Python Object-Oriented Program with Libraries

Unit 3: Web Programming

CHAPTER 1: NETWORK FUNDAMENTALS

DR. ERIC CHOU

IEEE SENIOR MEMBER

Objectives

- Understand the various fundamental aspects of web-programming: Low-Level sockets, Client/Server model, Data, Protocol, Parallel Computing (Distributed Computing)
- Understand Network Architecture
- Use basic network tools: Putty, Telnet, Ping
- Local host (loopback) and XAMPP Server
- Sockets

Python Networking Overview

LECTURE 1

Python Networking

- Network programming is a major use of Python
- Python standard library has wide support for network protocols, data encoding/decoding, and other things you need to make it work
- Writing network programs in Python tends to be substantially easier than in C/C++

This Unit

- This course focuses on the essential details of network programming that all Python programmers should probably know
  1. **Sockets:** Low-level programming with sockets
  2. **Client:** High-level client modules
  3. **Data:** How to deal with common data encodings
  4. **Protocol:** Simple web programming (HTTP)
  5. **Parallelism:** Simple distributed computing

Client

Internet

Server

Internet

HTML

JavaScript

AJAX

CSS

HTTP

Request

Response

GET

socket

POST

Python

Data Store

Templates

memcache

Standard Library

- We will only cover modules supported by the Python standard library
- These come with Python by default
- Keep in mind, much more functionality can be found in third-party modules
- Will give links to notable third-party libraries as appropriate

Prerequisites

- You should already know Python basics
- However, you don't need to be an expert on all of its advanced features (in fact, none of the code to be written is highly sophisticated)
- You should have some prior knowledge of systems programming and network concepts

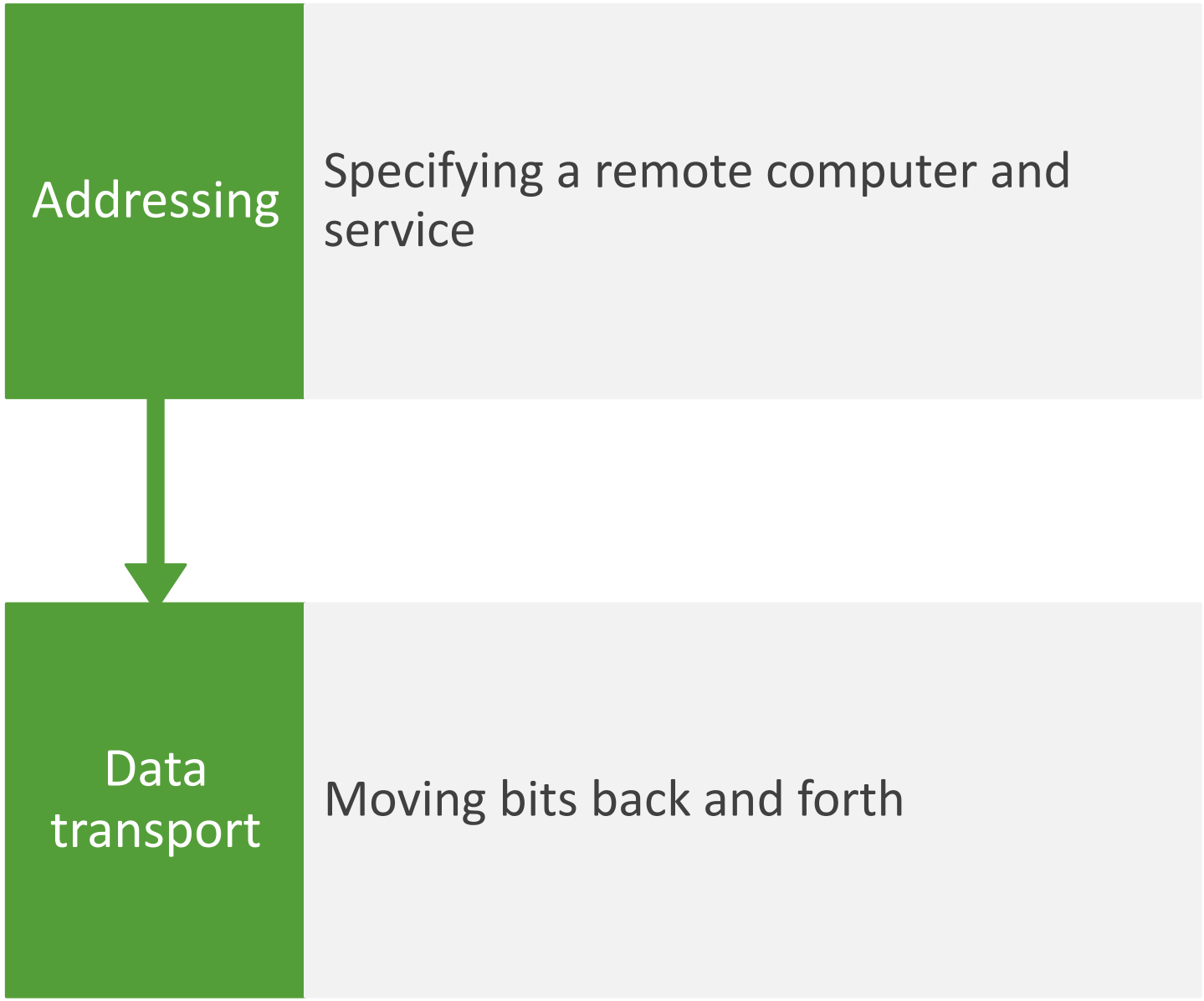
Network Fundamentals

LECTURE 2

The Problem

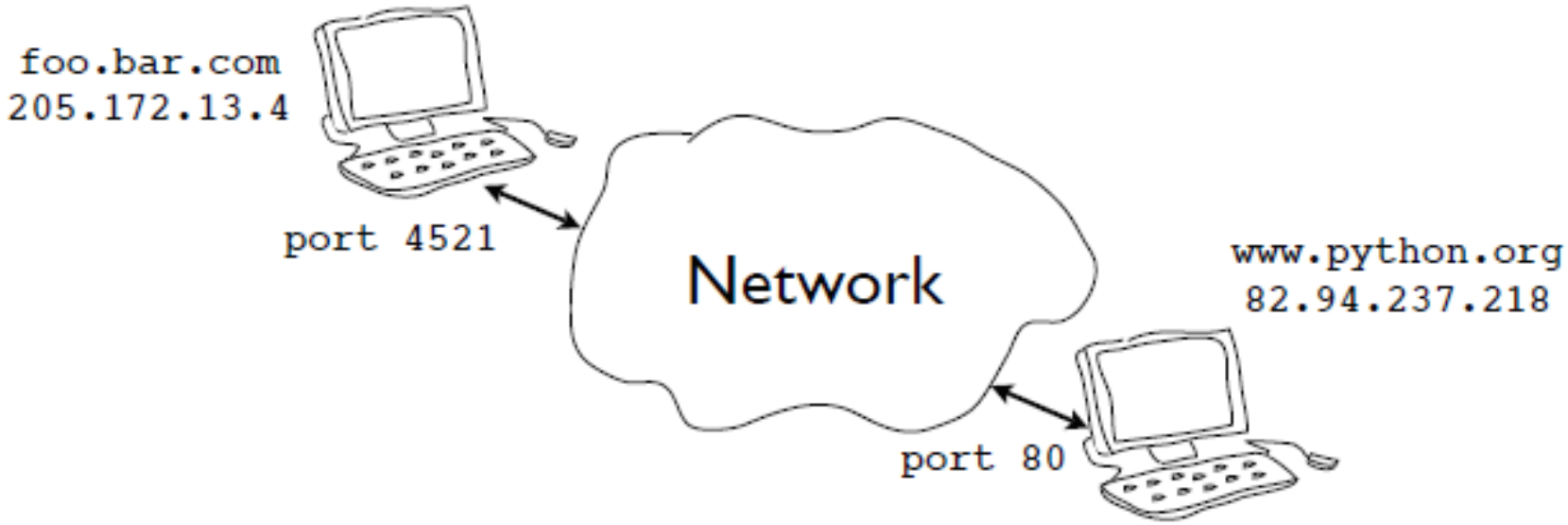
It's just sending/receiving bits.

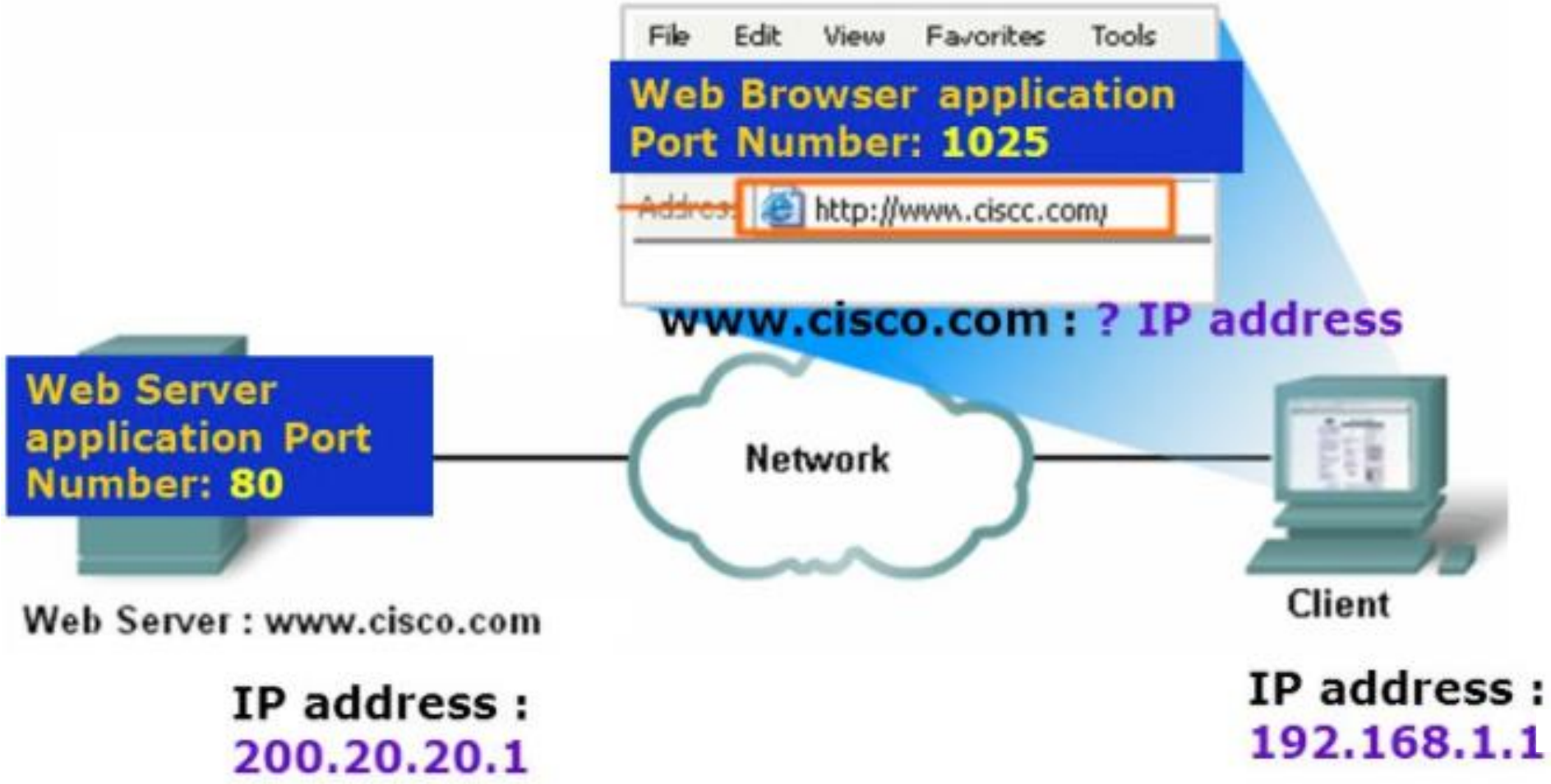
Two Main Issues



Network Addressing

- Machines have a hostname and IP address
- Programs/services have port numbers





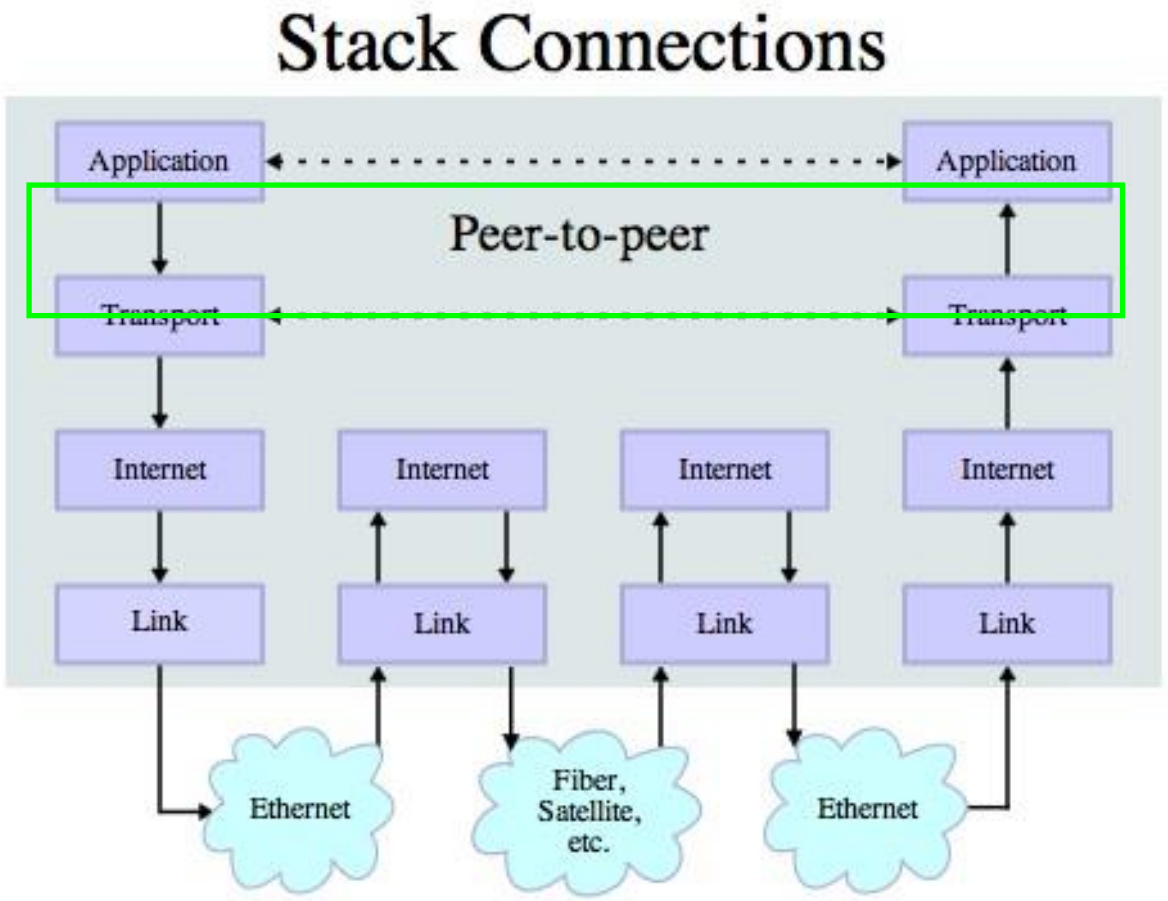
Domain Name, IP Address and Port Number

Network Architecture

LECTURE 3

Transport Control Protocol (TCP)

- Built on top of IP (Internet Protocol)
- Assumes IP might lose some data - stores and retransmits data if it seems to be lost
- Handles “flow control” using a transmit window
- Provides a nice reliable pipe

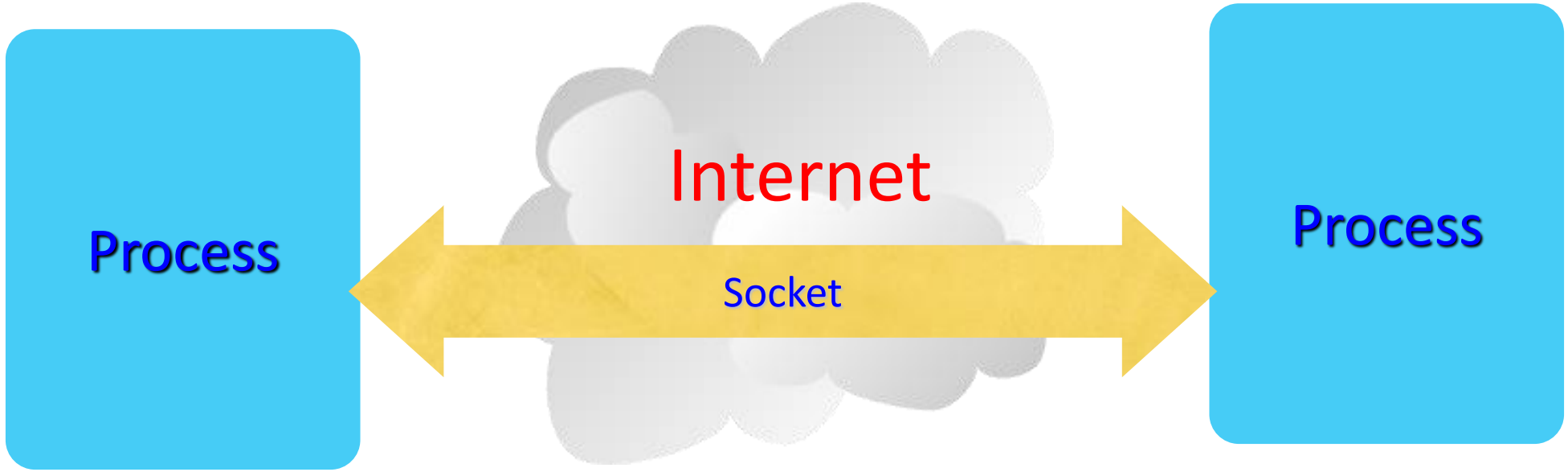


Source: http://en.wikipedia.org/wiki/Internet_Protocol_Suite

TCP Connections / Sockets

Process to Process Communication

"In computer networking, an Internet socket or network socket is an endpoint of a bidirectional inter-process communication flow across an Internet Protocol-based computer network, such as the Internet."



TCP Port Numbers

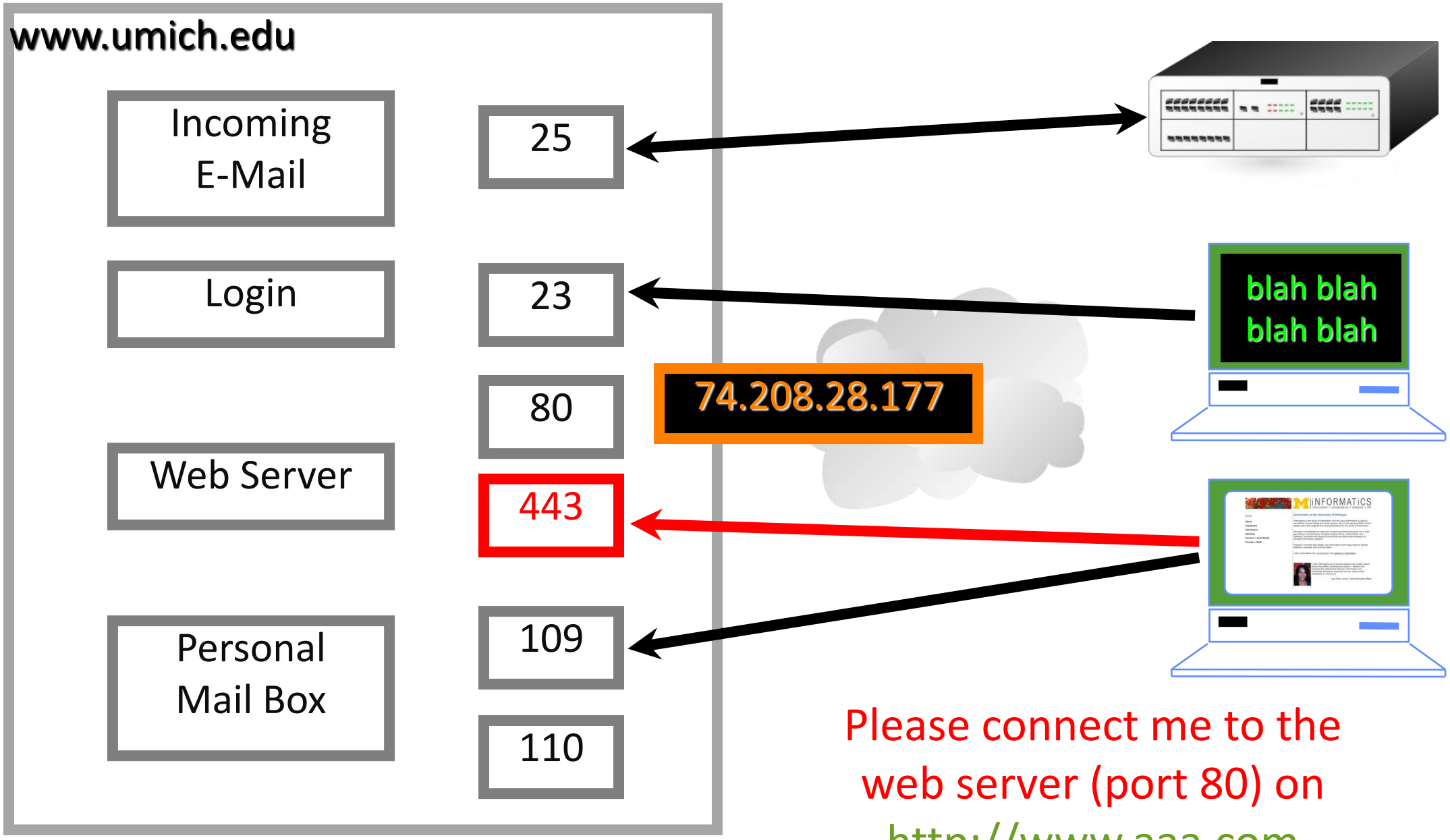
- A port is an application-specific or process-specific software communications endpoint
- It allows multiple networked applications to coexist on the same server.
- There is a list of well-known TCP port numbers

Standard Ports

Ports for common services are preassigned:

- 21 **FTP**
- 22 **SSH**
- 23 **Telnet**
- 25 **SMTP** (Mail)
- 53 **DNS** (Domain Name)
- 80 **HTTP** (Web) - 443 **HTTPS** (web, Secure)
- 110 **POP3** (Mail) - 119 **NNTP** (News)
- (143/220/993) **IMAP** - Mail Retrieval

• Other port numbers may just be randomly assigned to programs by the operating system

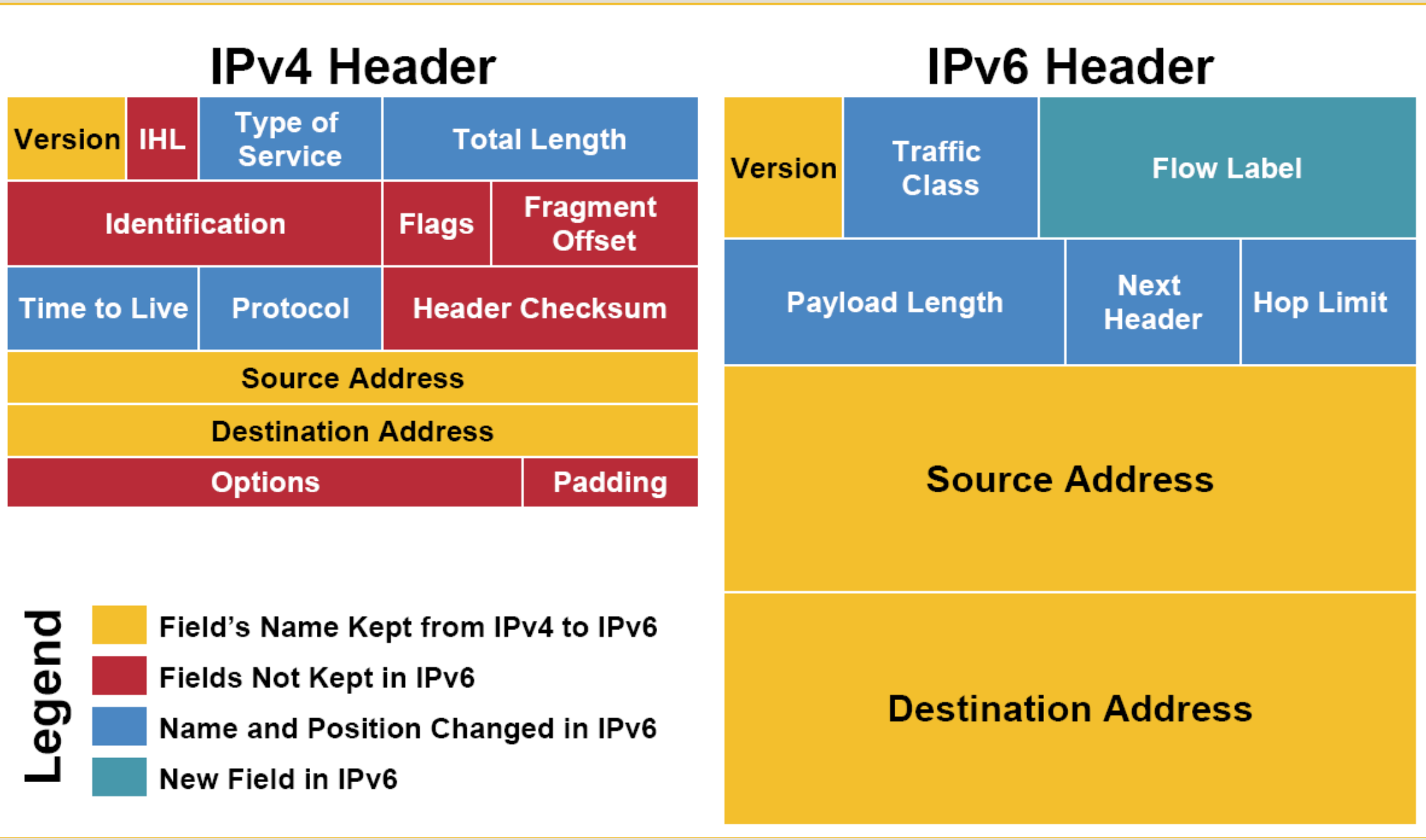


Please connect me to the web server (port 80) on http://www.aaa.com

http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

IP Address

	Internet Protocol version 4 (IPv4)	Internet Protocol version 6 (IPv6)
Deployed	1981	1999
Address Size	32-bit number	128-bit number
Address Format	Dotted Decimal Notation: 192.149.252.76	Hexadecimal Notation: 3FFE:F200:0234:AB00: 0123:4567:8901:ABCD
Prefix Notation	192.149.0.0/24	3FFE:F200:0234::/48
Number of Addresses	$2^{32} = \sim 4,294,967,296$	$2^{128} = \sim 340,282,366,$ $920,938,463,463,374,$ $607,431,768,211,456$


IPv4 Header
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding
IPv6 Header
Version
Traffic Class
Flow Label
Payload Length
Next Header
Hop Limit
Source Address
Destination Address
Legend
Field's Name Kept from IPv4 to IPv6
Fields Not Kept in IPv6
Name and Position Changed in IPv6
New Field in IPv6

Domain Name System (DNS)

the address of your website

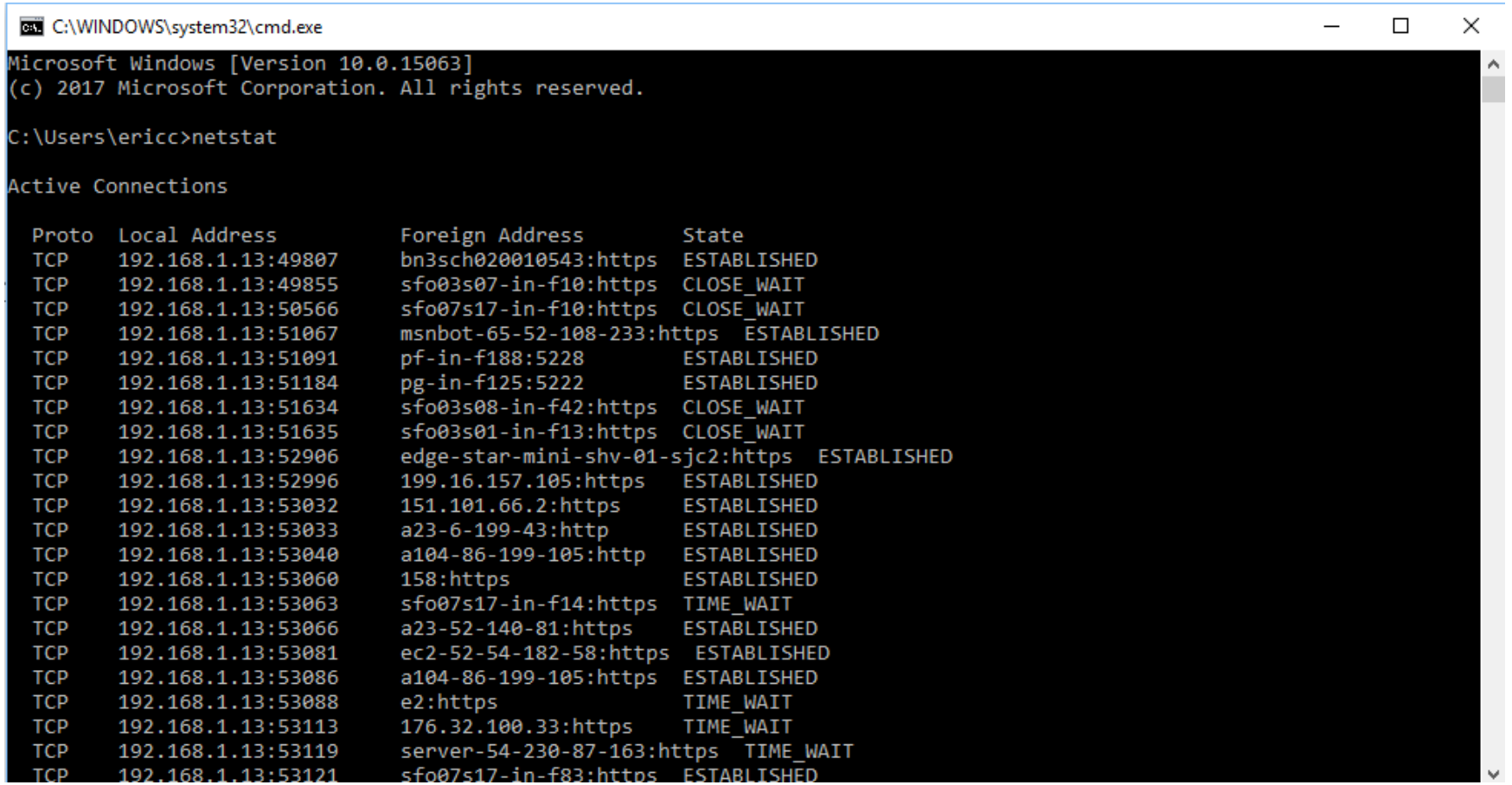
PuTTY (Terminal)

LECTURE 4

PuTTY

- **PuTTY** is a free implementation of **SSH** and **Telnet** for Windows and Unix platforms, along with an **xterm** terminal emulator. It is written and maintained primarily by Simon Tatham.

- **SSH**: Secure Shell (**SSH**) is a cryptographic network protocol for operating network services securely over an unsecured network
- **Telnet**:a network protocol that allows a user on one computer to log onto another computer that is part of the same network.
- **TTY**: virtual terminal



Using netstat

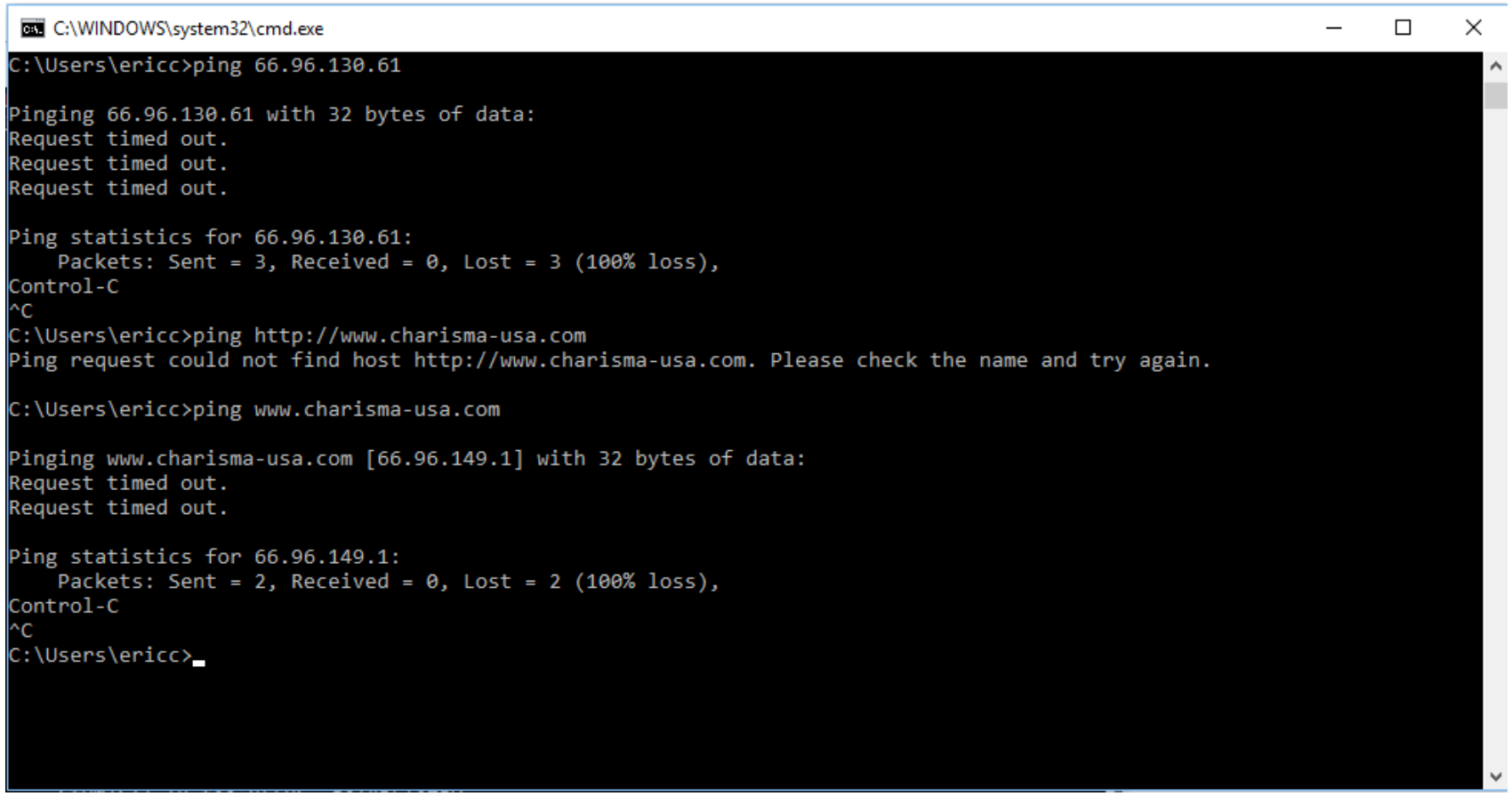
- Use 'netstat' to view active network connections
- Note: Must execute from the command shell on both Unix and Windows

Connections

- Each endpoint of a network connection is always represented by a host and **port #**
- In Python you write it out as a tuple (host,port)

  ("www.python.org",80)

  ("205.172.13.4",443)
- In almost all of the network programs you'll write, you use this convention to specify a network address



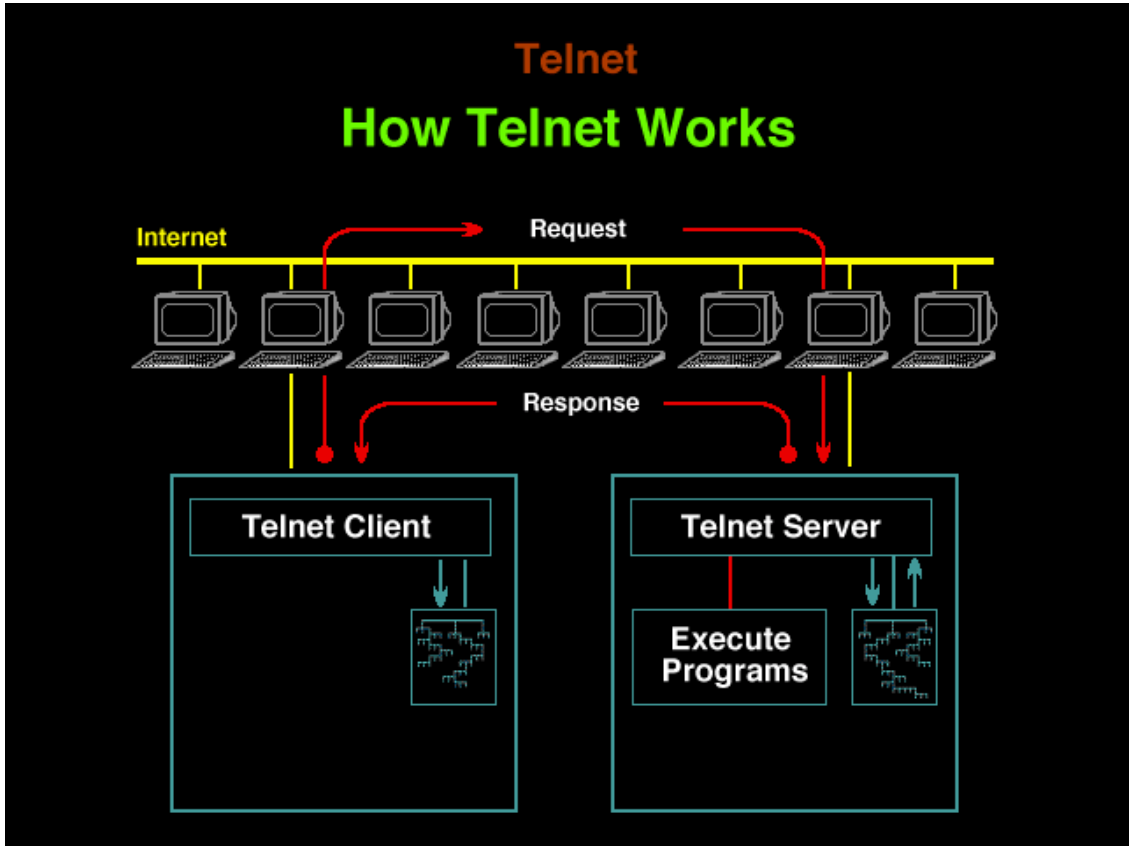
Using ping

- Use ‘ping' to check if the connection to a host is love.
- Note: In the example, the connection is not built

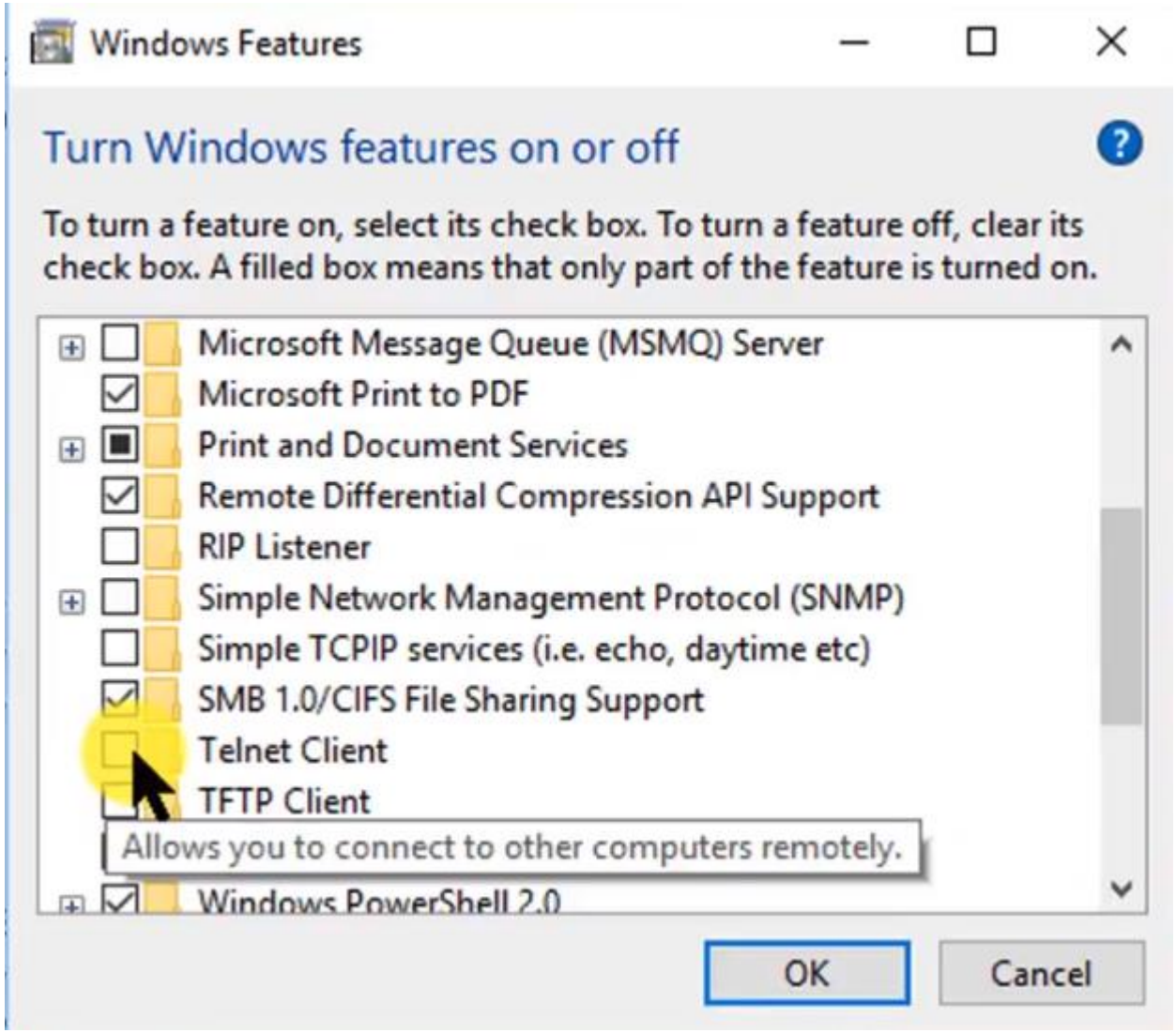
```
C:\Users\ericc>ping localhost

Pinging Sugarcane [::1] with 32 bytes of data:
Reply from ::1: time<1ms
Reply from ::1: time<1ms
Reply from ::1: time<1ms
Reply from ::1: time<1ms

Ping statistics for ::1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

Even localhost fails? Why? No local host server.

Using Telnet



App and Features -> Program and Features -> Telnet Client



Watch Video:
https://youtu.be/CJQfR1b43ns

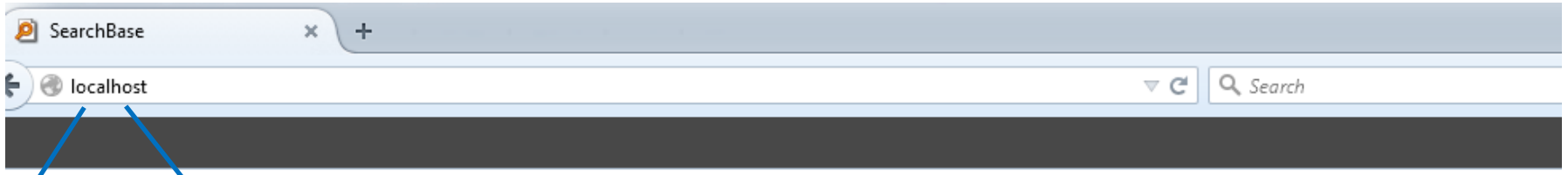
Local Host

Testing a Web Service Locally

How do you set up a local testing server?

- Local files versus remote files
- The problem with testing local files
- Running a simple local HTTP server
- Running server-side languages locally

Browser (Client)



Client

Server

Desktop Python Client Program

client.py – Poznámkový blok

Soubor Úpravy Formát Zobrazení Nápověda

```
import socket

target_ip = "127.0.0.1"
target_port = 80

c = socket.socket(socket.AF_INET,socket.SOCK_STREAM)
c.connect((target_ip,target_port))
response = c.recv(1024)
print "Server response: %s" % response
print "Sending HELLO message"
c.sendall("HELLO")
print "Sent"
```

Desktop Server Program

Terminal — bash — 80×24

```
Last login: Sun Feb  9 10:04:49 on ttys000
vishwarajs-Mac-Pro:~ vishwaraj$ python
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> import socket
>>> sock=socket.socket(socket.AF_INET,socket.SOCK_STREAM)
>>> sock.bind(("127.0.0.1",8000))
>>> sock.listen(2)
>>> (client,(ip,port))=sock.accept()
```

Installing IIS

To install IIS:

1.In Windows, access the Control Panel and click **Add or Remove Programs**.

2.In the Add or Remove Programs window, click **Add/Remove Windows Components**.

3.Select the **Internet Information Services (IIS)** check box, click **Next**, then click **Finish**.

To learn how to use IIS, you can view the documentation at http://localhost/iishelp/iis/misc/default.asp.

Watch Video:
https://youtu.be/bJrOASXslwU

XAMPP Server
Bring up Server and localhost

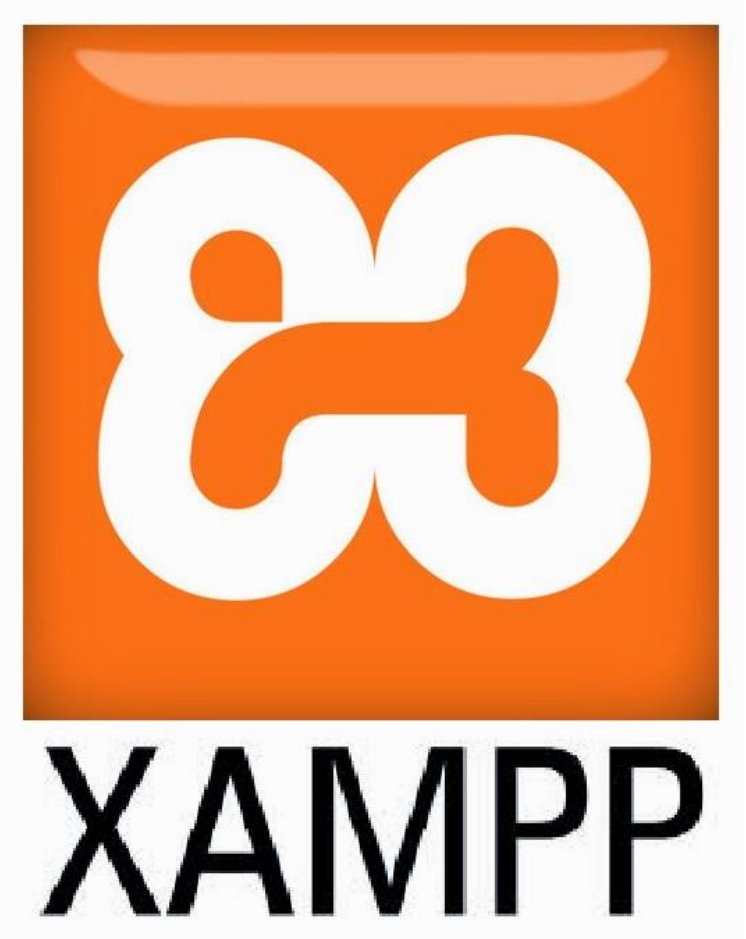
LECTURE 5

What is XAMPP?

- XAMPP stands for Cross-Platform (**X**), Apache (**A**), MySQL (**M**), PHP (**P**) and Perl (**P**).
- It is a simple, lightweight Apache distribution that makes it extremely easy for developers to create a local web server for testing purposes.
- Everything you need to set up a web server – server application (Apache), database (MySQL), and scripting language (PHP) – is included in a simple extractable file.
- XAMPP is also cross-platform, which means it works equally well on Linux, Mac and Windows.
- Since most actual web server deployments use the same components as XAMPP, it makes transitioning from a local test server to a live server is extremely easy as well.
- Web development using XAMPP is especially beginner friendly, as this popular PHP and MySQL for beginners course will teach you.

XAMPP

https://www.apachefriends.org/index.html



Component	On Windows	On Linux	On macOS
Apache 2.4.28	Yes	Yes	Yes
MariaDB 10.1.28	Yes	Yes	Yes
PHP	Yes - 7.1.10	Yes - 7.1.10[15]	Yes - 7.1.10[15]
phpMyAdmin	Yes - 4.7.4	Yes - 4.7.4	Yes - 4.7.4
OpenSSL	Yes - 1.0.2l	Yes - 1.0.2l	Yes - 1.0.2l
XAMPP Control Panel 3.2.2	Yes	No	No
Webalizer	Yes - 2.23-04	Yes - 2.23-05	Yes - 2.23-05
Mercury Mail	Yes	No	No
Transport System 4.63	Yes	No	No
Tomcat 7.0.56 (with mod_proxy_ajp as connector)	Yes	No	No
Strawberry Perl 7.0.56 Portable	Yes	No	No
FileZilla FTP Server 0.9.41	Yes	No	No

Installation

Watch video in the Software Installation Video Collection Course:

https://ec.teachable.com/p/software-installation-and-configuration-video-collection-free-mini-course

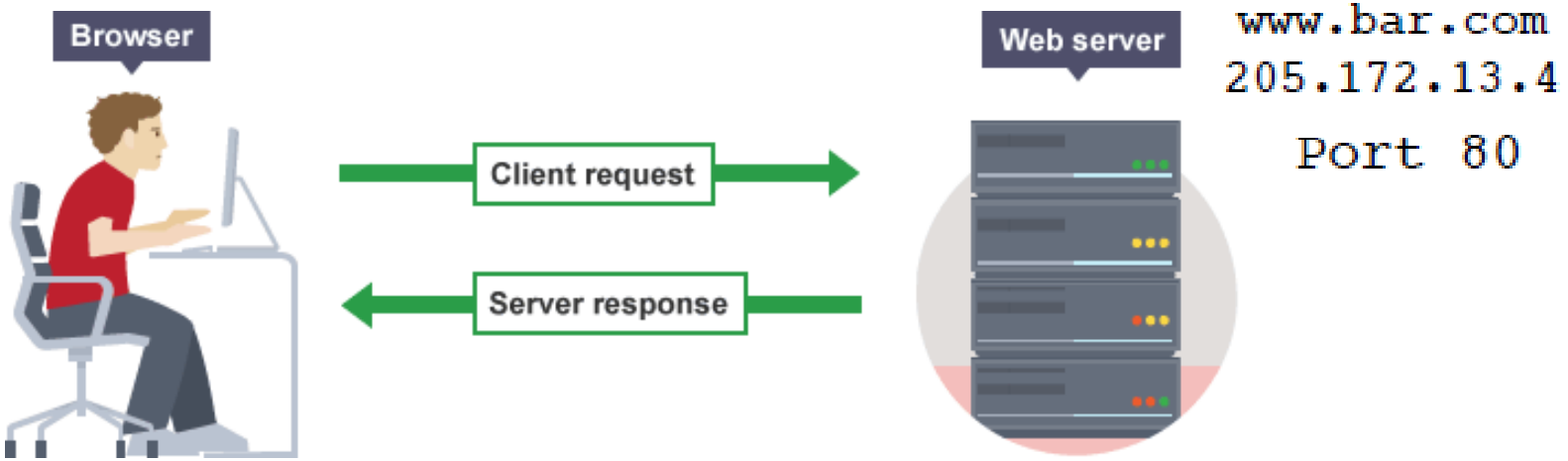
Check if the server has been brought up, especially the localhost has been brought up.

Client-Server Concept

LECTURE 6

Client/Server Concept

- Each endpoint is a running program
- Servers wait for incoming connections and provide a service (e.g., web, mail, etc.)
- Clients make connections to servers



Request/Response Cycle

- Most network programs use a request/response model based on messages
- Client sends a request message (e.g., HTTP)

  GET /index.html HTTP/1.0
- Server sends back a response message

  HTTP/1.0 200 OK

  Content-type: text/html

  Content-length: 48823

  <HTML>

  ...
- The exact format depends on the application

Using Telnet

on Linux/Unix

- As a debugging aid, telnet can be used to directly communicate with many services

```
telnet hostname portnum
```

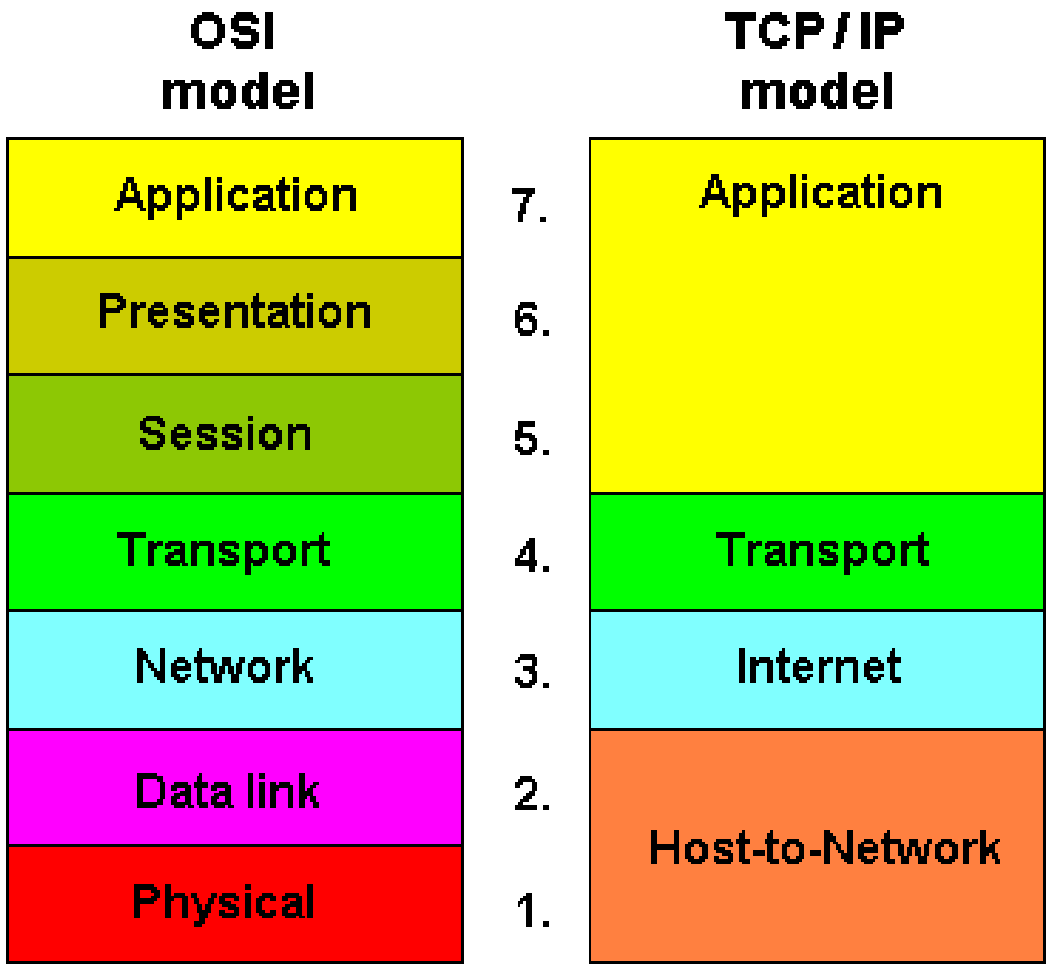
- Example:

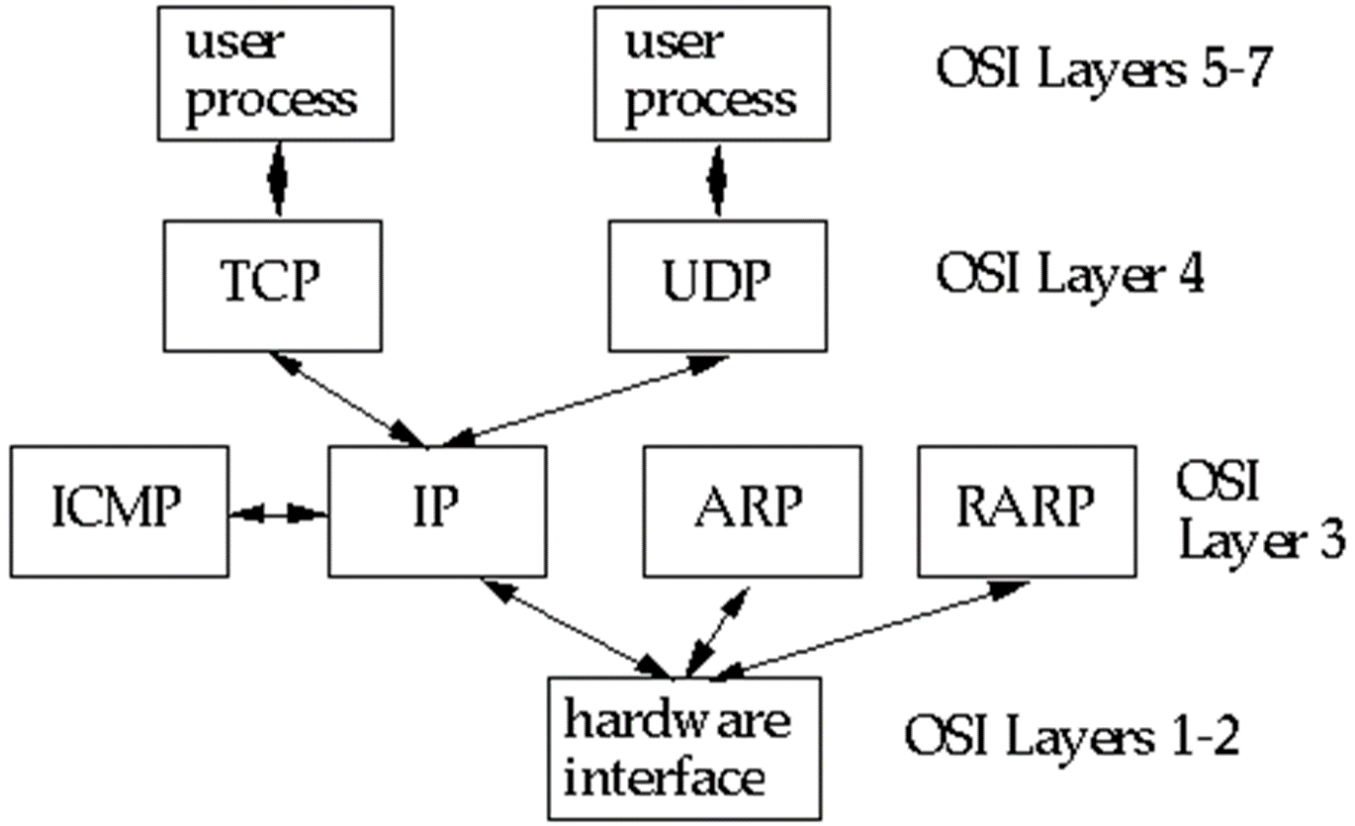
type this and press return a few times →

```
shell % telnet www.python.org 80
Trying 82.94.237.218...
Connected to www.python.org.
Escape character is '^]'.
GET /index.html HTTP/1.0

HTTP/1.1 200 OK
Date: Mon, 31 Mar 2008 13:34:03 GMT
Server: Apache/2.2.3 (Debian) DAV/2 SVN/1.4.2
mod_ssl/2.2.3 OpenSSL/0.9.8c
...
```

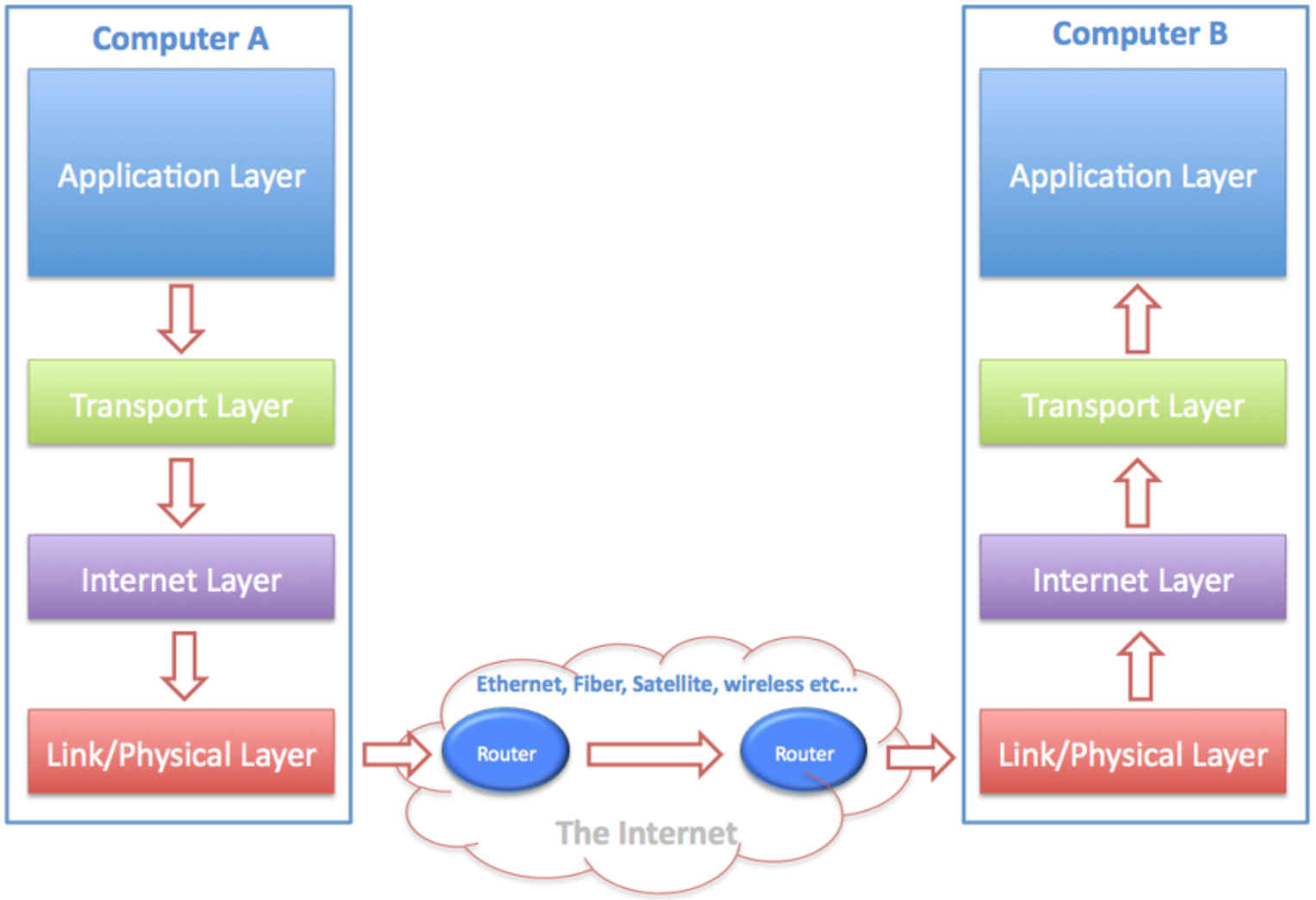
Data Transport

- There are two basic types of communication
- **Streams** (TCP): Computers establish a connection with each other and read/write data in a **continuous** stream of bytes---like a file. This is the most common.
- **Datagrams** (UDP): Computers send **discrete** packets (or messages) to each other. Each packet contains a collection of bytes, but each packet is separate and self-contained.


OSI model
TCP/IP model
Application
Presentation
Session
Transport
Network
Data link
Physical
7.
6.
5.
4.
3.
2.
1.
Application
Transport
Internet
Host-to-Network


user process
user process
OSI Layers 5-7
TCP
UDP
OSI Layer 4
ICMP
IP
ARP
RARP
OSI Layer 3
hardware interface
OSI Layers 1-2

Data Transmission over the Internet through TCP/IP



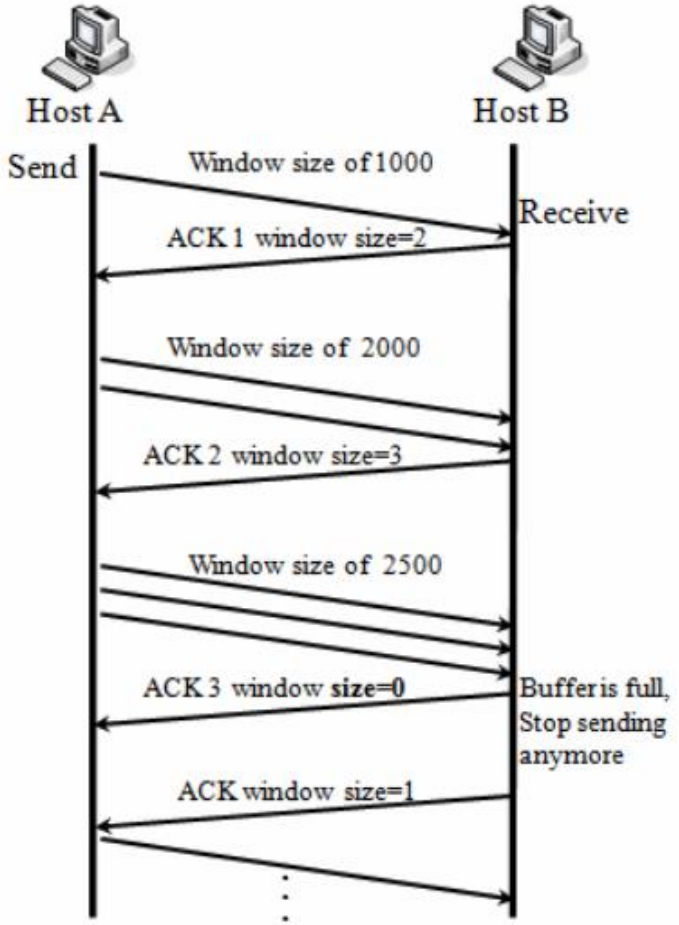
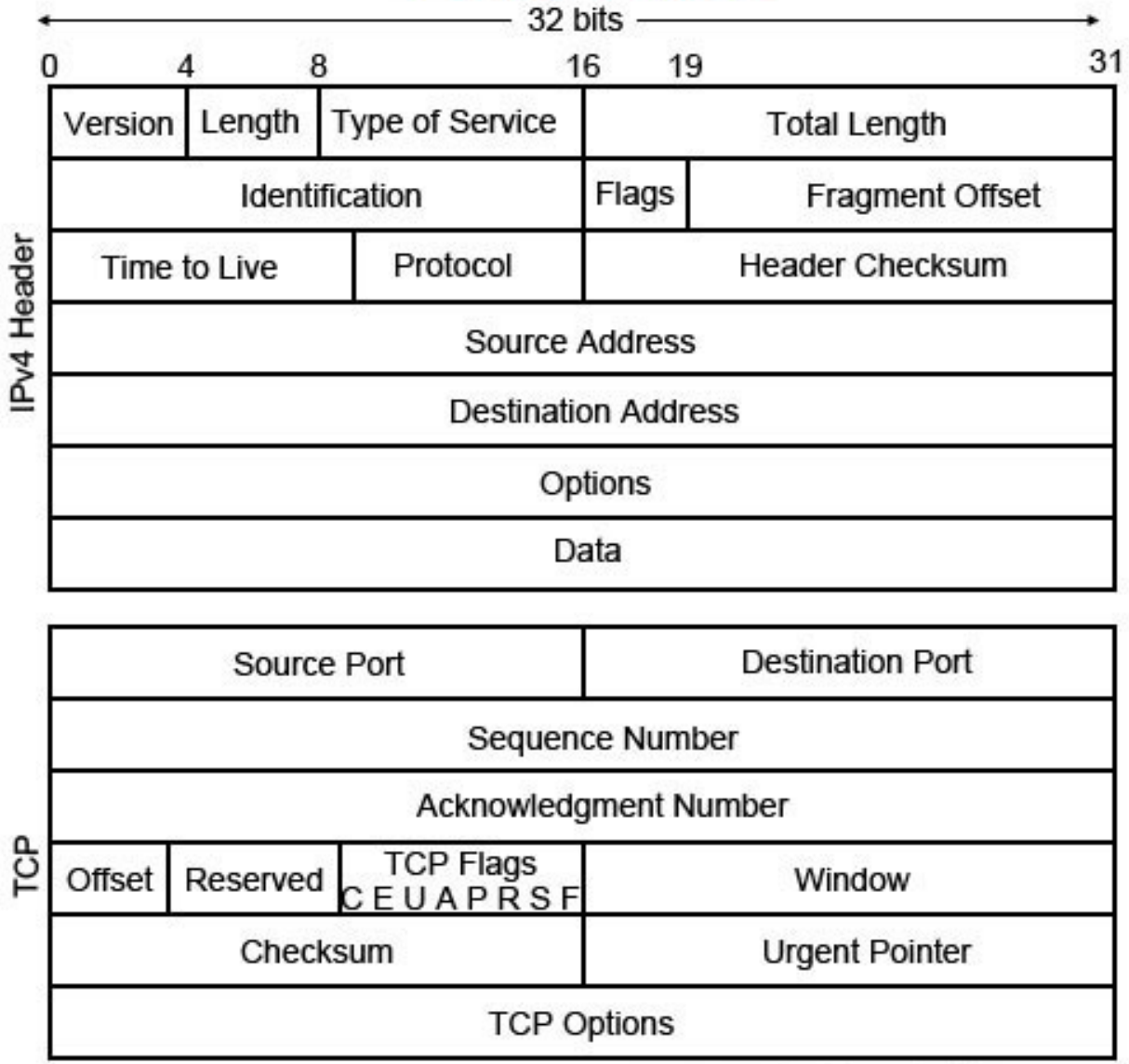
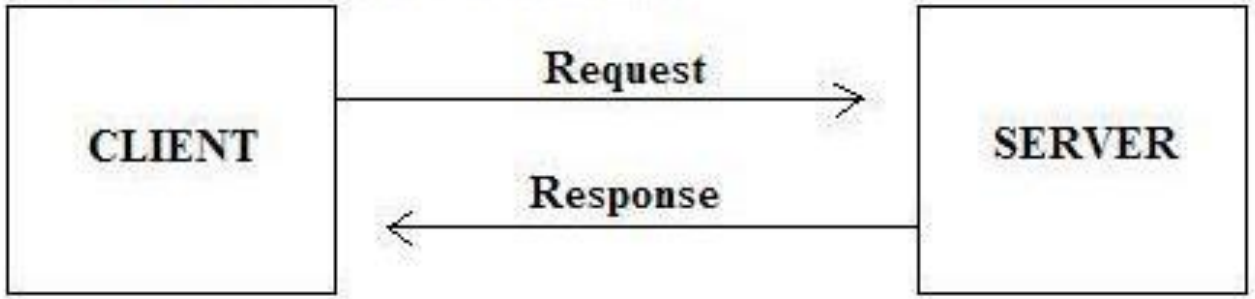


Figure 2.2. TCP flow control using *windowing*

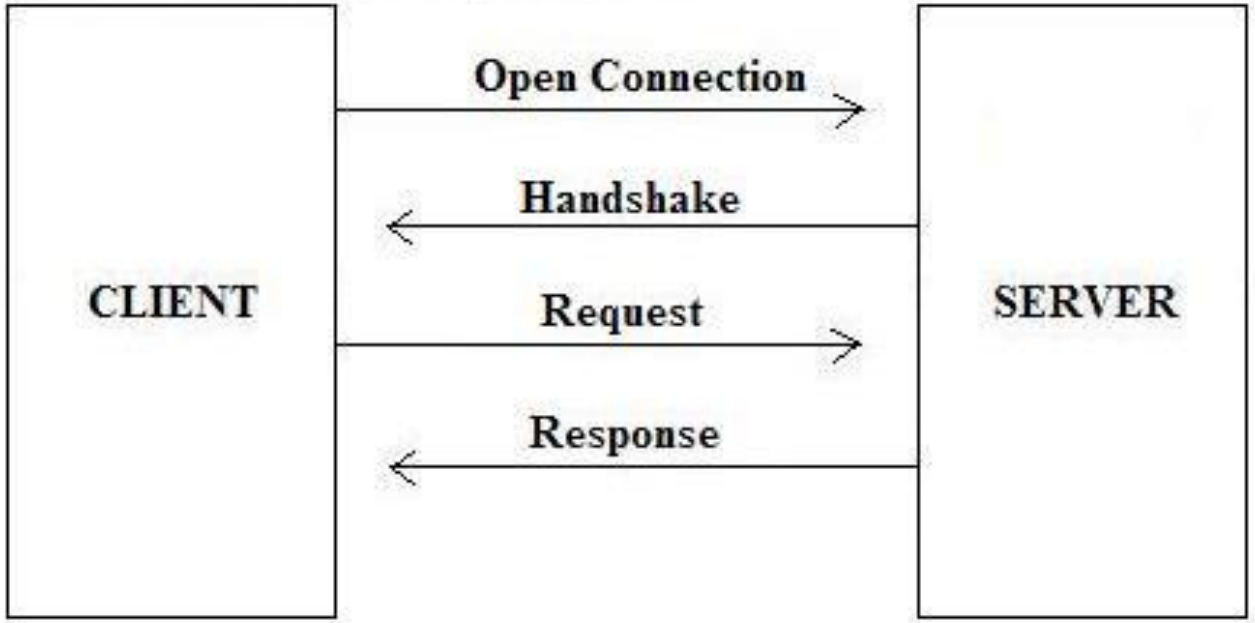
TCP/IP Packet



UDP Request / Response Paradigm



TCP Handshake Paradigm

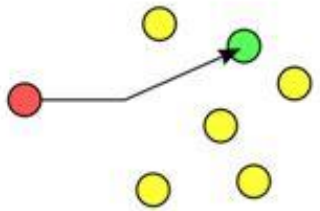


TCP

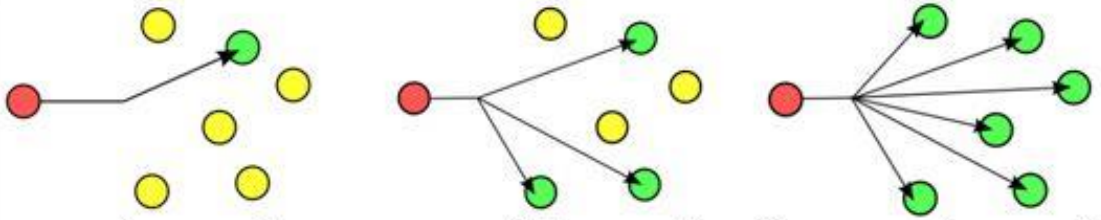
- Slower but reliable transfers
- Typical applications:
  - Email
  - Web browsing

UDP

- Fast but non-guaranteed transfers ("best effort")
- Typical applications:
  - VoIP
  - Music streaming



unicast



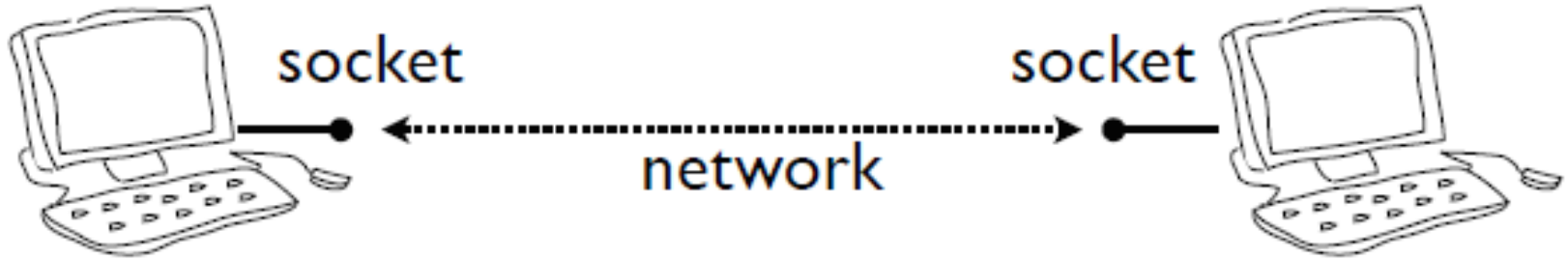
unicast multicast broadcast

Socket (Client)

LECTURE 7

Sockets

- Programming abstraction for network code
- Socket: A communication endpoint

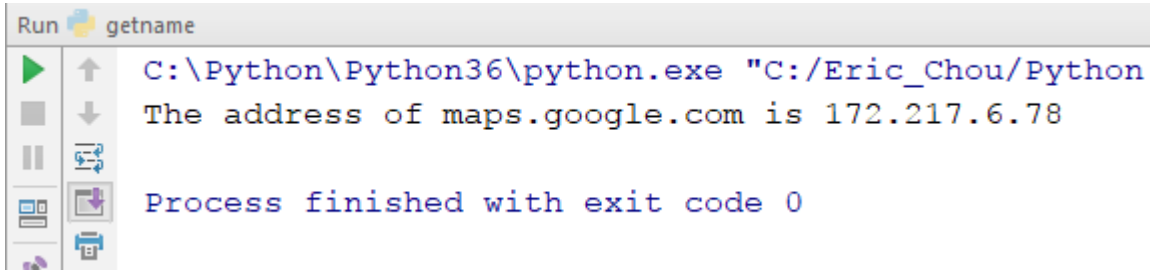


- Supported by **socket** library module
- Allows connections to be made and data to be transmitted in either direction

Get the Host Name

Demo Program: getname.py

```
import socket
hostname = 'maps.google.com'
addr = socket.gethostbyname(hostname)
print('The address of', hostname, 'is', addr)
```



Socket Basics

- To create a socket

```
import socket
s = socket.socket(addr_family, type)
```

- Address Familier

socket.AF_INET	Internet protocol (IPv4)
socket.AF_INET6	Internet protocol (IPv6)

- Socket types

socket.SOCK_STREAM	Connection based stream (TCP)
socket.SOCK_DGRAM	Datagrams (UDP)

- Example:

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
```

Socket Types

- Most common case: TCP connection

```
from socket import *
s = socket(AF_INET, SOCK_STREAM)        # TCP
s = socket(AF_INET, SOCK_DGRAM)         # UDP
```

- Almost all code will use one of following

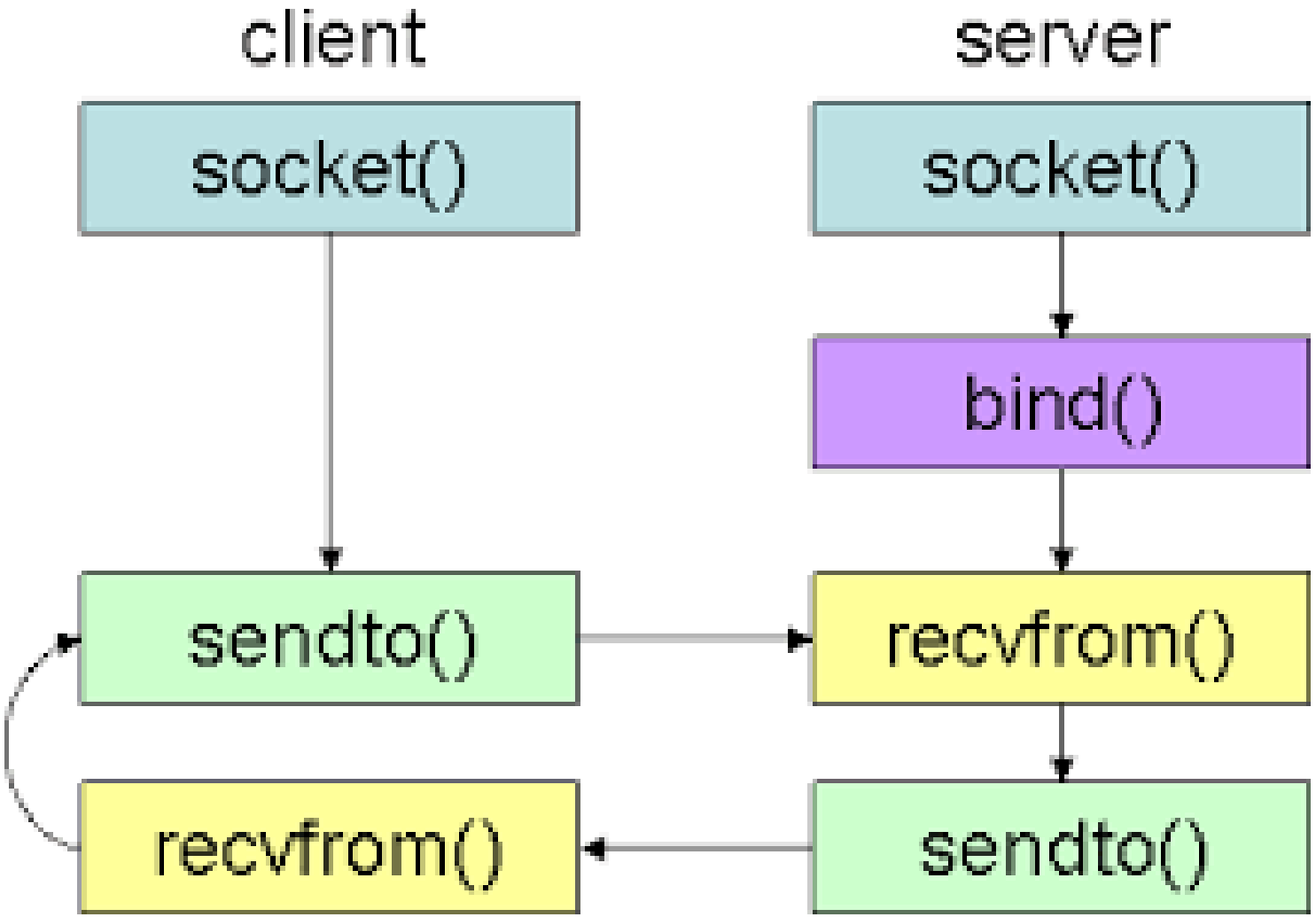
```
s = socket(AF_INET, SOCK_STREAM)        # TCP
```

Using a Socket

- Creating a socket is only the first step

```
s = socket(AF_INET, SOCK_STREAM)
```

- Further use depends on application
- Server
  - Listen for incoming connections
- Client
  - Make an outgoing connection


client
server
socket()
socket()
bind()
sendto()
recvfrom()
recvfrom()
sendto()

TCP Client

- How to make an outgoing connection

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.connect(("www.python.org",80)) # Connect
s.send(bytes("GET /index.html HTTP/1.0\n\n“), ‘utf8’) # Send request
data = s.recv(10000) # Get response
s.close()
```

- **s.connect(addr)** makes a connection

```
s.connect(("www.python.org",80))
```

- Once connected, use **sendto()**, **recvfrom()** to transmit and receive data
- **close()** shuts down the connection

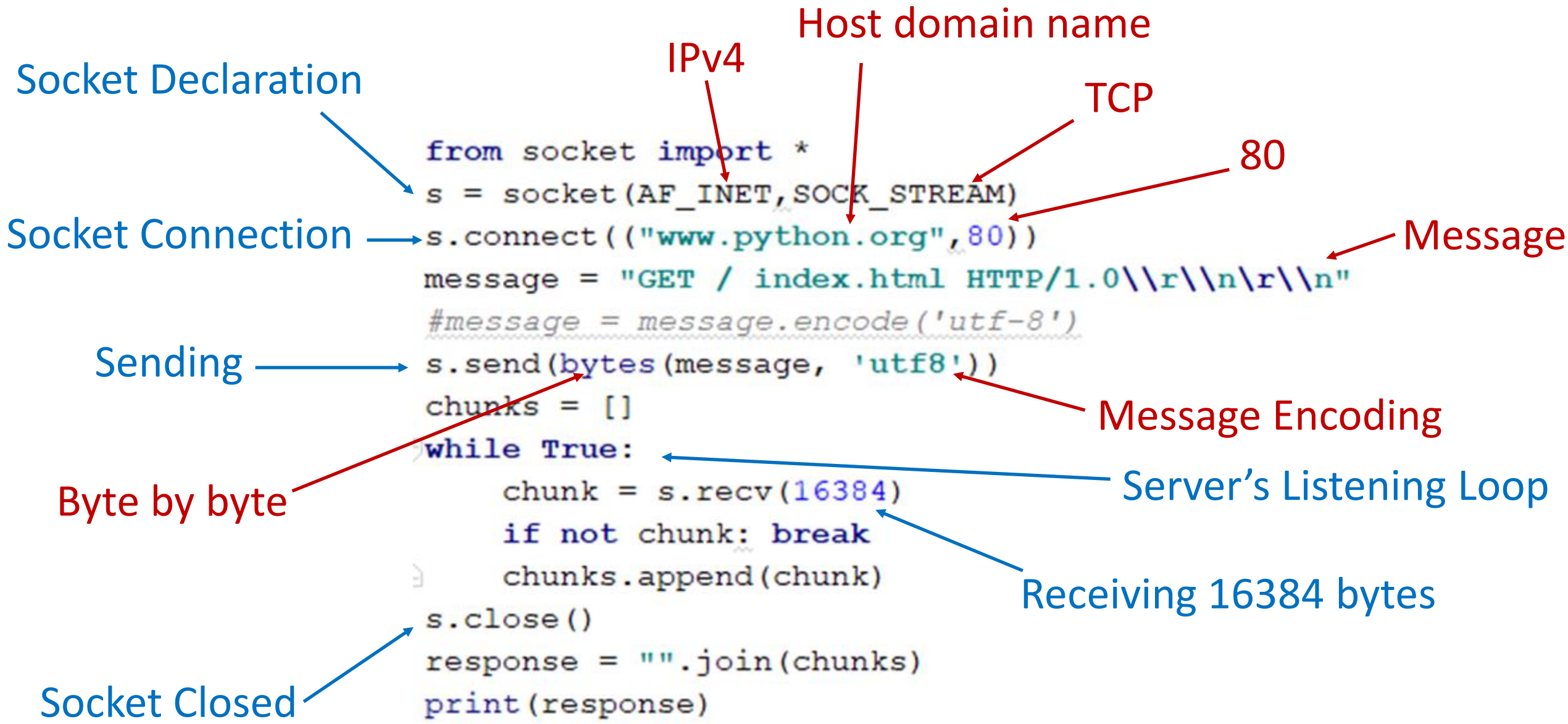
Basic Example (Client Side)

Demo Program: basic0.py (can't run by itself)

Objectives:

- Low-level network programming with sockets
- How to connect to a TCP server

- This code is fairly typical for TCP client code.
- Once connected to a server, use **send**() to send request data. To read a response, you will typically have to read data in chunks with multiple **recv**() operations.
- **recv**() returns an empty string to signal the end of data (i.e., if the server closed its end of the connection).
- Recall that using the string **join**() method is significantly faster than using string concatenation (+) to join string fragments together.


Socket Declaration
IPv4
Host domain name
TCP
80
Socket Connection
Message
Sending
Message Encoding
Byte by byte
Server's Listening Loop
Receiving 16384 bytes
Socket Closed
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.connect(("www.python.org",80))
message = "GET / index.html HTTP/1.0\\r\\n\r\\n"
#message = message.encode('utf-8')
s.send(bytes(message, 'utf8'))
chunks = []
while True:
chunk = s.recv(16384)
if not chunk: break
chunks.append(chunk)
s.close()
response = "".join(chunks)
print(response)

Analogy between File I/O Stream and Socket I/O Stream

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.connect(("www.python.org",80))
message = "GET / index.html HTTP/1.0\\r\\n\\r\\n"
#message = message.encode('utf-8')
s.send(bytes(message, 'utf8'))
chunks = []
while True:
    chunk = s.recv(16384)
    if not chunk: break
    chunks.append(chunk)
s.close()
response = "".join(chunks)
print(response)
```

```
f = open("usdeclar.txt", "r")
tokens=f.read().split()
count = 0
for token in tokens:
    token = token.strip()
    try:
        if len(token)!=0:
            count += 1
            if count % 20 != 0: print(token, end=" ")
            else: print(token)
    except:
        print("Error Input Format!!!")
print("usdeclar.txt has ", count, " words.")
f.close()
```

Socket (Server)

LECTURE 8

Server Implementation

- Network servers are a bit more tricky
- Must listen for incoming connections on a well-known port number
- Typically run forever in a server-loop
- May have to service multiple clients

TCP Server

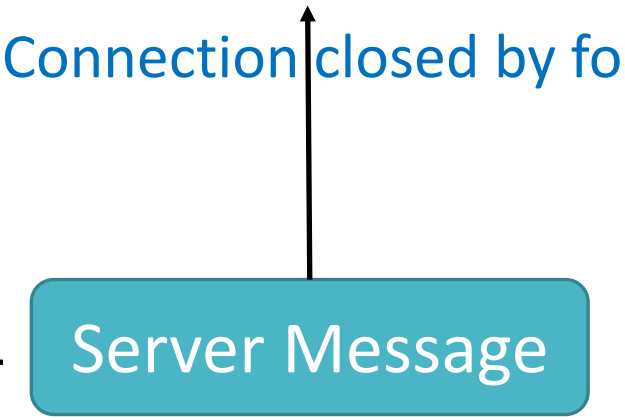
- A simple server

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

maximum number of queued connections and should be at least 1

- Send a message back to a client

```
% telnet localhost 9000
Connected to localhost.
Escape character is '^]'.
Hello 127.0.0.1
Connection closed by foreign host.
```



TCP Server

- Address binding

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c, a = s.accept()
    print("Received connection from",  a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

binds the socket to a specific address

- Addressing

```
s.bind(("",9000))
```

binds to local host

```
s.bind(("localhost",9000))
s.bind(("192.168.2.1",9000))
s.bind(("104.21.4.2",9000))
```

If system has multiple IP addresses, can bind to a specific address

TCP Server

- Start listening for connections

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

- s.listen(backlog)
- backlog is # of pending connections to allow
- Note: not related to max number of clients

Tells operating system to start listening for connections on the socket

TCP Server

- Accepting a new connection

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c, a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

- s.accept() blocks until connection received
- Server sleeps if nothing is happening

Accept a new client connection

TCP Server

- Client Socket and address pair

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c, a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

Accept returns a pair (client_socket, addr)

<socket._socketobject ("104.23.11.4",27743) object at 0x3be30>
This is a new socket that's used for data

("104.23.11.4",27743)
This is the network/port address of the client that connected

TCP Server

- Client Socket and address pair

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c, a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

Note: Use the client socket for transmitting data. The server socket is only used for accepting new connections.

Send data to client

TCP Server

- Client Socket and address pair

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c, a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

Close client connection

- Note: Server can keep client connection alive as long as it wants
- Can repeatedly receive/send data

TCP Server

- Client Socket and address pair

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c, a = s.accept()
    print("Received connection from", a)
    c.send("Hello %s\n" % a[0])
    c.close()
```

Wait for next connection

- Original server socket is reused to listen for more connections
- Server runs forever in a loop like this

Simple Client-Server Sockets Example

LECTURE 9

Simple Client Server Programs

Demo Program: basic1s0.py (Server Program), basic1c0.py (client program) Watch Video: client_server.wmv

Server (PyCharm)	Client (IDLE)
from socket import * s = socket(AF_INET, SOCK_STREAM) s.bind(("",15000)) s.listen(5) c, a = s.accept()	from socket import * s = socket(AF_INET, SOCK_STREAM) s.connect(("localhost",15000))
c	
a	
	s.send(bytes("Hello World“, ‘utf8’))
data = c.recv(1024)	
data	

Simple Client Server Programs

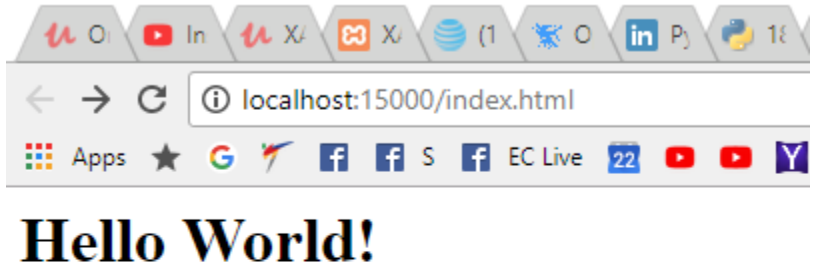
Demo Program: basic1.py (client program)

Server (PyCharm)	Client (IDLE)
c.send(bytes("Hello Yourself“, ‘utf8’))	
	resp = s.recv(1024)
	Resp
	s.recv(1024)
c.send(bytes("Goodbye“, ‘utf8’))	
c.close()	
	s.recv(1024)
	s.recv(1024)

Send a Web-page to a Web-site Connecting to server

Demo Program: browse.py

```
from socket import *
print("Server side starts ...")

# step 1 make a connection
s = socket(AF_INET, SOCK_STREAM)
s.bind(("",15000))
s.listen(5)
c,a = s.accept()
request = c.recv(8192)
print(request)
c.send(bytes("HTTP/1.0 200 OK\r\n", 'utf8'))
c.send(bytes("Content-type: text/html\r\n",'utf8'))
c.send(bytes("\r\n",'utf8'))
c.send(bytes("<h1>Hello World!</h1>",'utf8'))
c.close()
s.close()
```



Connecting to the Website

Server (PyCharm)	Client (Chrome Browser)
from socket import * s = socket(AF_INET, SOCK_STREAM) s.bind(("",15000)) s.listen(5) c, a = s.accept()	
	http://localhost:15000/index.html
request = c.recv(8192)	
print(request)	
c.send(bytes("HTTP/1.0 200 OK\r\n", 'utf8')) c.send(bytes("Content-type: text/html\r\n", 'utf8')) c.send(bytes("\r\n", 'utf8')) c.send(bytes(" Hello World ", 'utf8')) c.close()	