

CMSC 132: Object-Oriented Programming II



Networking Support in Java

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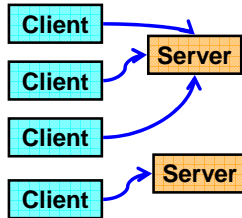
Overview

- Networking
 - Background
 - Concepts & terms
 - Network applications
 - Java's object-oriented view
 - Java's networking API
(Application Program Interface)
- } Last lecture
 } This lecture

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Client / Server Model

- Relationship between two computer programs
- Client
 - Initiates communication
 - Requests services
- Server
 - Receives communication
 - Provides services
- Other models
 - Master / worker
 - Peer-to-peer (P2P)



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Client / Server Model Examples

Application	Client	Server
Web Browsing	Internet Explorer, Mozilla Firefox	Apache, Microsoft IIS
Email	MS Outlook, Thunderbird	POP, IMAP, Exchange
Streaming Music	Windows Media Player, iTunes	Internet Radio
Online Gaming	World of Warcraft, Halo 3, PartyPoker	Game / Realm Servers

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Client Programming

- Basic steps
 1. Determine server location – IP address & port
 2. Open network connection to server
 3. Write data to server (request)
 4. Read data from server (response)
 5. Close network connection
 6. Stop client

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Simple Server Programming

- Basic steps
 1. Determine server location - port (& IP address)
 2. Create ServerSocket to listen for connections
 3. Loop


```
while (true) {
    Accept network connection from client
    Read data from client (request)
    Write data to client (response)
    Close network connection to client
}
```

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Advanced Server Programming

- Server supports multiple connections / clients
- Two approaches
 1. Loop
 - Handles multiple connections in order
 - Limits on amount of network traffic
 - Not resilient in face of slow / stopped clients
 2. Multithreading
 - Allows multiple simultaneous connections

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Networking in Java

- Packages
 - java.net ⇒ Networking
 - java.io ⇒ I/O streams & utilities
 - java.rmi ⇒ Remote Method Invocation
 - java.security ⇒ Security policies
 - java.lang ⇒ Threading classes
- Support at multiple levels
 - Data transport ⇒ Socket classes
 - Network services ⇒ URL classes
 - Utilities & security

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Java Networking API

- Application Program Interface
 - Set of routines, protocols, tools
 - For building software applications
- Java networking API
 - Helps build network applications
 - Interfaces to sockets, network resources
 - Code implementing useful functionality
 - Includes classes for
 - Sockets
 - URLs

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Java Networking Classes

- IP addresses
 - InetAddress
- Packets
 - DatagramPacket
- Sockets
 - Socket
 - ServerSocket
 - DatagramSocket
- URLs
 - URL

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InetAddress Class

- Represents an IP address
- Can convert domain name to IP address
 - Performs DNS lookup
- Getting an InetAddress object
 - getLocalHost()
 - getByName(String host)
 - getByAddress(byte[] addr)

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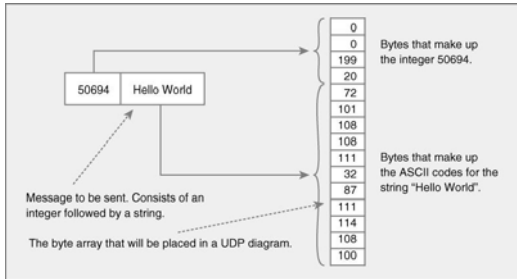
DatagramPacket Class

- Each packet contains
 - InetAddress
 - Port of destination
 - Data

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DatagramPacket Class

- Data in packet represented as byte array



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DatagramPacket Methods

- getAddress()
- getData()
- getLength()
- getPort()
- setAddress()
- setData()
- setLength()
- setPort()

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Socket Classes

- Provides interface to TCP, UDP sockets
- 1. **Socket**
 - TCP client sockets
- 2. **ServerSocket**
 - TCP server sockets
- 3. **DatagramSocket**
 - UDP sockets (server or client)

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Socket Class

- Creates socket for client
- Constructor connects to
 - Machine name or IP address
 - Port number
- Transfer data via **streams**
 - Standard Java I/O streams
 - Bytes → InputStream, OutputStream
 - Characters → FileReader, PrintWriter

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Socket Methods

- getInputStream()
- getOutputStream()
- close()
- getInetAddress()
- getPort()
- getLocalPort()

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ServerSocket Class

- Create socket on server
- Constructor specifies local port
 - Server listens to port
- Usage
 - Begin waiting after invoking accept()
 - Listen for connection (from client socket)
 - Returns **Socket** for connection

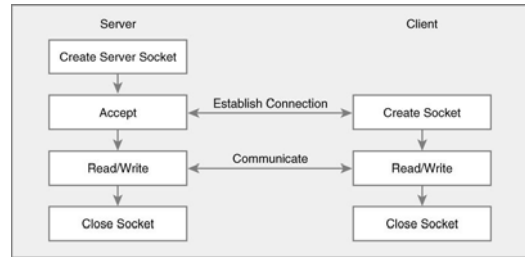
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ServerSocket Methods

- `accept()`
- `close()`
- `getInetAddress()`
- `getLocalPort()`

Connection Oriented

■ TCP Protocol



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Server Example

```
public class Server {
    public static void main(String args[] ) throws Exception {
        ServerSocket ss = new ServerSocket(4242);
        while (true) {
            Socket s = ss.accept();
            BufferedReader r = new BufferedReader(
                new InputStreamReader(s.getInputStream()));
            PrintWriter out = new PrintWriter(
                new OutputStreamWriter(s.getOutputStream()));
            String name = r.readLine();
            out.println("Hello " + name);
            out.flush();
            s.close();
        }
    }
}
```

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Client Example

```
public class Client {
    public static void main(String args[] ) throws Exception {
        String host = "localhost";
        InetAddress server = InetAddress.getByName(host);
        Socket s = new Socket(server, 4242);
        BufferedReader r = new BufferedReader(
            new InputStreamReader(s.getInputStream()));
        PrintWriter out = new PrintWriter(
            new OutputStreamWriter(s.getOutputStream()));
        out.println("MyName");
        out.flush();
        String response = r.readLine();
        System.out.println(response);
        s.close();
    }
}
```

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DatagramSocket Class

- Create UDP socket
 - Does not distinguish server / client sockets
- Constructor specifies InetAddress, port
- Set up UDP socket connection
- Send / receive DatagramPacket

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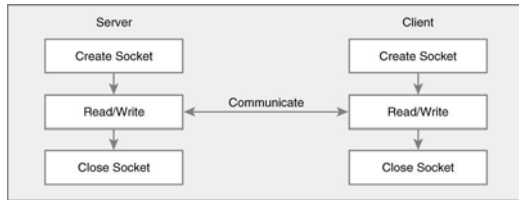
DatagramSocket Methods

- `close()`
- `getLocalAddress()`
- `getLocalPort()`
- `receive(DatagramPacket p)`
- `send(DatagramPacket p)`
- `setSoTimeout(int t)`
- `getSoTimeout()`

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Packet Oriented

■ UDP Protocol



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URL Class

- Provides high-level access to network data
- Abstracts the notion of a connection
- Constructor opens network connection
 - To resource named by URL

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URL Constructors

- URL(fullURL)
 - URL("http://www.cs.umd.edu/class/index.html")
- URL(baseURL, relativeURL)
 - URL base = new URL("http://www.cs.umd.edu/");
 - URL class = new URL(base, "/class/index.html ");
- URL(protocol, baseURL, relativeURL)
 - URL("http", www.cs.umd.edu, "/class/index.html")
- URL(protocol, baseURL, port, relativeURL)
 - URL("http", www.cs.umd.edu, 80, "/class/index.html")

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URL Methods

- getProtocol()
- getHost()
- getPort()
- getFile()
- getContent()
- openStream()
- openConnection()

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URL Connection Classes

- High-level description of network service
- Access resource named by URL
- Can define own protocols
- Examples
 - URLConnection ⇒ Reads resource
 - HttpURLConnection ⇒ Handles web page
 - JarURLConnection ⇒ Manipulates Java Archives
 - URLClassLoader ⇒ Loads class file into JVM

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Java Applets

- Applets are Java programs
 - Classes downloaded from network
 - Run in browser on client
- Applets have special security restrictions
 - Executed in applet sandbox
 - Controlled by java.lang.SecurityManager

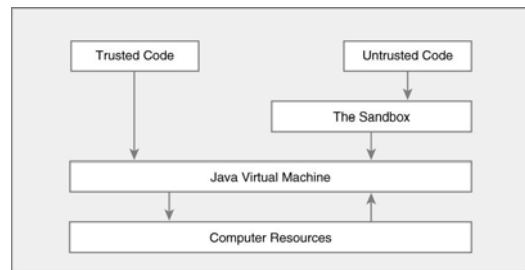
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Applet Sandbox

- **Prevents**
 - Loading libraries
 - Defining native methods
 - Accessing local host file system
 - Running other programs (Runtime.exec())
 - Listening for connections
 - Opening sockets to new machines
 - Except for originating host
- **Restricted access to system properties**

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Applet Sandbox



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Network Summary

- **Internet**
 - Designed with multiple layers of abstraction
 - Underlying medium is unreliable, packet oriented
 - Provides two views
 - Reliable, connection oriented (TCP)
 - Unreliable, packet oriented (UDP)
- **Java**
 - Object-oriented classes & API
 - Sockets, URLs
 - Extensive networking support

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