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
- Packet-Switching

- 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 \(\Rightarrow 128.8.128.8\)
- Domain name \(\Rightarrow\) cs.umd.edu

Name and address for local machine
- localhost
- 127.0.0.1
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

Transport Layer

TCP or UDP

Packet

Port #, data

Applications

Port
Uniform Resource Locators (URLs)

- Represent web resources
  - Web pages
  - Arbitrary files
  - ...
- Examples
  - 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)
- 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