# CMSC 132:
# Object-Oriented Programming II


## Networking

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# Networking

- **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**

# Internet (IP) Address

- Unique address for machine on internet
  - Get from ISP when connecting to internet
  - Allows network to find your machine
- Format
  - 32-bit unsigned integer ⇒ 128.8.128.8
  - Domain name ⇒ cs.umd.edu
- Name and address for local machine
  - Localhost
  - 127.0.0.1

# Internet (IP) Address

- **Problem**
  - **Running out of 32-bit IP addresses**
  - **Caused by initial address allocation**
    - **Stanford & MIT initially given more IP addresses than China**
      - **fixed in 2000**
    - **Univ. of Maryland is currently assigned 131,072 IP addresses**
- **Switching to 128-bit IP addresses in IPv6**
  - **1+ million addresses per square meter on Earth**

# 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

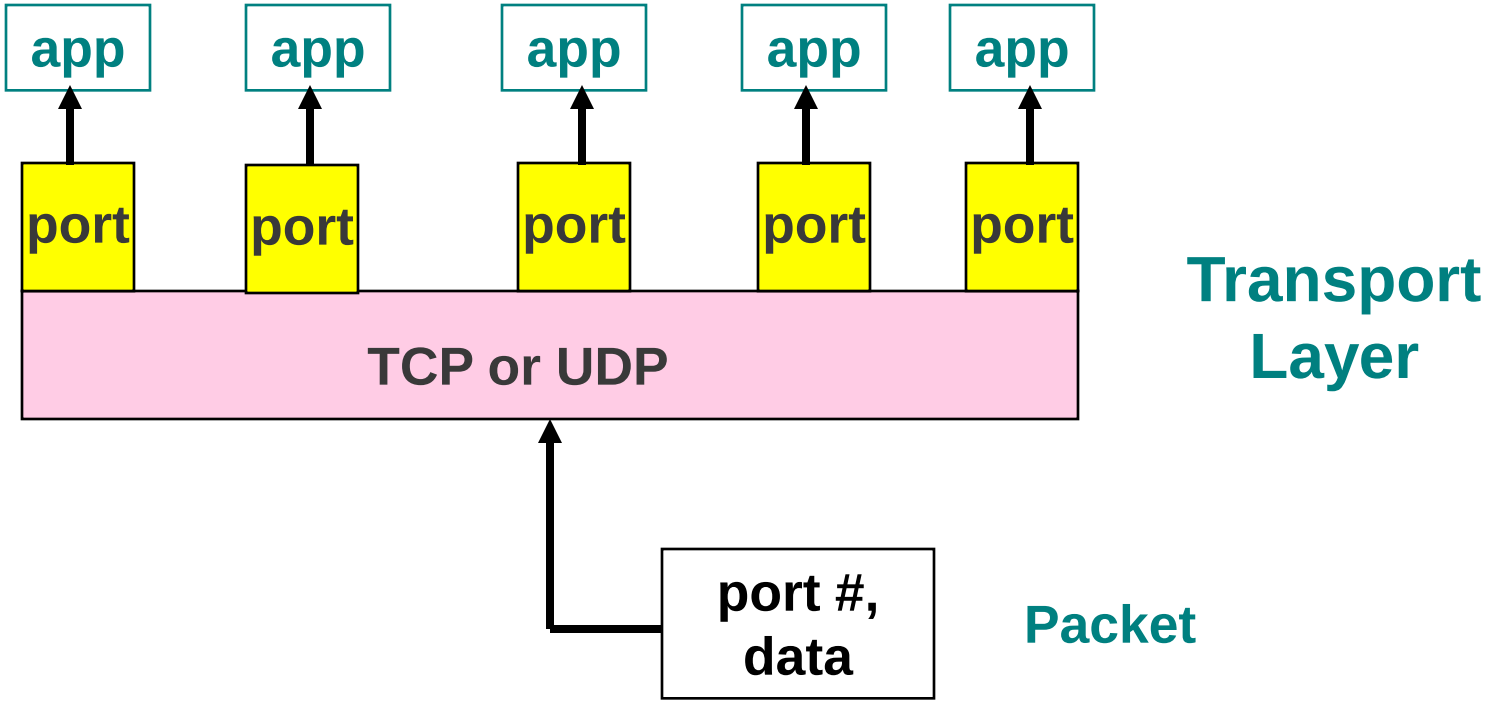
- Abstraction to identify (refine) destination
  - Provide multiple destinations at single IP address
- Format
  - Unsigned 16-bit integer (0 to 65,535)
  - Ports 0 to 4096 often reserved & restricted
- Many ports pre-assigned to important services
  - 21 ftp (file transfer)
  - 23 telnet (remote terminal)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

# 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**



# 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**
  1. **Connection-oriented (TCP)**
  2. **Packet-oriented (UDP)**

# Transmission Control Protocol (TCP)

- Connection oriented
- Message split into datagrams
- Send datagrams as packets on network layer
- Provides illusion of reliable connection
  - Extra messages between sender / recipient
  - Resend packets if necessary
  - Ensure all packets eventually arrive
  - Store packets and process in order
  - Provides warning if packets are lost

# Transmission Control Protocol (TCP)

- Reliable but more overhead for small messages
- Application can treat as reliable connection
  - Despite unreliability of underlying IP (network)
- Examples
  - ftp (file transfer)
  - ssh (remote secure shell)
  - http (web)
- Vast majority of internet traffic is TCP

# User Datagram Protocol (UDP)

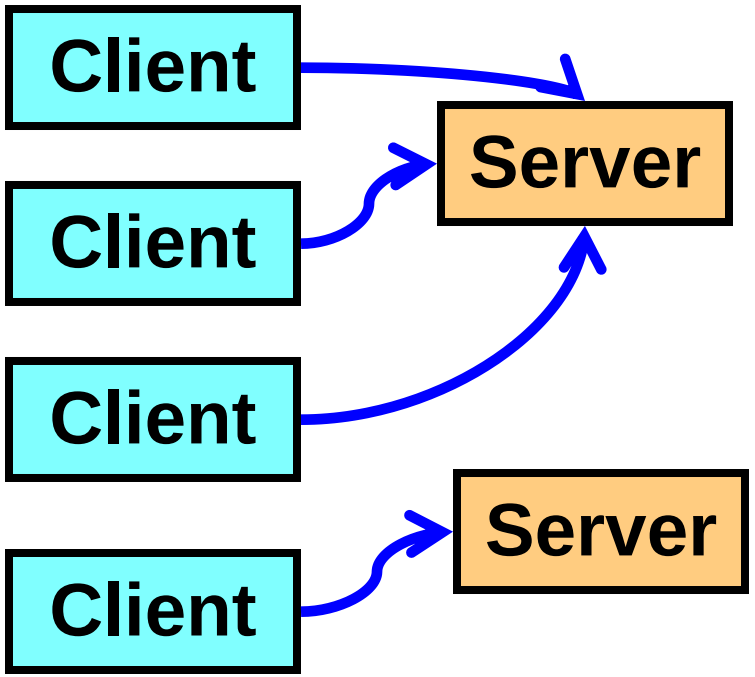
- More like sending a postcard
- Limited size message
- Might get lost with no notification
- Useful is some specialized cases
  - messages are small
  - if a packet is lost, would rather just lose it than delay receipt of next packet

# Network address translation

- How we get by with only 4 billion IP addresses
  - Allows a group of locally allocated IP addresses to share a single globally allocated IP address
- Make a request from inside NAT realm to an external web server
- The NAT box assigns a external facing port to the communication, forwards communication, redirects response to that port
- When a response returns, NAT box knows who to forward the msg to

# 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)



# 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**

# 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
}
```

# Java Networking Classes

- IP addresses
  - InetAddress
- Packets
  - DatagramPacket
- Sockets
  - Socket - TCP client sockets
  - ServerSocket - TCP server sockets
  - DatagramSocket - 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 ⇒ Reads resource
    - HttpURLConnection ⇒ Handles web page
    - JarURLConnection ⇒ Manipulates Java Archive

# Java Networking Examples

- **TCP Client/Server: See tcpServerClient package**
- **UDP Client/Server: See udpServerClient package**
- **URL Reader: See urlReader package**
- **Toy Web Server: See toyWebServer package**

# 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**