

## 61A Lecture 34

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## Announcements

# Distributed Computing

## Distributed Computing

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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

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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)

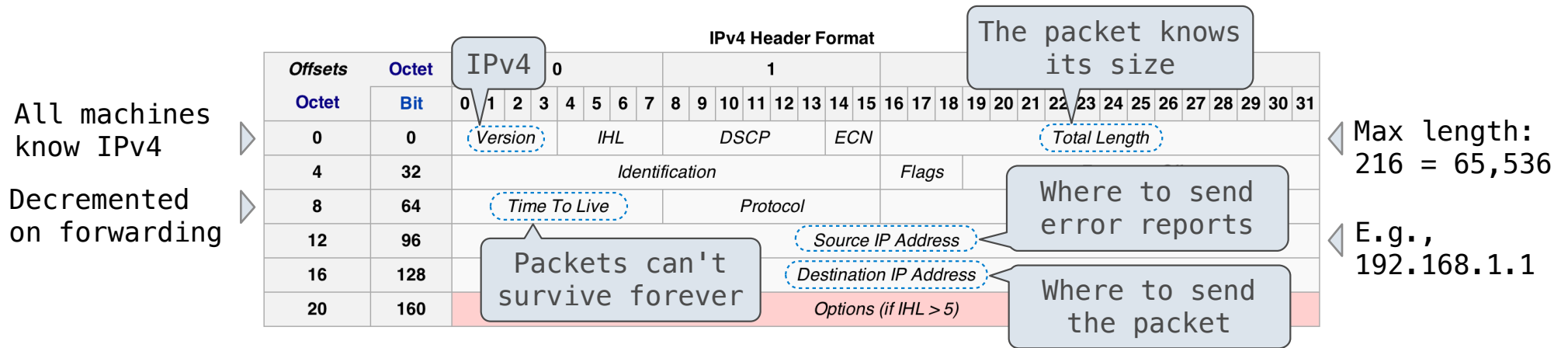
- For example, bits at fixed positions may have fixed meanings
- Components of a message may be separated by delimiters
- Protocols are designed to be implemented by many different programming languages on many different types of machines

# 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

# Transmission Control Protocol



## Transmission Control Protocol

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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

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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

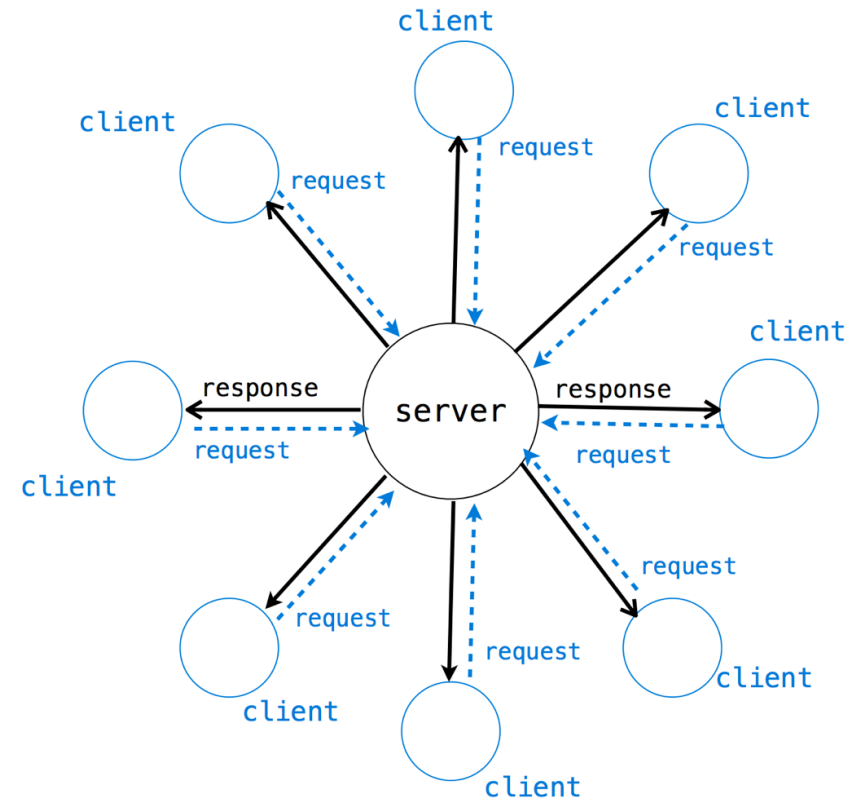
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One server provides information to multiple clients through request and response messages

**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

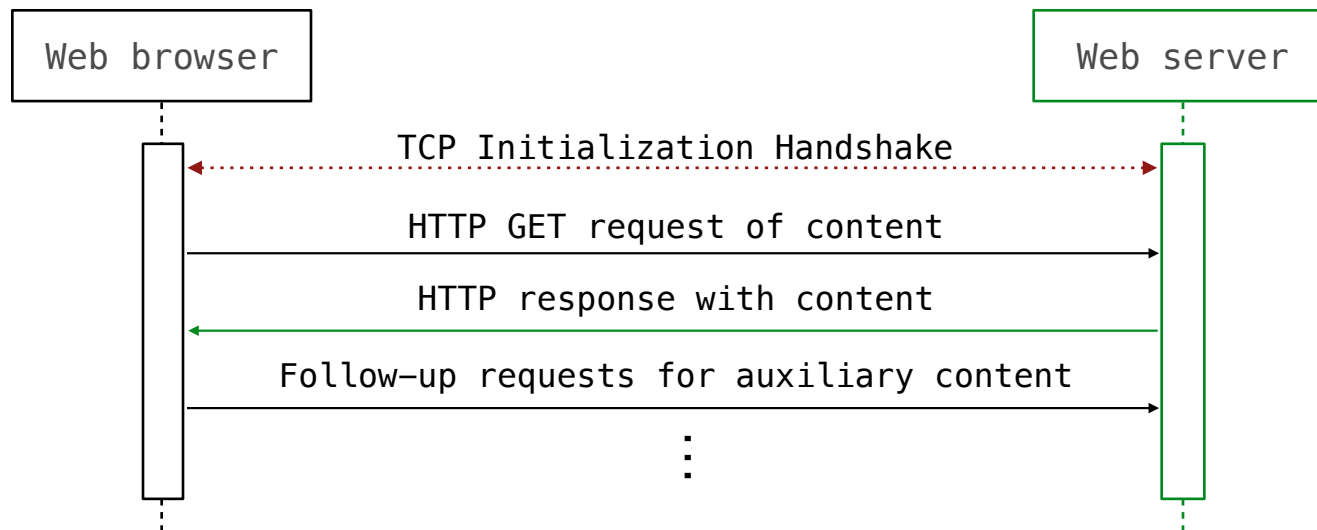
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The client is a web browser (e.g., Firefox):

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

The server is a web server:

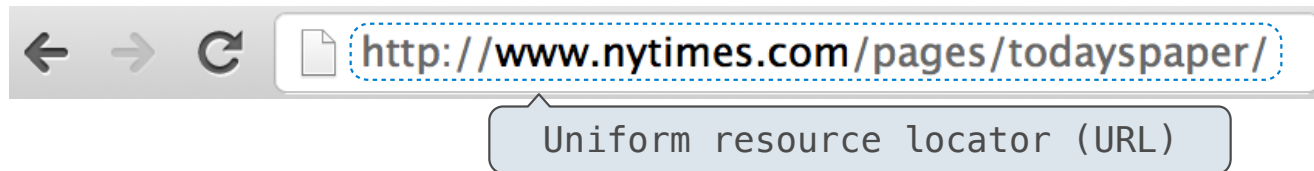
- Interpret requests and respond with content



## The Hypertext Transfer Protocol

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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](http://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

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### 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

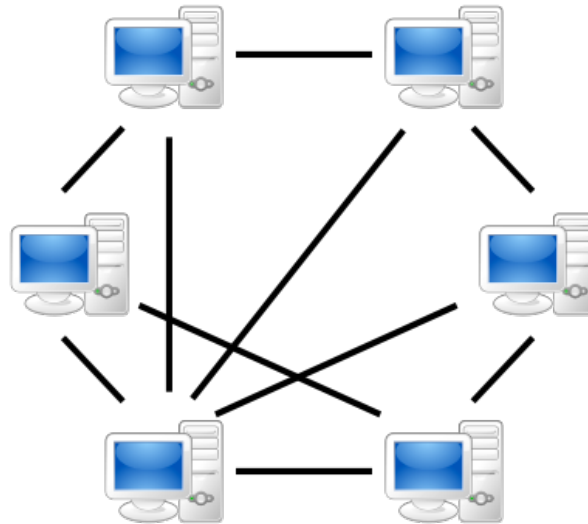
## The Peer-to-Peer Architecture

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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

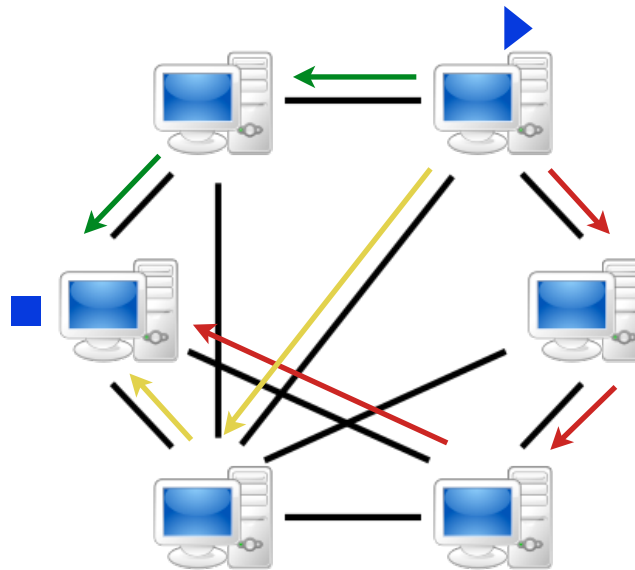


## Network Structure Concerns

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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

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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

