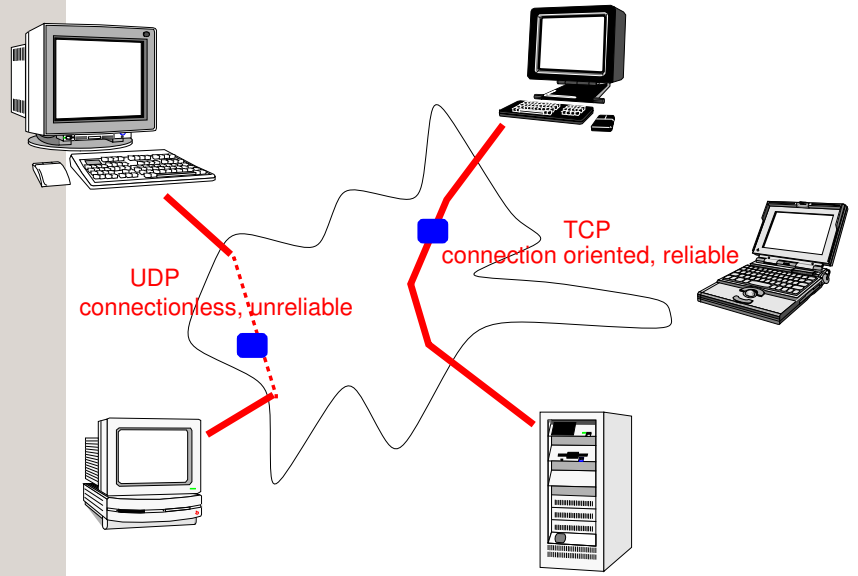
31.2 Sockets



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31.3 Connection-oriented Sockets

- **`java.net.Socket`**
  - TCP/IP
  - reliable
  - represents a communication endpoint at client and server
  - creating a new socket:

```
socket= new Socket("www4.informatik.uni-erlangen.de",80);
```

  - a connection endpoint is defined by *host and port* (16 bit, < 1024 privileged)
  - **`close`** closes the socket

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31.3.1 TCP Client/Server

Server

```
ServerSocket serverSocket = new ServerSocket(5124);
```

Client

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31.3.2 TCP Client/Server

Server

```
ServerSocket serverSocket = new ServerSocket(5124);
Socket socket = serverSocket.accept();
```

Client

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31.3.3 TCP Client/Server

Server

```
ServerSocket serverSocket = new ServerSocket(5124);
Socket socket = serverSocket.accept();
```

Client

```
Socket socket = new Socket("hal",5124);
```


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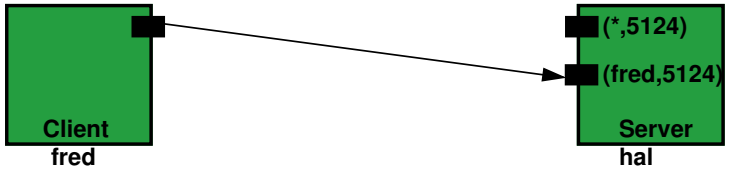
31.3.4 TCP Client/Server



Server

```
ServerSocket serverSocket = new ServerSocket(5124);
Socket socket = serverSocket.accept(); // accept returns
```

Client

```
Socket socket = new Socket("hal",5124);
```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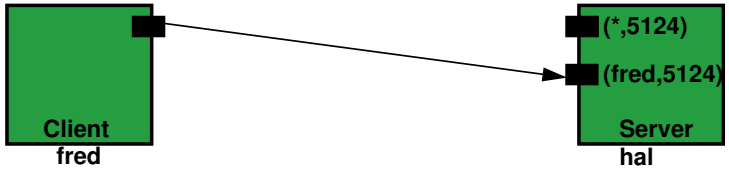
31.3.5 TCP Client/Server



Server

```
ServerSocket serverSocket = new ServerSocket(5124);
Socket socket = serverSocket.accept();
InputStream in = socket.getInputStream();
OutputStream out = socket.getOutputStream();
```

Client

```
Socket socket = new Socket("hal",5124);
InputStream in = socket.getInputStream();
OutputStream out = socket.getOutputStream();
```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31.4 Remarks

- **`java.net.ServerSocket`**
  - is used at server side to wait for client connection requests
  - **`accept`** waits for connection request and returns a new **`Socket`** object

```
ServerSocket serverSocket = new ServerSocket(10412);
Socket socket = serverSocket.accept();
```

  - **`close`** closes the port
- use streams to read/write from/to sockets

```
InputStream inStream = socket.getInputStream();
OutputStream outStream = socket.getOutputStream();
```

- use these streams to create more capable streams

```
DataOutputStream out =
  new DataOutputStream(new BufferedOutputStream(outStream));
```


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31.5 Connectionless Sockets

- **`java.net.DatagramSocket`**
  - UDP/IP
  - unreliable: Datagrams can get lost!
  - low latency
  - Constructors:

    `DatagramSocket(int port)`
    bind to local port **`port`**

    `DatagramSocket()`
    bind to arbitrary local port
  - Methods:

    `send(DatagramPacket packet)`
    send packet, you must write receiver address in packet

    `receive(DatagramPacket packet)`
    receive packet, sender address contained in packet

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31.5.1 Receiver

- receive packets at specific port

```
DatagramSocket socket = new DatagramSocket(10412);
byte[] buf = new byte[1024];
DatagramPacket packet = new DatagramPacket(buf, buf.length);
socket.receive(packet);
InetAddress from = packet.getAddress();
int bytesReceived = packet.getLength();
```


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31.5.2 Sender

- send packets from arbitrary port

```
InetAddress addr = InetAddress.getByName("faui40");
int port = 10412;
DatagramSocket socket = new DatagramSocket();
byte[] buf = new byte[1024];
buf[0] = ...
DatagramPacket packet = new DatagramPacket(buf, buf.length,
                                           addr,port);
socket.send(packet);
```


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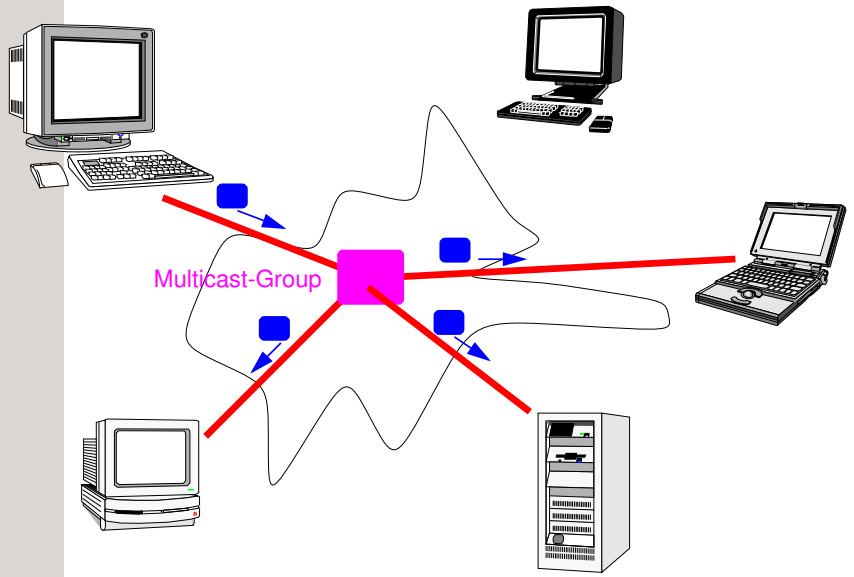
31.6 Multicast-Sockets



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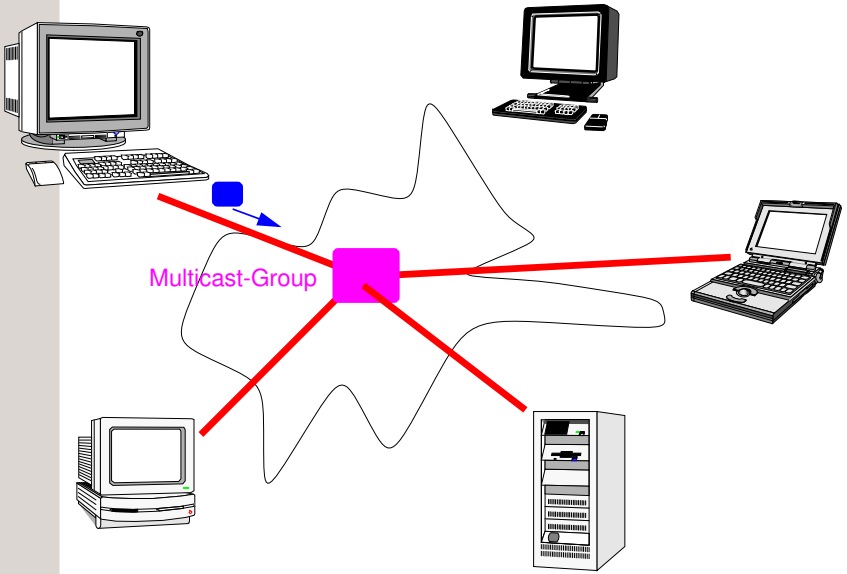
31.6 Multicast-Sockets



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31.6 Multicast-Sockets

- **`java.net.MulticastSocket`**
  - connection-less (subclass of **`DatagramSocket`**)
  - uses *class D* IP-addresses (**`224.0.0.1`** to **`239.255.255.255`**)
  - you can send packets after creating the socket
  - to receive packets you must join the group with **`joinGroup()`**
  - packet propagation is controlled by time-to-live parameter (TTL) (decremented when crossing network border)

```
InetAddress group = InetAddress.getByName("228.5.6.7");
MulticastSocket socket = new MulticastSocket(6789);
socket.setTTL((byte)2);
socket.joinGroup(group);
```


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31.7 Applets and Sockets

- Security restriction:
  - applets can only open connections to the host they are loaded from
  - use `getDocumentBase().getHost()` to get the Web servers hostname

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31.8 Summary

- `Socket`: one end of a two-way TCP communication (server or client)
  - containes target address/port and local port
  - use streams for reading/writing
- `SocketServer`: a server end point, creates `Socket` instances
- `DatagramSocket`: UDP communication
  - use `send()`/`receive()` for communication
  - target address is contained in `DatagramPacket` instance
- `MulticastSocket`: Multicast UDP communication
  - reserved range of IP-Addresses
  - use `joinGroup()` before receiving from a multicast goup

Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

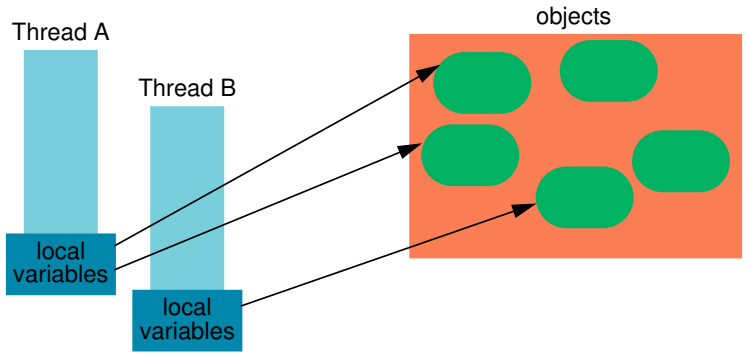
32 Threads

- Reference
  - D. Lea. *Concurrent Programming in Java - Design Principles and Patterns*. Second Edition. The Java Series. Addison-Wesley 1999.

Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

32.1 Threads

- What is a thread?
  - unit of activity with own program counter, own registers, and own stack
  - all threads use the same address space



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32.2 Advantages / Disadvantages

- Advantages
  - execute parallel algorithms on a multiprocessor
  - waiting for slow devices (e.g. network, user) does not block whole program
- Disadvantages
  - complex semantics
  - difficult to debug
  - John Ousterhout. *Why Threads Are A Bad Idea (for most purposes).* (available from the OODS web page)

Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

32.3 Thread Creation (1)

1. Subclass **`java.lang.Thread`** and override the **`run()`** method.
2. Create an instance of this class and call the **`start()`** method at this instance.

```
class Test extends Thread {
    public void run() {
        System.out.println("Test");
    }
}

Test test = new Test();
test.start();
```


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32.4 Thread Creation (2)

1. Implement the interface **`Runnable`**, this requires implementing a **`run()`** method
2. Create a new **`Thread`** instance by passing the **`Thread`** constructor your **`Runnable`** object.
3. Call the **`start()`** method at the **`Thread`** object.

```
class Test implements Runnable {
    public void run() {
        System.out.println("Test");
    }
}

Test test = new Test();
Thread thread = new Thread(test);
thread.start();
```


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32.5 Multithreading Problems

```
public class Test implements Runnable {
  public int a=0;
  public void run() {
    for(int i=0; i<100000; i++) {
      a = a + 1;
    }
  }

  public static void main(String[] args) {
    Test value = new Test();
    Thread t1 = new Thread(value);
    Thread t2 = new Thread(value);
    t1.start();
    t2.start();
    try {
      t1.join();
      t2.join();
    } catch(Exception e) {
      System.out.println("Exception");
    }
    System.out.println("Expected a=200000; a="+value.a);
  }
}
```

What is the result of this program?

create two threads that use the same object

start the two threads

wait for the threads to finish

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32.5.1 Result

- Results of several runs: 173274, 137807, 150683
- What happens when `a = a + 1` is executed?

```
LOAD a into Register
ADD 1 to Register
STORE Register into a
```

- 2 possible sequences of actions when two threads are involved (initial a=0):

1. T1-load: a=0, Reg1=0	1. T1-load: a=0, Reg1=0
2. T1-add: a=0, Reg1=1	2. T2-load: a=0, Reg2=0
3. T1-store: a=1, Reg1=1	3. T1-add: a=0, Reg1=1
4. T2-load: a=1, Reg2=1	4. T1-store: a=1, Reg1=1
5. T2-add: a=1, Reg2=2	5. T2-add: a=1, Reg2=1
6. T2-store: **a=2**, Reg2=2	6. T2-store: **a=1**, Reg2=1

- The three operations must be executed in one step (atomically)!!

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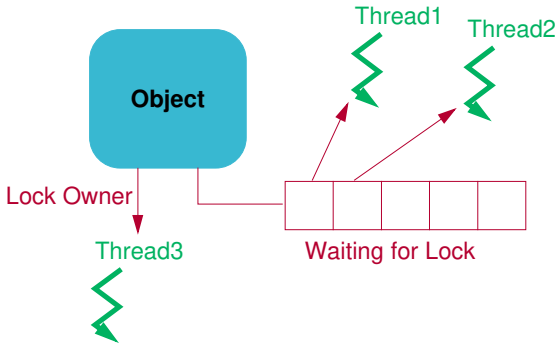
32.5.2 Synchronization

- every object can be used as a lock (monitor)



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32.5.3 synchronized

- use **`synchronized`** to acquire and release locks
- declare method or block as **`synchronized`**

```
class Test {
    public synchronized void m() { ... }
    public void n() { ...
            synchronized(this) {
                ...
            }
    }
}
```

- a thread can acquire one lock multiple times (recursive lock)
- improved example: **`synchronized(this) { a = a + 1; }`**

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32.5.4 Use of synchronized Methods

- no **`synchronized`** necessary
  - ◆ if code always runs in single-threaded context
  - ◆ for simple getter methods (see exception below)
- use **`synchronized`**
  - ◆ if object is written
  - ◆ if computations with the object are done (even if they *only read* the state)
  - ◆ for getter methods that read **`long`** or **`double`** types
  - ◆ for simple getter methods that must be blocked if a state update happens

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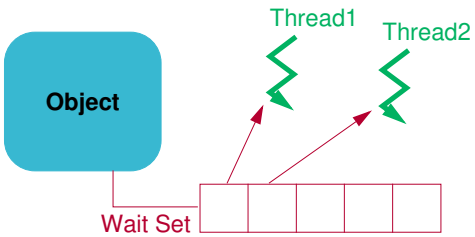
32.6 Condition Variables

- threads must wait for a condition to become true
- two ways for waiting
  - ◆ active (polling)
  - ◆ passive (condition variables)
- every object can be used as a condition variable (every object is associated with a "wait set" = list of waiting threads)



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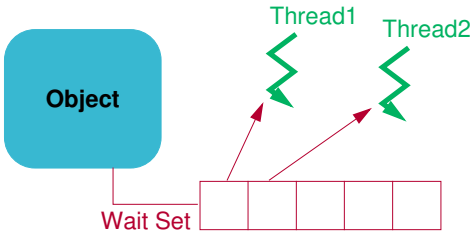
32.6.1 wait and notify

- `Object` contains methods to use the object as a condition variable
  - ◆ **`wait`**: wait for condition (inserts thread into the wait set)

```
while(! condition) { wait(); }
```

  - ◆ **`notify`**: state changed, condition could be true, inform one waiting thread (removes one thread from the wait set)
  - ◆ **`notifyAll`**: wake up all waiting threads (expensive!) (removes all threads from the wait set)



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32.6.2 Condition Variables and Locks

- **`wait`**, **`notify`**, **`notifyAll`** can only be executed if calling thread holds object lock
- **`wait`** releases the lock before blocking (atomically)
  - ◆ another thread can then change the object state (making the condition true)
- acquiring the lock and unblocking happens atomically
- **`wait`** can be called with a timeout

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32.6.3 Condition Variables Example

- PV system: condition is *count > 0*

```
class Semaphore {
    private int count;
    public Semaphore(int count) { this.count = count; }
    public synchronized void P() throws InterruptedException{
        while (count <= 0) {
            wait();
        }
        count--;
    }
    public synchronized void V() {
        count++;
        notify();
    }
}
```


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32.6.4 Condition Variables Example

- Order system: one thread accepts customer requests (**SecretaryThread**) and another thread processes them (**WorkerThread**)

```
class SecretaryThread implements Runnable {
   public void run() {
      for(;;) {
         Customer customer = customerLine.nextCustomer();
         WorkerThread worker = classify(customer);
         worker.insertCustomer(customer);
      }
   }
}

interface WorkerThread {
   public void insertCustomer(Customer c);
}
```


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32.6.4 Condition Variables Example

- Worker

```
class SpecificWorker implements Runnable, WorkerThread {
   public void run() {
      for(;;) {
        Customer customer;
        synchronized (this) {
           while(queue.empty()) wait();
           customer = queue.next();
        }
         // do something nice with customer
         // ...
      }
   }
   public synchronized void insertCustomer(Customer c) {
      queue.insert(c);
      notify();
   }
}
```


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32.7 sleep

- thread has **sleep(long n)** method to go to sleep for n milliseconds
- thread can be suspended after return from **sleep()**
- sleep method is a static method of Thread; called like **Thread.sleep(...);**

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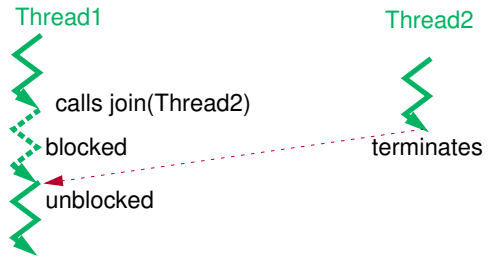
32.8 join

- a thread can wait for another thread to die

```
workerThread = new Thread(worker);
...
workerThread.join();
worker.result();
```



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32.9 Daemon Threads

- daemon threads are used for background tasks
- should not be used for main task of program
- if all *non-daemon* threads are dead the program is finished
- How can you tell if a thread should be daemon thread?
  - You cannot state a termination condition for the thread.
- Important methods of the **`Thread`** class:
  - **`setDaemon(boolean switch)`**: turns daemon property on/off
  - **`boolean isDaemon()`**: tests if thread is a daemon

Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

32.10 ThreadGroup

- Group of related threads (**`ThreadGroup`**):
  - Can contain threads and other thread groups.
  - Every thread can only influence threads in its own ThreadGroup
- Methods that can only used with threads of own thread group:
  - **`list()`**
  - **`stop()`**
  - **`suspend()`**
  - **`resume()`**

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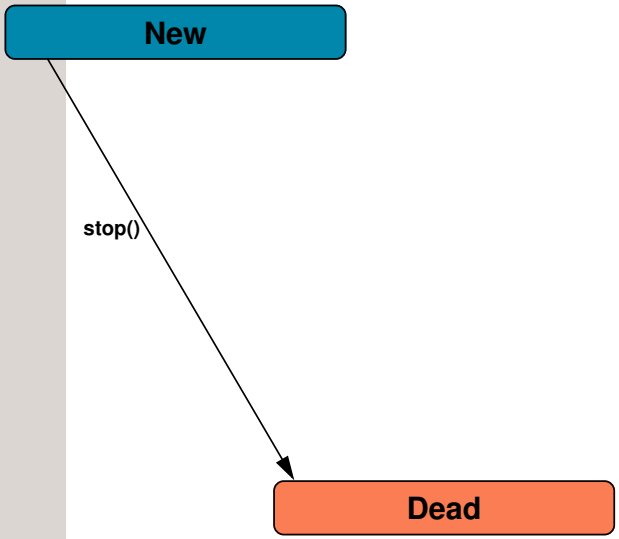
32.11 Thread States

Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

32.11 Thread States



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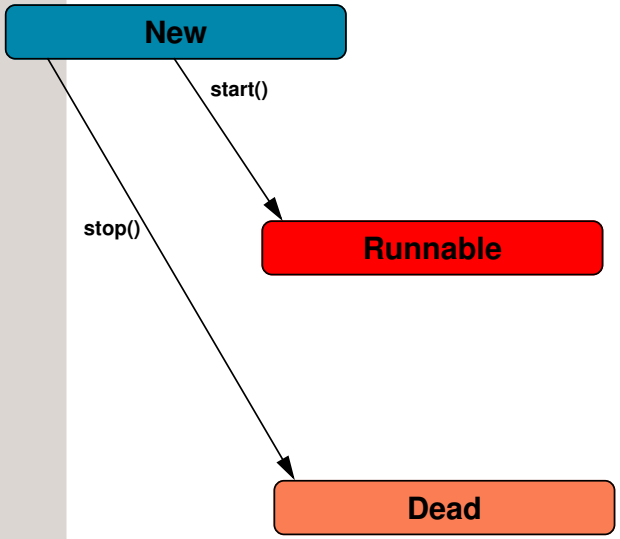
32.11 Thread States



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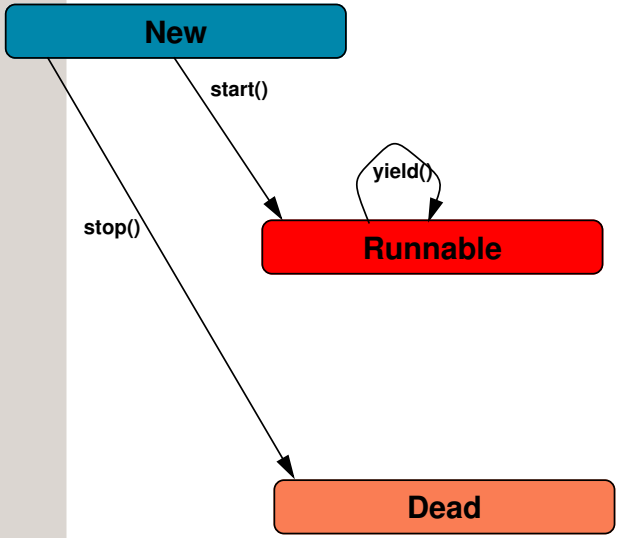
32.11 Thread States



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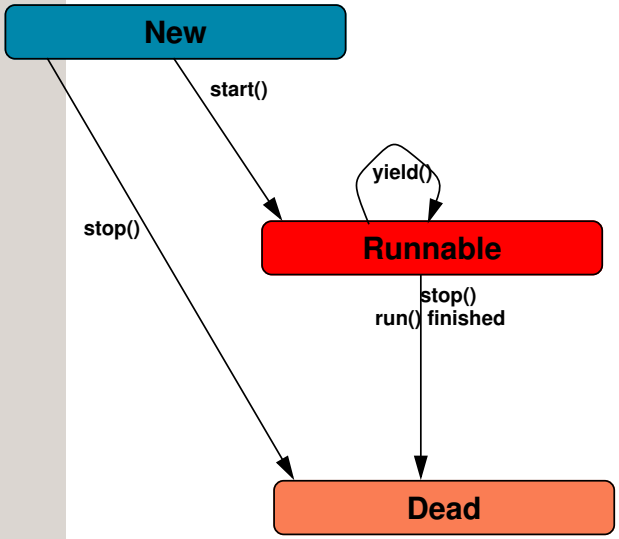
32.11 Thread States



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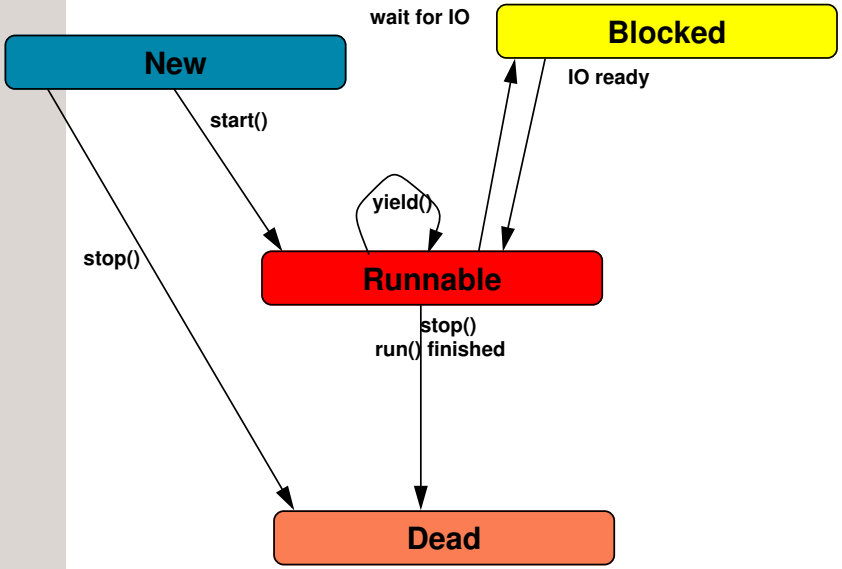
32.11 Thread States



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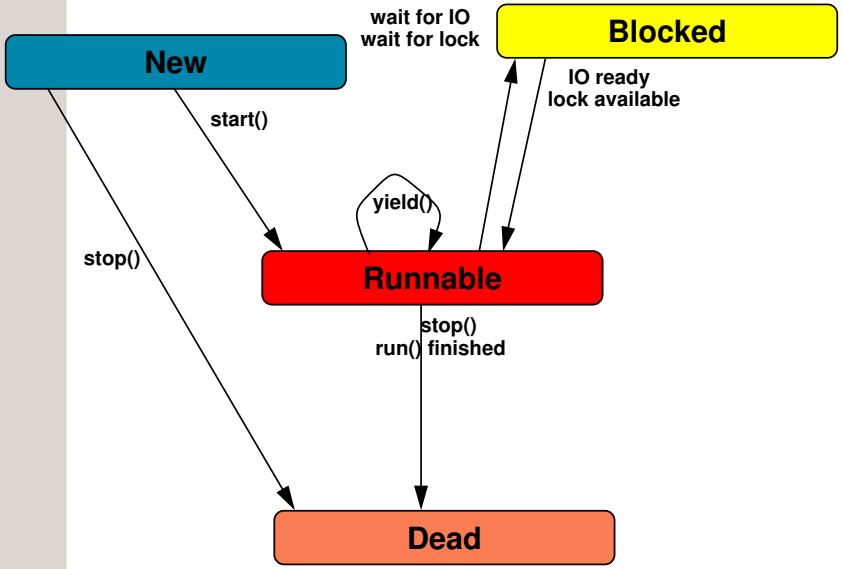
32.11 Thread States



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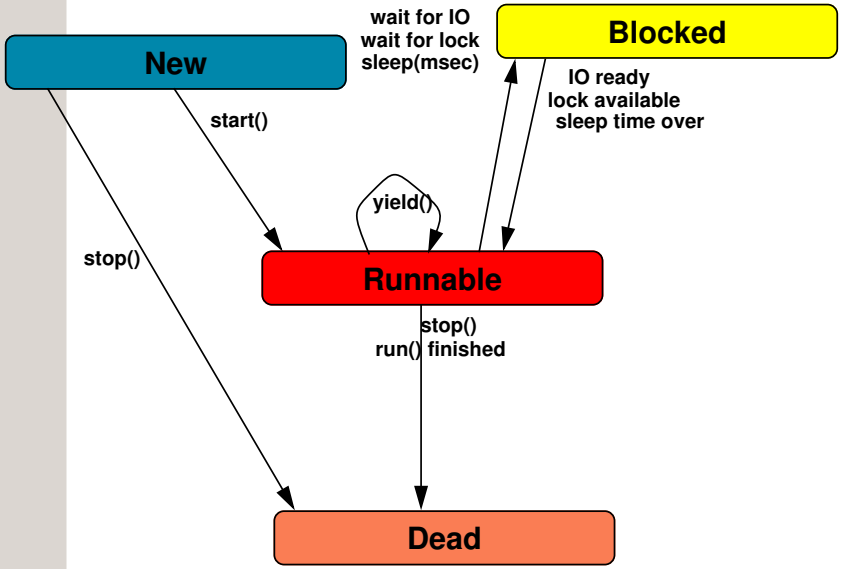
32.11 Thread States



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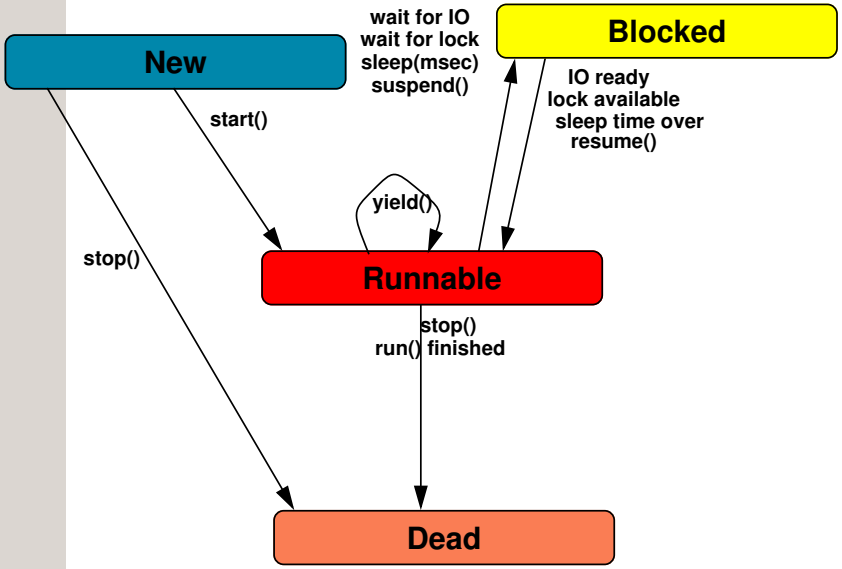
32.11 Thread States



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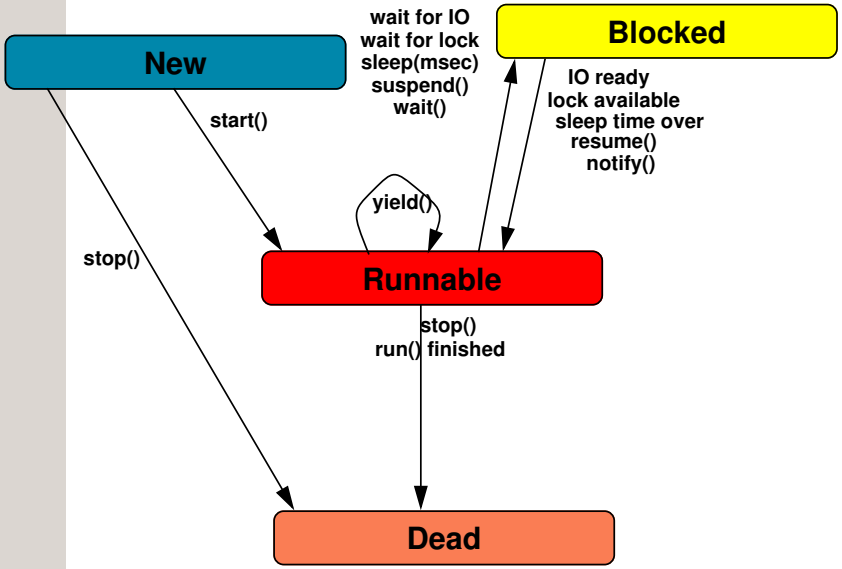

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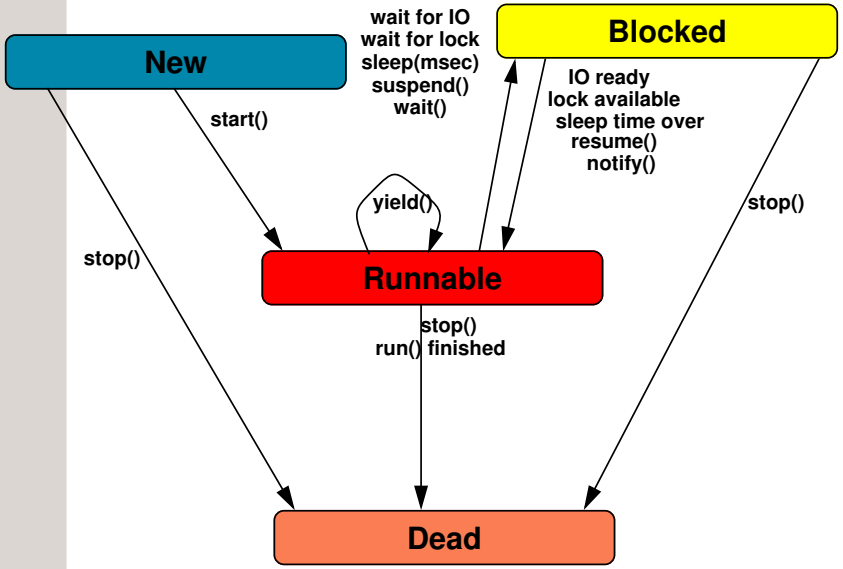
32.11 Thread States



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32.12 Scheduling

- default scheduling in jdk 1.1 on Solaris: preemptive, without *timeslicing*
  - a thread with higher priority preempts a thread with lower one
  - threads with equal priority are scheduled non-preemptive (FIFO)
  - if a thread blocks the next runnable thread with equal priority gets the CPU
- Java 1.1 and 1.2 on Solaris:
  - default or **`THREADS_FLAG=green`**: preemptive without timeslicing
  - **`THREADS_FLAG=native`**: preemptive with timeslicing
- Java 1.1 on WinNT/Win95
  - preemptive with timeslicing
- Correctness of a program must not depend on the scheduling strategy!!!

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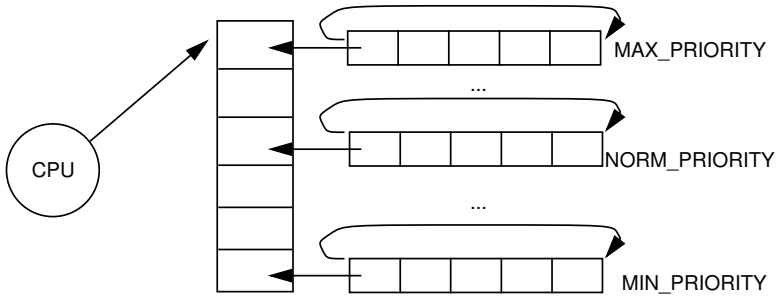
32.13 Priority based Round-Robin Scheduling

- Run queues of a timesliced, round-robin scheduler with static priorities



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32.14 Deprecated Methods of Thread

- **`stop()`**, **`suspend()`**, **`resume()`** are deprecated in Java 1.2
- **`stop()`** releases all locks the thread holds - this is unsafe
- **`suspend()`** and **`resume()`** could lead to deadlock - stopped thread holds locks

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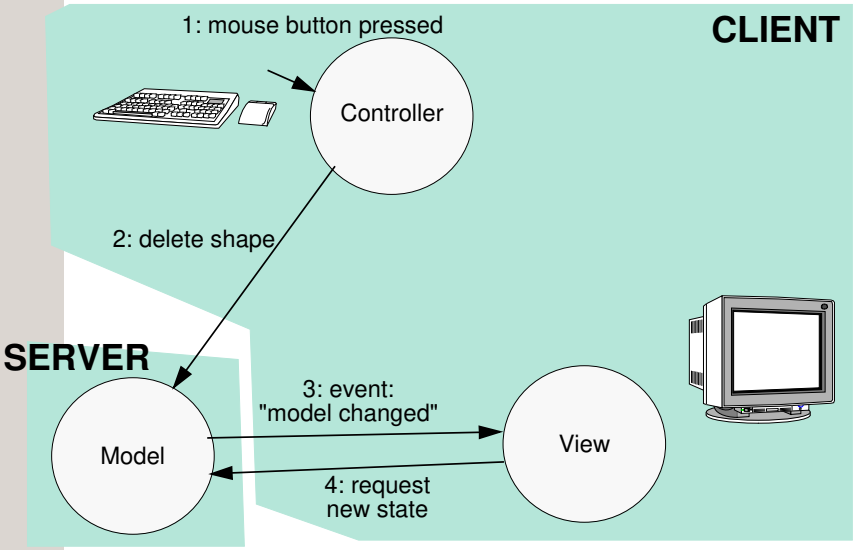
33 Design Patterns for the C/S Assignment

- "elements of reusable design"
- Examples
  - Model-View-Controller
  - Observer
  - Iterator
  - Command
  - Proxy

Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

33.1 Model-View-Controller



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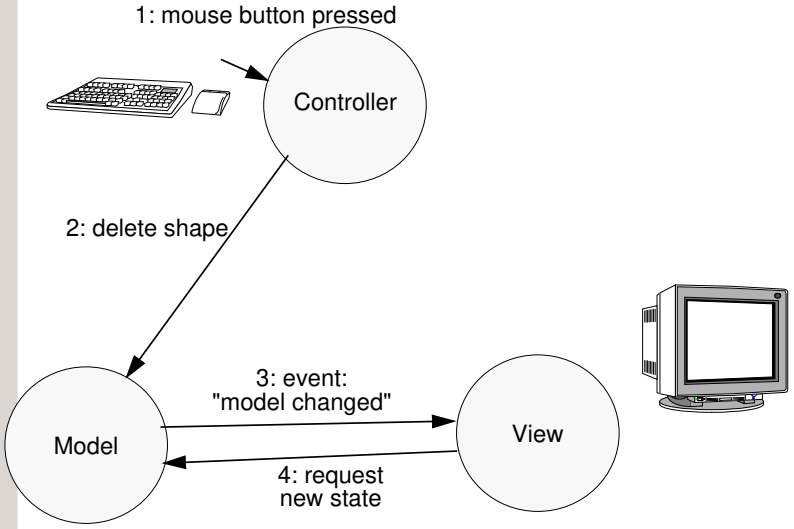
33.1 Model-View-Controller



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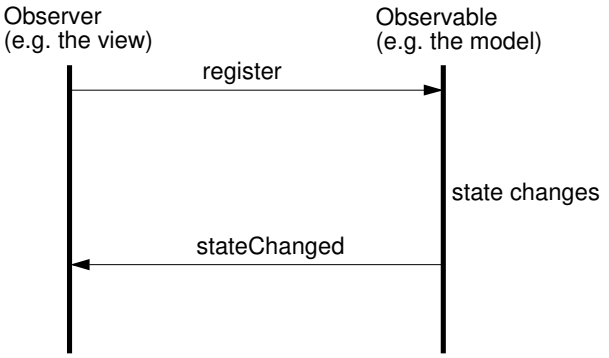
33.2 Observer

- used in MVC by the view to observe model changes



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33.3 Iterator

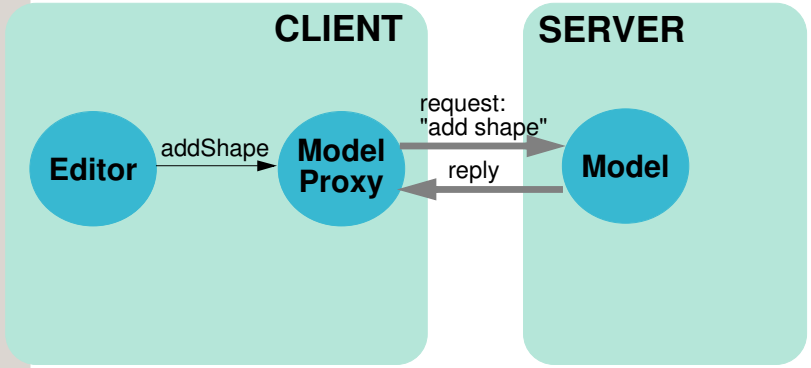
- used to "walk through" a set of objects
- iterator is responsible for maintaining the current position

```
class Iter implements java.util.Enumeration {
  int cursor;
  Shape[] shapes;

  public Iter(Shape[] shapes) {
    this.shapes = new Shape[shapes.length];
    System.arraycopy(shapes, 0, this.shapes, 0, shapes.length);
  }

  public boolean hasMoreElements() {
   while (cursor<shapes.length && shapes[cursor]==null) cursor++;
    return cursor < shapes.length; }

  public Object nextElement() { return shapes[cursor++]; }
}
```


Reproduktion jeder Art oder Verwendung dieser Unterlage bedarf der Zustimmung des Autors.

33.4 Proxy

- can be used to have a local representative of a remote object
- implements the same interface as the "real" object
- DrawingEditor with remote model:



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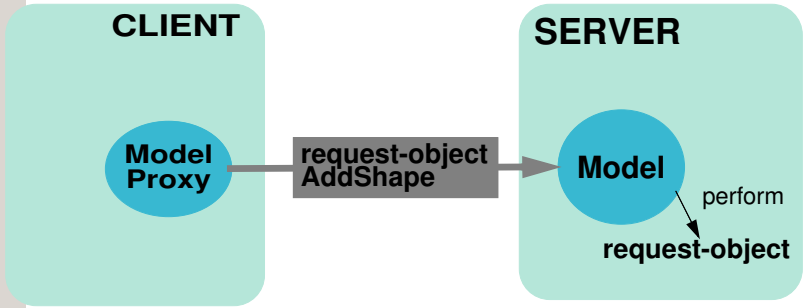
33.5 Command

- used to transfer a request to the server
- state contains information from client
- method perform() is called by server
- parameters contain information from server



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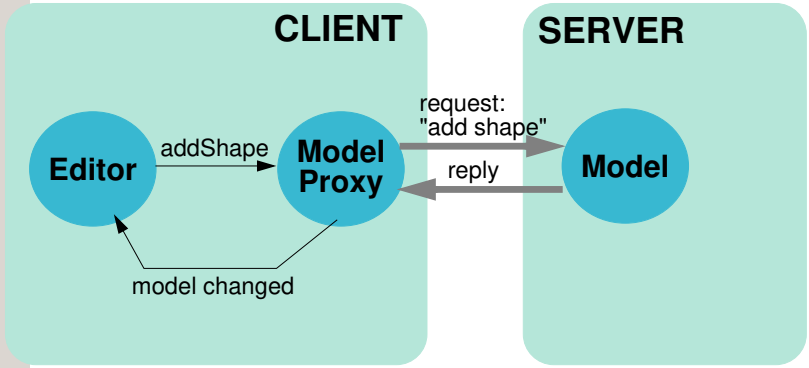
34 Repaint handling (local)

- "Quick hack": Model proxy send model changed requests



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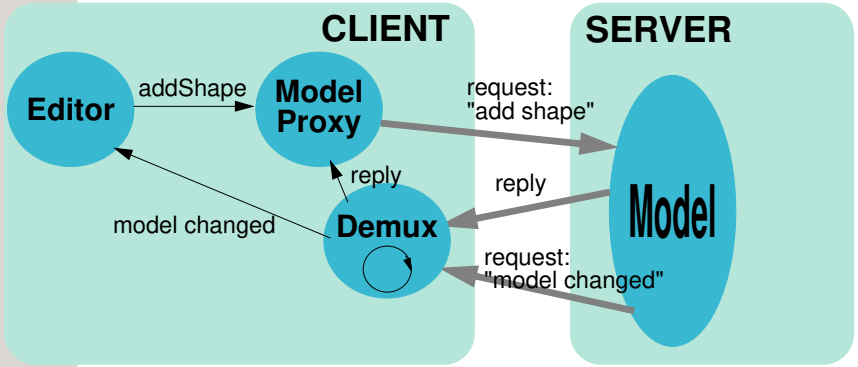
34.1 Repaint handling (Remote Observable)

- Better: "real" model sends model changed requests over the wire
- multiplex: send replies and requests on the same stream
- demultiplex the stream: separate replies from requests



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35 Object identity in distributed programs

- when objects transfered through an ObjectStream they loose their identity
- you can no longer use references to check for identity
- Solution: use an object ID
  - ◆ does not change between hosts and different runs of the program

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