Network Programming and Java Sockets

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Agenda

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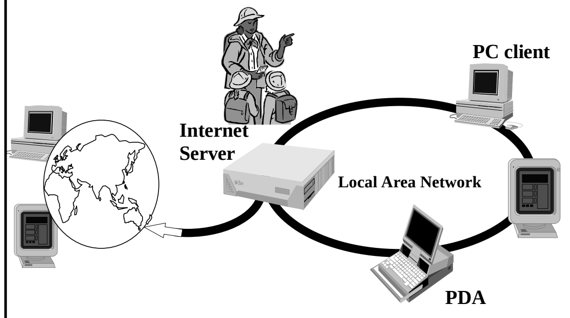
- Elements of Client Server Computing
- Networking Basics
- Understanding Ports and Sockets
- Java Sockets
  - Implementing a Server
  - Implementing a Client
- Sample Examples
- Conclusions

Introduction

- Recently Internet and WWW have emerged as global ubiquitous media for communication and changing the way we conduct science, engineering, and commerce.
- They also changed the way we learn, live, enjoy, communicate, interact, engage, etc. It appears like the modern life activities are getting completely centered around the Internet.

Internet Applications Serving Local and Remote Users



Internet & Web as a delivery Vehicle

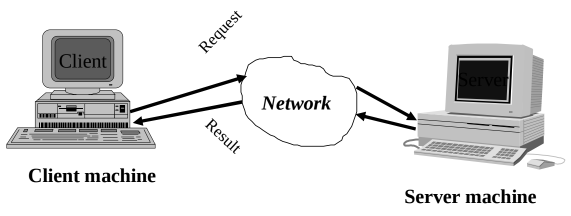
book reviews	captions to cartoons	fairy tales	flora/fauna report
food reviews	greeting cards or post cards	grocery lists	how-to pages
interviews	job descriptions	jokes	local menus
local legends / myths	local remedies	local folklore	movie critiques
newspapers	news analyses	problem solving	protest signs
puzzles	questionnaires	quotations	real estate notices
recipes	sayings	schedules	serialized stories
song lyrics	sports page	superstitions	traffic rules
TV reviews	used car descriptions	want ads	wanted posters

Increased demand for Internet applications

- To take advantage of opportunities presented by the Internet, businesses are continuously seeking new and innovative ways and means for offering their services via the Internet.
- This created a huge demand for software designers with skills to create new Internet-enabled applications or migrate existing/legacy applications on the Internet platform.
- Object-oriented Java technologies—Sockets, threads, RMI, clustering, Web services-- have emerged as leading solutions for creating portable, efficient, and maintainable large and complex Internet applications.

Elements of C-S Computing

a client, a server, and network



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Networking Basics

- Applications Layer
  - Standard apps
    - HTTP
    - FTP
    - Telnet
  - User apps
- Transport Layer
  - TCP
  - UDP
  - Programming Interface:
    - Sockets
- Network Layer
  - IP
- Link Layer
  - Device drivers
- TCP/IP Stack

Application (http,ftp,telnet,…)
Transport (TCP, UDP,..)
Network (IP,..)
Link (device driver,..)

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Networking Basics

- TCP (Transport Control Protocol) is a connection-oriented protocol that provides a reliable flow of data between two computers.
- Example applications:
  - HTTP
  - FTP
  - Telnet
- TCP/IP Stack

Application (http,ftp,telnet,…)
Transport (TCP, UDP,..)
Network (IP,..)
Link (device driver,..)

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Networking Basics

- UDP (User Datagram Protocol) is a protocol that sends independent packets of data, called *datagrams*, from one computer to another with no guarantees about arrival.
- Example applications:
  - Clock server
  - Ping
- TCP/IP Stack

Application (http,ftp,telnet,…)
Transport (TCP, UDP,..)
Network (IP,..)
Link (device driver,..)

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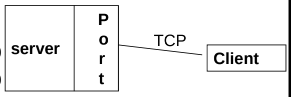
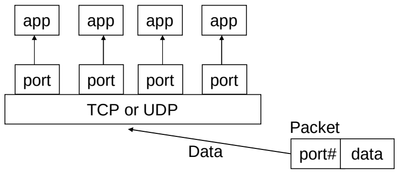
Understanding Ports

- The TCP and UDP protocols use *ports* to map incoming data to a particular *process* running on a computer.





Understanding Ports

- Port is represented by a positive (16-bit) integer value
- Some ports have been reserved to support common/well known services:
  - ftp 21/tcp
  - telnet 23/tcp
  - smtp 25/tcp
  - login 513/tcp
- User level process/services generally use port number value >= 1024

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Sockets

- Sockets provide an interface for programming networks at the transport layer.
- Network communication using Sockets is very much similar to performing file I/O
  - In fact, socket handle is treated like file handle.
  - The streams used in file I/O operation are also applicable to socket-based I/O
- Socket-based communication is programming language independent.
  - That means, a socket program written in Java language can also communicate to a program written in Java or non-Java socket program.

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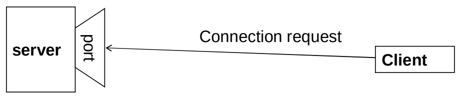
Socket Communication

- A server (program) runs on a specific computer and has a socket that is bound to a specific port. The server waits and listens to the socket for a client to make a connection request.



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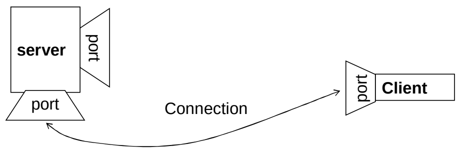
Socket Communication

- If everything goes well, the server accepts the connection. Upon acceptance, the server gets a new socket bounds to a different port. It needs a new socket (consequently a different port number) so that it can continue to listen to the original socket for connection requests while serving the connected client.



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Sockets and Java Socket Classes

- A socket is one endpoint of a two-way communication link between two programs running on the network.
- A socket is bound to a port number so that the TCP layer can identify the application that data destined to be sent.
- Java's .net package provides two classes:
  - Socket – for implementing a client
  - ServerSocket – for implementing a server

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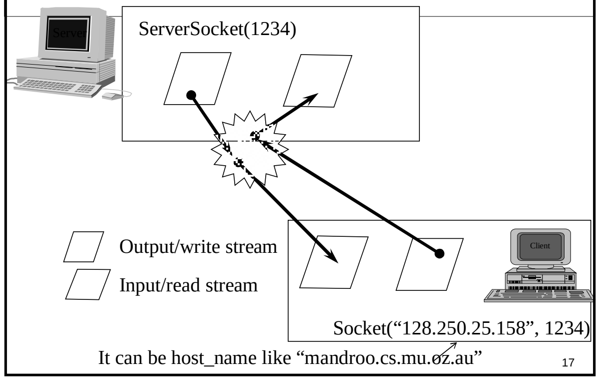
Java Sockets



It can be host_name like "mandroo.cs.mu.oz.au"

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Implementing a Server

```
1. Open the Server Socket:
   ServerSocket server;
   DataOutputStream os;
   DataInputStream is;
   server = new ServerSocket( PORT );
2. Wait for the Client Request:
   Socket client = server.accept();
3. Create I/O streams for communicating to the client
   is = new DataInputStream( client.getInputStream() );
   os = new DataOutputStream( client.getOutputStream() );
4. Perform communication with client
   Receive from client: String line = is.readLine();
   Send to client: os.writeBytes("Hello\n");
5. Close sockets:   client.close();
```

For multithreaded server:

```
  while(true) {
    i. wait for client requests (step 2 above)
    ii. create a thread with "client" socket as parameter (the thread creates streams (as in step
    (3) and does communication as stated  in (4). Remove thread once service is provided.
}
```

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Implementing a Client

1. Create a Socket Object:
   `client = new Socket( server, port_id );`
2. Create I/O streams for communicating with the server.
   ```
   is = new DataInputStream(client.getInputStream() );
    os = new DataOutputStream( client.getOutputStream() );
   ```
3. Perform I/O or communication with the server:
   - Receive data from the server:
     `String line = is.readLine();`
   - Send data to the server:
     `os.writeBytes("Hello\n");`
4. Close the socket when done:
   `client.close();`

A simple server (simplified code)

```
// SimpleServer.java: a simple server program
import java.net.*;
import java.io.*;
public class SimpleServer {
  public static void main(String args[]) throws IOException {
    // Register service on port 1234
    ServerSocket s = new ServerSocket(1234);
    Socket s1=s.accept(); // Wait and accept a connection
    // Get a communication stream associated with the socket
    OutputStream s1out = s1.getOutputStream();
    DataOutputStream dos = new DataOutputStream (s1out);
    // Send a string!
    dos.writeUTF("Hi there");
    // Close the connection, but not the server socket
    dos.close();
    s1out.close();
    s1.close();
  }
}
```

A simple client (simplified code)

```
// SimpleClient.java: a simple client program
import java.net.*;
import java.io.*;
public class SimpleClient {
  public static void main(String args[]) throws IOException {
    // Open your connection to a server, at port 1234
    Socket s1 = new Socket("mundroo.cs.mu.oz.au",1234);
    // Get an input file handle from the socket and read the input
    InputStream s1In = s1.getInputStream();
    DataInputStream dis = new DataInputStream(s1In);
    String st = new String (dis.readUTF());
    System.out.println(st);
    // When done, just close the connection and exit
    dis.close();
    s1In.close();
    s1.close();
  }
}
```

Run

- Run Server on mundroo.cs.mu.oz.au
  - [raj@mundroo] java SimpleServer &
- Run Client on any machine (including mundroo):
  - [raj@mundroo] java SimpleClient
    Hi there
- If you run client when server is not up:
  - [raj@mundroo] sockets [1:147] java SimpleClient

```
Exception in thread "main" java.net.ConnectException: Connection refused
        at java.net.PlainSocketImpl.socketConnect(Native Method)
        at java.net.PlainSocketImpl.doConnect(PlainSocketImpl.java:320)
        at java.net.PlainSocketImpl.connectToAddress(PlainSocketImpl.java:133)
        at java.net.PlainSocketImpl.connect(PlainSocketImpl.java:120)
        at java.net.Socket.<init>(Socket.java:273)
        at java.net.Socket.<init>(Socket.java:100)
        at SimpleClient.main(SimpleClient.java:6)
```

Socket Exceptions

```
try {
    Socket client = new Socket(host, port);
    handleConnection(client);
}
catch(UnknownHostException uhe) {
    System.out.println("Unknown host: " + host);
    uhe.printStackTrace();
}
catch(IOException ioe) {
System.out.println("IOException: " + ioe);
    ioe.printStackTrace();
}
```

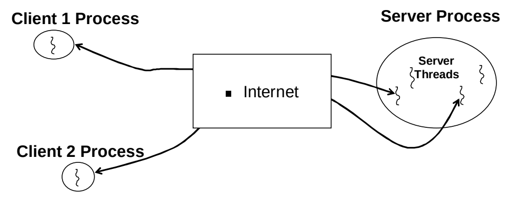
ServerSocket & Exceptions

- public **ServerSocket**(int port) throws IOException
  - Creates a server socket on a specified port.
  - A port of 0 creates a socket on any free port. You can use **getLocalPort**() to identify the (assigned) port on which this socket is listening.
  - The maximum queue length for incoming connection indications (a request to connect) is set to 50. If a connection indication arrives when the queue is full, the connection is refused.
- Throws:
  - IOException - if an I/O error occurs when opening the socket.
  - SecurityException - if a security manager exists and its checkListen method doesn't allow the operation.

Server in Loop: Always up

```
// SimpleServerLoop.java: a simple server program that runs forever in a single thead
import java.net.*;
import java.io.*;
public class SimpleServerLoop {
  public static void main(String args[]) throws IOException {
    // Register service on port 1234
    ServerSocket s = new ServerSocket(1234);
    while(true)
    {
            Socket s1=s.accept(); // Wait and accept a connection
            // Get a communication stream associated with the socket
            OutputStream s1out = s1.getOutputStream();
            DataOutputStream dos = new DataOutputStream (s1out);
            // Send a string!
            dos.writeUTF("Hi there");
            // Close the connection, but not the server socket
            dos.close();
            s1out.close();
            s1.close();
    }
  }
}
```

Multithreaded Server: For Serving Multiple Clients Concurrently



Conclusion

- Programming client/server applications in Java is fun and challenging.
- Programming socket programming in Java is much easier than doing it in other languages such as C.
- Keywords:
  - Clients, servers, TCP/IP, port number, sockets, Java sockets