

CMSC 132:

OBJECT-ORIENTED PROGRAMMING II



Networking

Department of Computer Science
University of Maryland, College Park

Networking

- **Internet**

- Designed with multiple layers of abstraction
- Underlying medium is unreliable, packet oriented
- Packet-Switching
 - <https://www.youtube.com/watch?v=vSlcoQowe9I>

Internet (IP) Address

- **Unique address for machine on internet**
 - Get from ISP when connecting to internet
 - Allows network to find your machine
- **Internet Protocols IPV4, IPV6**
 - Define how data is sent between computers over packet-switched network
- **(IPV4) Internet Protocol Version 4**
 - 32-bit unsigned integer $\Rightarrow$ 128.8.128.8
 - Domain name $\Rightarrow$ cs.umd.edu
 - **localhost** $\Rightarrow$ **127.0.0.1**
- **(IPV6) Internet Protocol Version 6**
 - 128-bit address
 - Designed to replace IPV4
 - Addresses exhaustion of addresses associated with IPV4 (now we have 2^{128})
 - Format: <http://msdn.microsoft.com/en-us/library/aa921042.aspx>

IP Address (DNS)

- Domain Name System (DNS)
 - Protocol for translating domain names to IP addresses
 - Example: cs.umd.edu → 128.8.128.44
 - Multiple DNS servers on internet
 - DNS server may need to query other DNS servers
 - edu DNS server queries umd.edu server to find cs.umd.edu

Ports

- Abstraction to identify (refine) destination
 - Provide multiple destinations at single IP address
- Format
 - Unsigned 16-bit integer (0 to 65,535)
 - Ports **0** to **4096** often reserved & restricted
- Many ports pre-assigned to important services
 - 21 ftp (file transfer)
 - 23 telnet (remote terminal)
 - 25 SMTP (email)
 - **80** http (web)
 - Others
 - http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

Uniform Resource Locators (URLs)

- **Represent web resources**
 - Web pages
 - Arbitrary files
 - ...
- **Examples**
 - `http://www.cs.umd.edu/index.html`
 - `ftp://www.cs.umd.edu/pub/doc/csd_policies.pdf`
 - `https://login.yahoo.com/`
 - `file://dir/my.txt`

Uniform Resource Locators (URLs)

- Consists of
 - Protocol
 - http:
 - https: (secure http)
 - file:
 - ...
 - IP address (or domain name)
 - Port (optional, 80 if not specified)
 - http://www.cs.umd.edu:80/
 - Reference to anchor (optional)
 - Query terms

Internet Connections

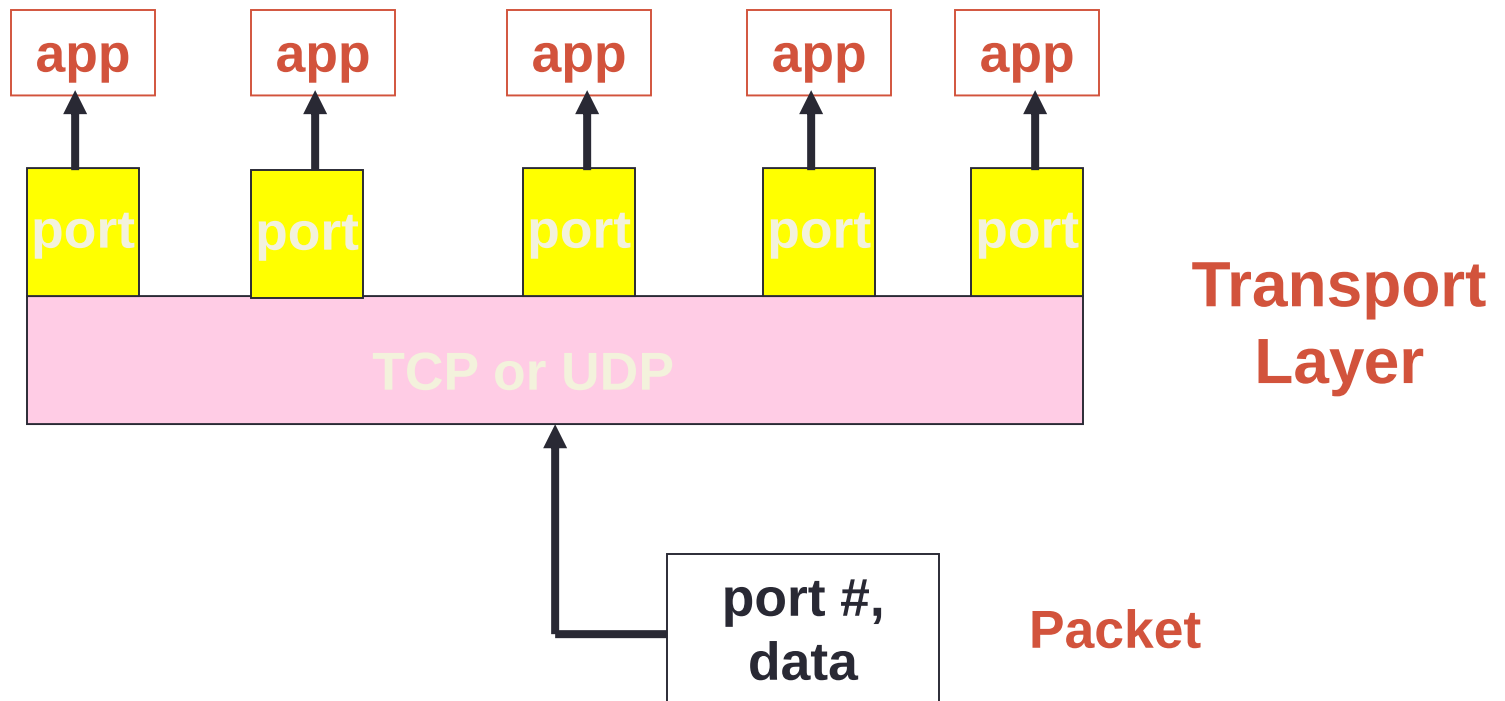
- Two types of connections: **TCP** and **UDP**
- **TCP**
 - Connection oriented
 - Provides illusion of reliable connection
 - Extra messages between sender / recipient
 - Resend packets if necessary
 - Reliable but more overhead for small messages
 - Application can treat as reliable connection
 - Despite unreliability of underlying IP (network)
 - **Examples:** ftp, ssh, http
 - **Vast majority of internet traffic is TCP**
- **UDP**
 - More like sending a postcard
 - Might get lost with no notification
 - Useful in some specialized cases
 - Messages are small
 - if a packet is lost, would rather just lose it than delay receipt of next packet

Sockets

- Application-level abstraction
 - Represents network connection
 - Implemented in software
 - Supports both UDP and TCP protocols
- History
 - Introduced in Berkley UNIX in 1980s
 - Networking API

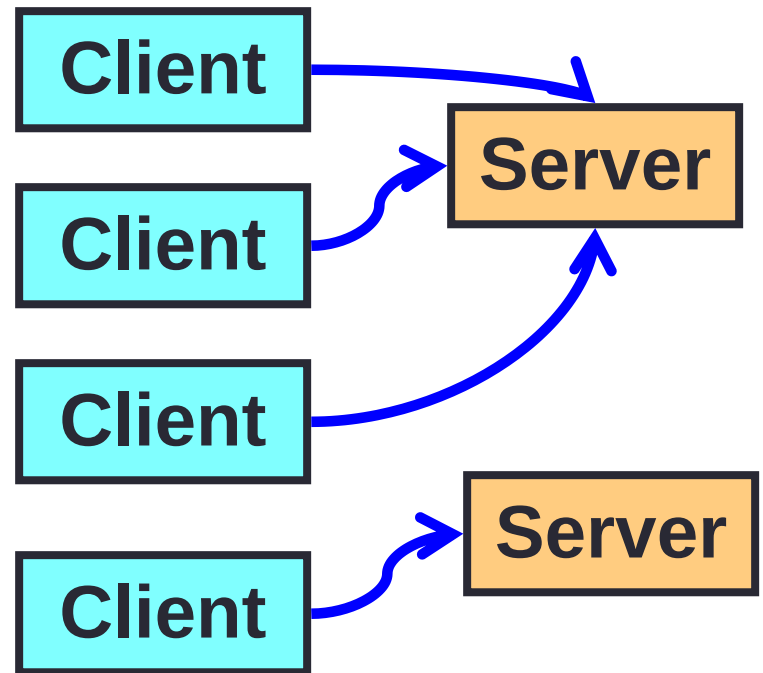
Sockets

- Socket is bound to port number
 - Receives data packet
 - Relays to specific port



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)



Server Programming

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

Simple Server Programming (Loop)

- Basic steps

1. Determine server location → port & IP address
2. Creates server socket 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
```

```
}
```

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

Java Networking Classes

- **IP addresses**
 - InetAddress
- **Packets**
 - DatagramPacket
- **Sockets**
 - Socket $\Rightarrow$ TCP client sockets
 - ServerSocket $\Rightarrow$ TCP server sockets
 - DatagramSocket $\Rightarrow$ UDP sockets (server or client)
 - Sockets transfer data via Java I/O **streams**
- **URL Connection Classes**
 - High-level description of network service
 - Access resource named by URL
 - Examples
 - URLConnection $\Rightarrow$ Reads resource
 - HttpURLConnection $\Rightarrow$ Handles web page
 - JarURLConnection $\Rightarrow$ Manipulates Java Archive

Java Networking Examples

- TCP Client/Server: See [tcpServerClient](#) package
- Toy Web Server: See [toyWebServer](#) package