61A Lecture 35

Monday, November 26

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 spread across multiple machines (Wednesday).

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.

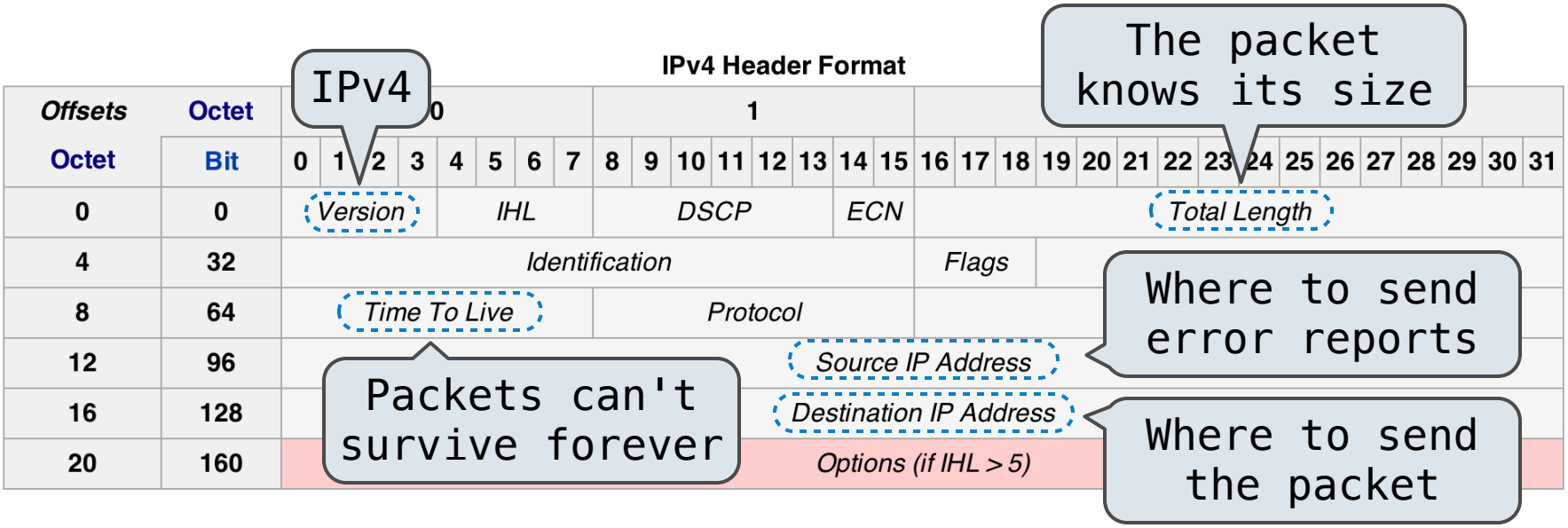
Messages conform to a *message protocol* adopted by both the sender to encode the message & the receiver to interpret it.

- 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 a variety of platforms.

The Internet Protocol

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

- Networks are inherently unreliable at any point.
- The structure of a network is dynamic.
- No system exists to monitor or track communications.



Packets are forwarded toward their destination using simple rules on a best-effort basis.

Transmission Control Protocol

The design of the **Internet Protocol** (IP) 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.

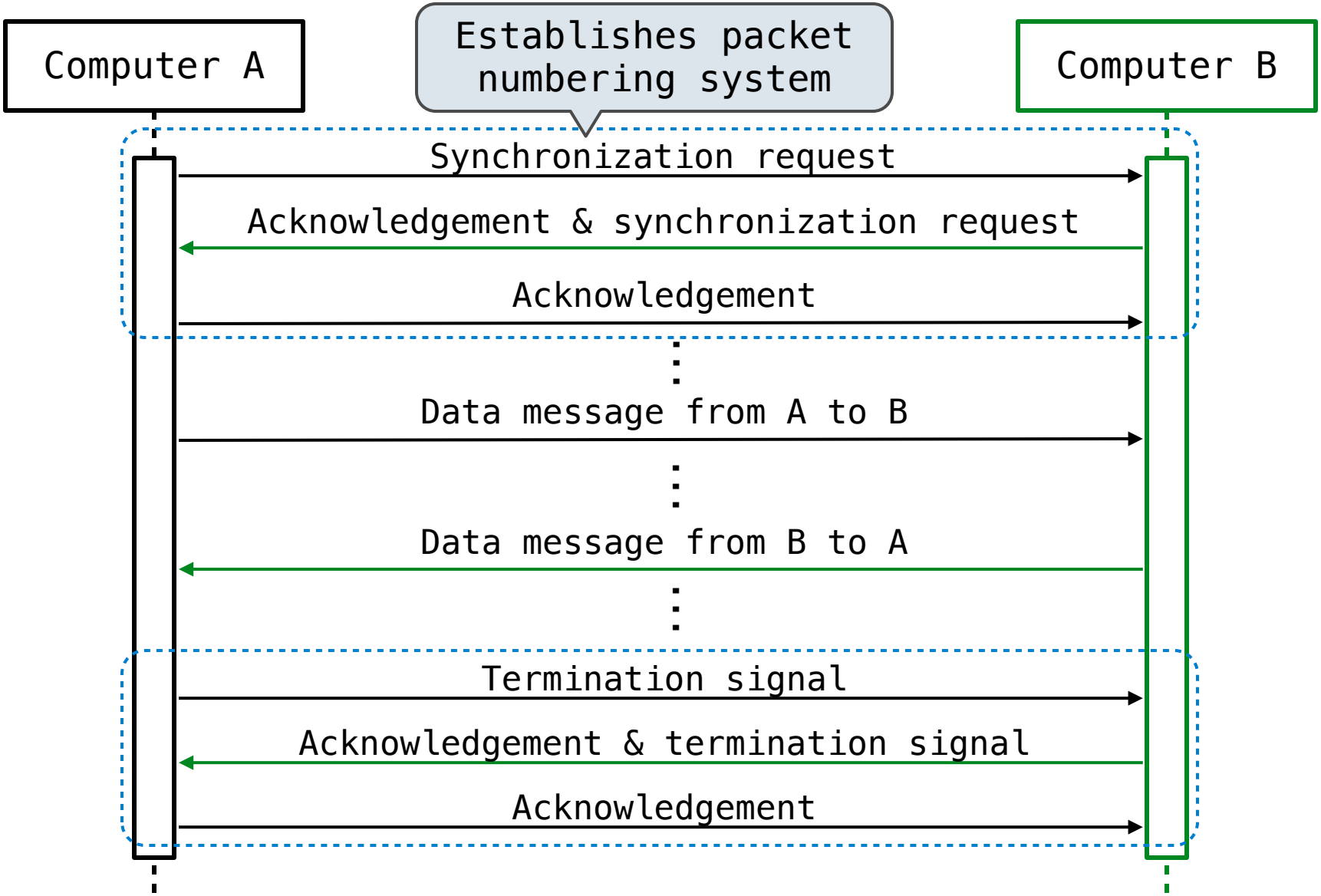
The **Transmission Control Protocol** (TCP) improves reliability:

- Ordered, reliable transmission of arbitrary byte streams.
- Implemented using the IP.
- Correctly orders packets by including sequence numbers.
- Removes duplicates; requests retransmission of lost packets.

TCP connection initiates with a "handshake" procedure.

- What's the minimum number of messages needed to prove to both computers that two-way communication is possible?

Message Sequence of a TCP Connection



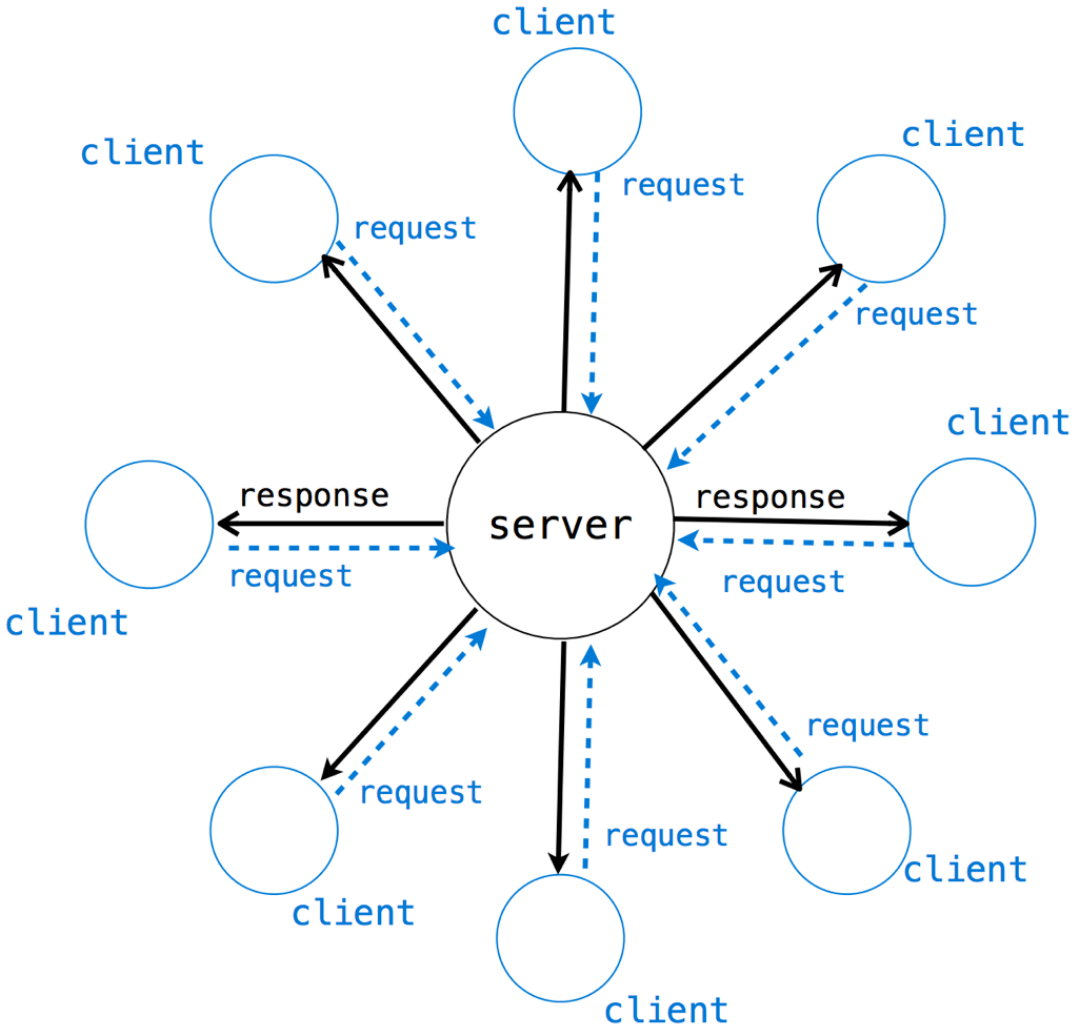
Client/Server Architecture

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.



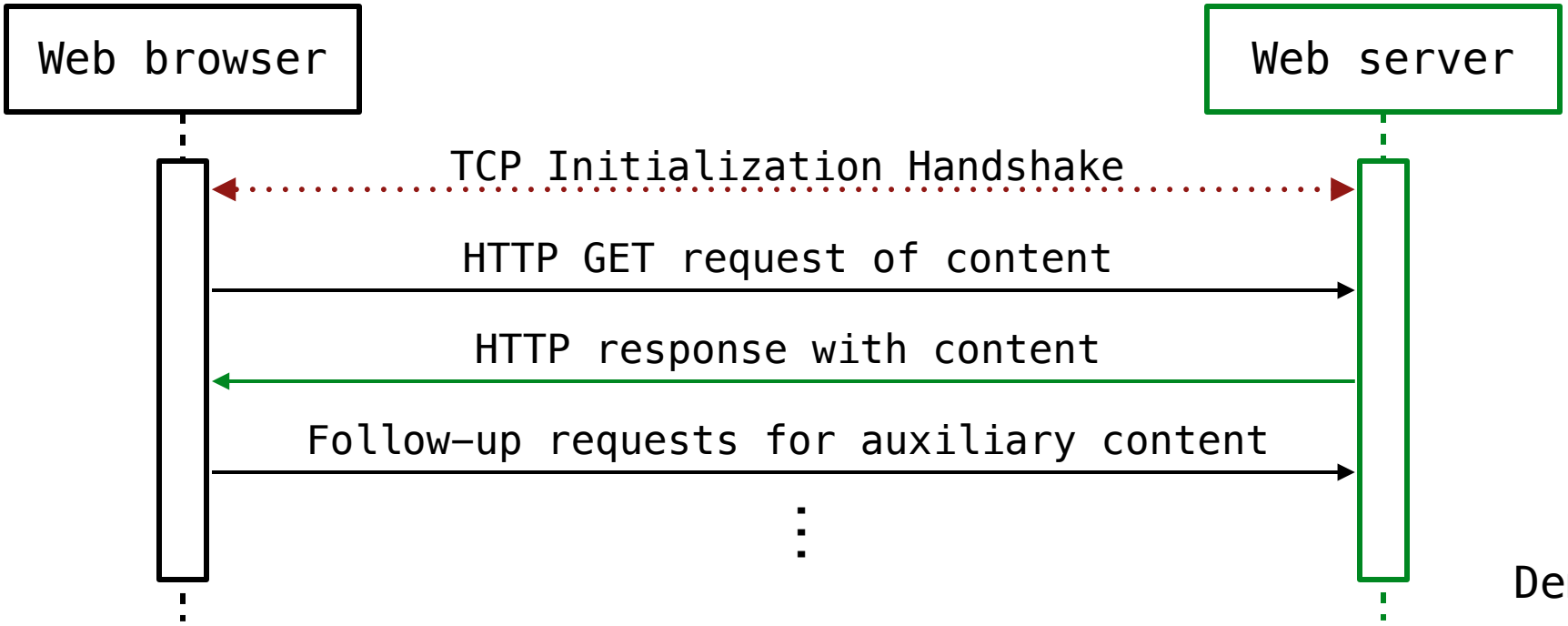
Client/Server Example: The World Wide Web

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

- Request content from a location on behalf of the user.
- Display the content to the user.

The **server** is a web server (e.g., www.nytimes.com)

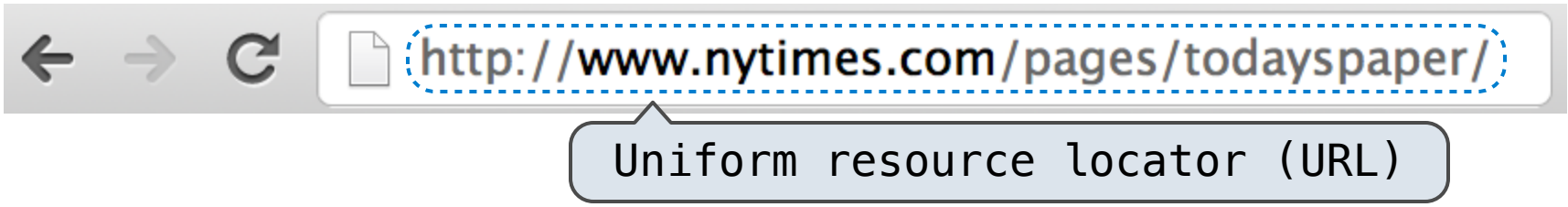
- Respond with (perhaps personalized) content at that location.



Demo

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 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

Demo

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 with increasing demand.

Common use cases:

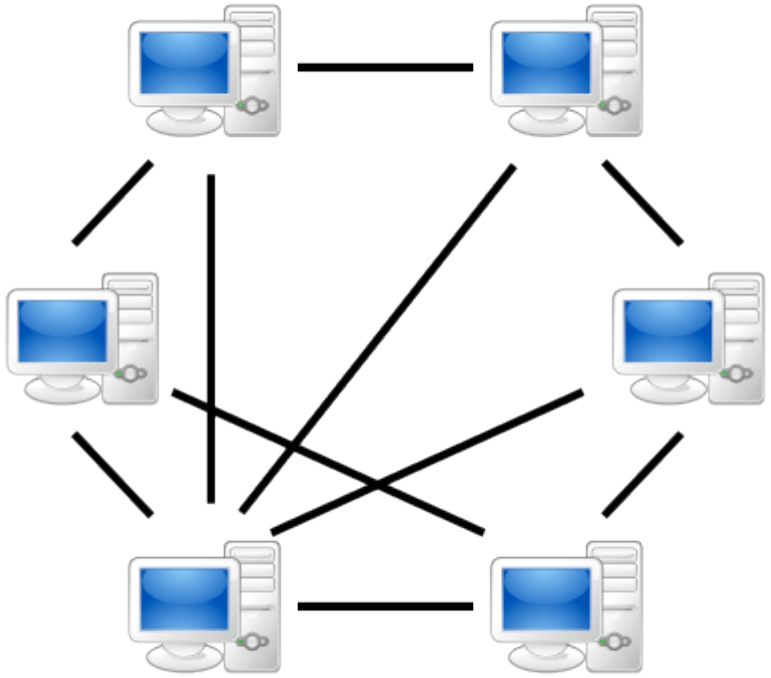
- Databases – The database serves responses to query requests.
- Open Graphics Library (OpenGL) – A graphics processing unit (GPU) serves images to a central processing unit (CPU).
- File and resource transfer: HTTP, FTP, email, etc.

Peer-to-Peer Architecture

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

Messages are relayed through a network of participants.

Each participant has only partial knowledge of the network.

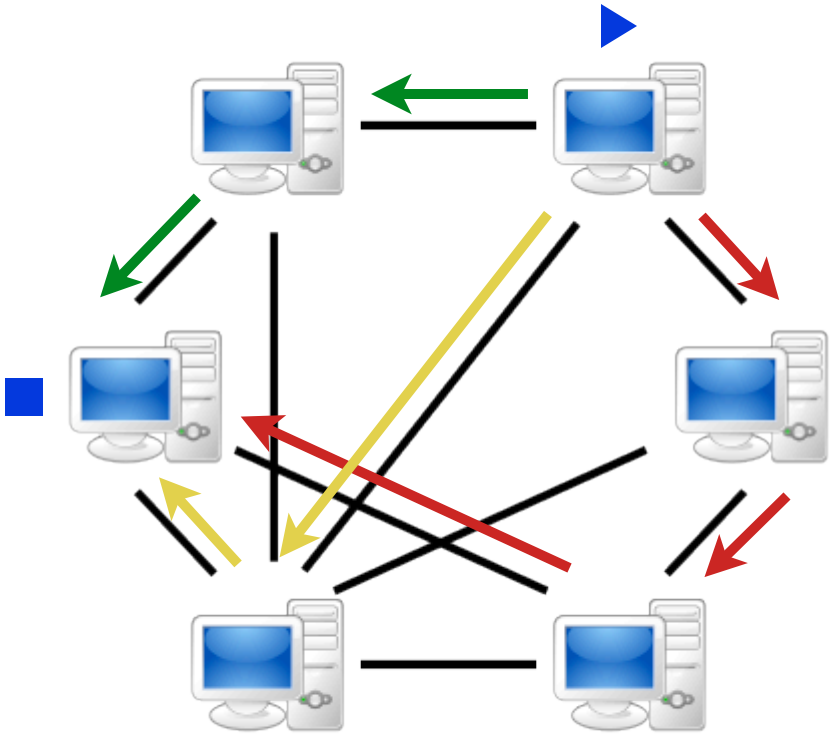


http://en.wikipedia.org/wiki/File:P2P-network.svg

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.



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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.