61A Lecture 34

Announcements

Distributed Computing

Distributed Computing

A distributed computing application consists of multiple programs running on multiple computers that together coordinate to perform some task

- Computation is performed in parallel by many computers
- Information can be restricted to certain computers
- Redundancy and geographic diversity improve reliability

Characteristics of distributed computing:

- Computers are independent — they do not share memory
- Coordination is enabled by messages passed across a network
- Individual programs have differentiating roles

Distributed computing for large-scale data processing:

- Databases respond to queries over a network
- Data sets can be partitioned across multiple machines (next lecture)

Network Messages

Computers communicate via messages: sequences of bytes transmitted over a network

Messages can serve many purposes:

- Send data to another computer
- Request data from another computer
- Instruct a program to call a function on some arguments
- Transfer a program to be executed by another computer

Messages conform to a message protocol adopted by both the sender (to encode the message) & receiver (to interpret the message)

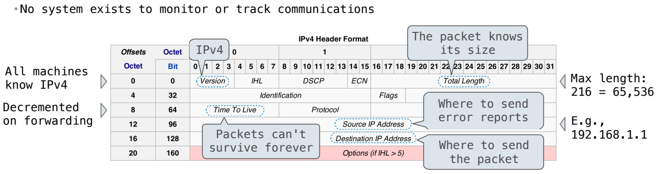
- For example, bits at fixed positions may have fixed meanings
- Components of a message may be separated by delimiters
- Protocols are designed to be implemented by many different programming languages on many different types of machines

Internet Protocol

The Internet Protocol

The Internet Protocol (IP) specifies how to transfer packets of data among networks

- Networks are inherently unreliable at any point
- The structure of a network is dynamic, not fixed
- No system exists to monitor or track communications



Packets are forwarded toward their destination on a best effort basis

Programs that use IP typically need a policy for handling lost packets

http://en.wikipedia.org/wiki/IPv4

Transmission Control Protocol

Transmission Control Protocol

The design of the Internet Protocol (IPv4) imposes constraints:

- Packets are limited to 65,535 bytes each
- Packets may arrive in a different order than they were sent
- Packets may be duplicated or lost

The Transmission Control Protocol (TCP) improves reliability:

- Ordered, reliable transmission of arbitrary byte streams
- Implemented using the IP. Every TCP connection involves sending IP packets
- Each packet in a TCP session has a sequence number:
  - The receiver can correctly order packets that arrive out of order
  - The receiver can ignore duplicate packets
- All received packets are acknowledged; both parties know that transmission succeeded
- Packets that aren't acknowledged are sent repeatedly

The socket module in Python implements the TCP

TCP Handshakes

All TCP connections begin with a sequence of messages called a "handshake" which verifies that communication is possible

"Can you hear me now?" *Let's design a handshake protocol*

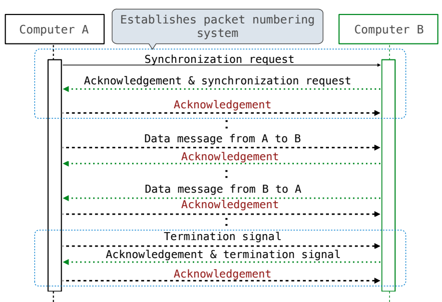
Handshake Goals:

- Computer A knows that it can send data to and receive data from Computer B
- Computer B knows that it can send data to and receive data from Computer A
- Lots of separate connections can exist without any confusion
- The number of required messages is minimized

Communication Rules:

- Computer A can send an initial message to Computer B requesting a new connection
- Computer B can respond to messages from Computer A
- Computer A can respond to messages from Computer B

Message Sequence of a TCP Connection



Client/Server Architecture

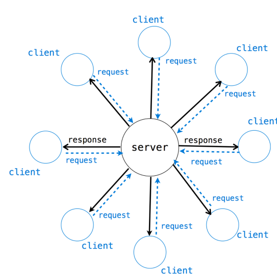
The Client/Server Architecture

One server provides information to multiple clients through request and response messages

Server role: Respond to service requests with requested information

Client role: Request information and make use of the response

Abstraction: The client knows what service a server provides, but not how it is provided



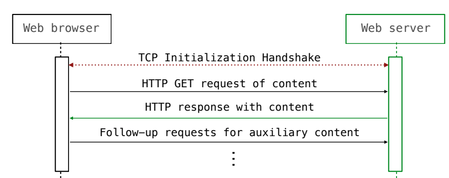
Client/Server Example: The World Wide Web

The client is a web browser (e.g., Firefox):

- Request content for a location
- Interpret the content for the user

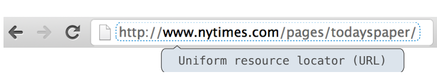
The server is a web server:

- Interpret requests and respond with content



The Hypertext Transfer Protocol

The Hypertext Transfer Protocol (HTTP) is a protocol designed to implement a Client/Server architecture



Browser issues a GET request to a server at www.nytimes.com for the content (resource) at location "pages/todayspaper"

Server response contains more than just the resource itself:

- Status code, e.g. 200 OK, 404 Not Found, 403 Forbidden, etc.
- Date of response; type of server responding
- Last-modified time of the resource
- Type of content and length of content

Properties of a Client/Server Architecture

Benefits:

- Creates a separation of concerns among components
- Enforces an abstraction barrier between client and server
- A centralized server can reuse computation across clients

Liabilities:

- A single point of failure: the server
- Computing resources become scarce when demand increases

Common use cases:

- Databases — The database serves responses to query requests
- Open Graphics Library (OpenGL) — A graphics processing unit (GPU) serves images to a central processing unit (CPU)
- Internet file and resource transfer: HTTP, FTP, email, etc.

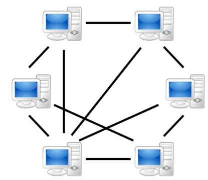
Peer-to-Peer Architecture

The Peer-to-Peer Architecture

All participants in a distributed application contribute computational resources: processing, storage, and network capacity

Messages are relayed through a network of participants

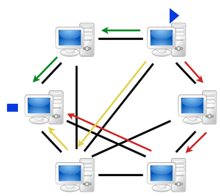
Each participant has only partial knowledge of the network



Network Structure Concerns

Some data transfers on the Internet are faster than others

The time required to transfer a message through a peer-to-peer network depends on the route chosen



Example: Skype

Skype is a Voice Over IP (VOIP) system that uses a hybrid peer-to-peer architecture

Login & contacts are handled via a centralized server

Conversations between two computers that cannot send messages to each other directly are relayed through supernodes

Any Skype client with its own IP address may be a supernode