

61A Lecture 35

Monday, November 26

Distributed Computing

Distributed Computing

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

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.

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.

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*.

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:

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.

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.

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

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**:

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.

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

Network Messages

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

Network Messages

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

Messages can serve many purposes:

Network Messages

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

Messages can serve many purposes:

- **Send data** to another computer

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

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.

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.

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.

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.

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.

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

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

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 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.

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.

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.

IPv4 Header Format

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version				IHL				DSCP				ECN		Total Length																	
4	32	Identification															Flags		Fragment Offset														
8	64	Time To Live								Protocol							Header Checksum																
12	96	Source IP Address																															
16	128	Destination IP Address																															
20	160	Options (if IHL > 5)																															

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.

IPv4 Header Format																																	
Offsets	Octet	IPv4																															
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version			IHL				DSCP						ECN		Total Length																
4	32	Identification															Flags			Fragment Offset													
8	64	Time To Live							Protocol							Header Checksum																	
12	96	Source IP Address																															
16	128	Destination IP Address																															
20	160	Options (if IHL > 5)																															

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.

IPv4 Header Format																																	
Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version			IHL				DSCP						ECN		Total Length																
4	32	Identification															Flags			Fragment Offset													
8	64	Time To Live							Protocol							Header Checksum																	
12	96	Source IP Address																															
16	128	Destination IP Address																															
20	160	Options (if IHL > 5)																															

IPv4

Where to send the packet

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.

IPv4 Header Format																																	
Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version			IHL				DSCP				ECN		Total Length																		
4	32	Identification															Flags																
8	64	Time To Live								Protocol																							
12	96																Source IP Address																
16	128																Destination IP Address																
20	160	Options (if IHL > 5)																															

IPv4

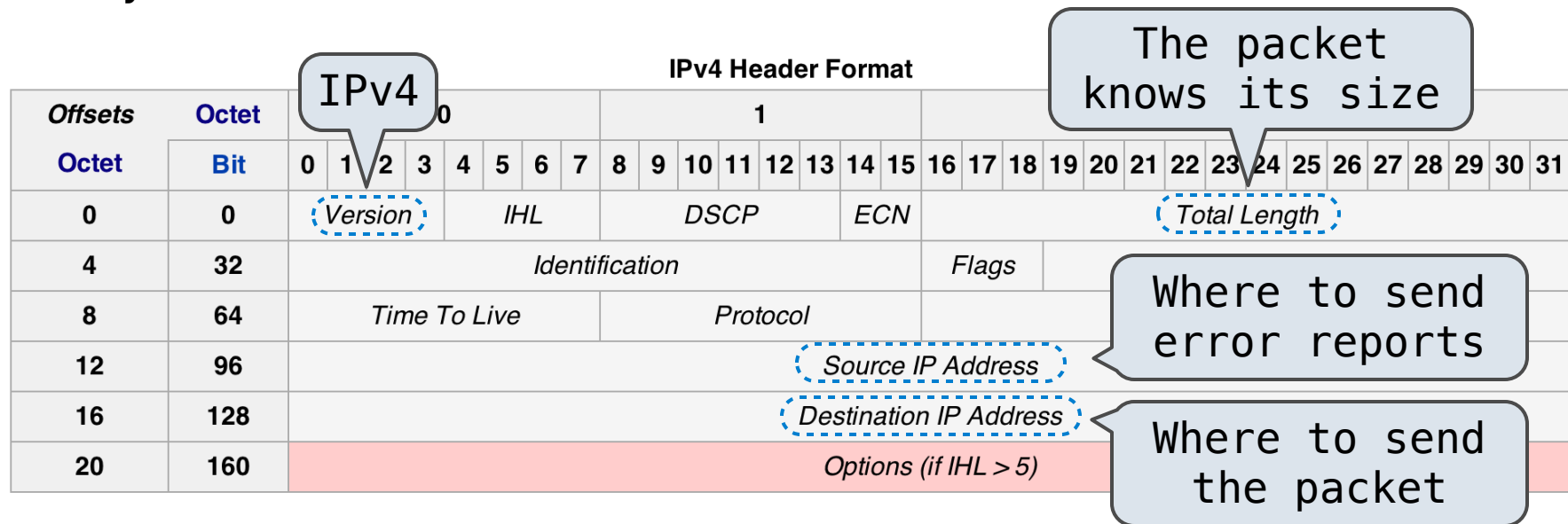
Where to send error reports

Where to send the packet

The Internet Protocol

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

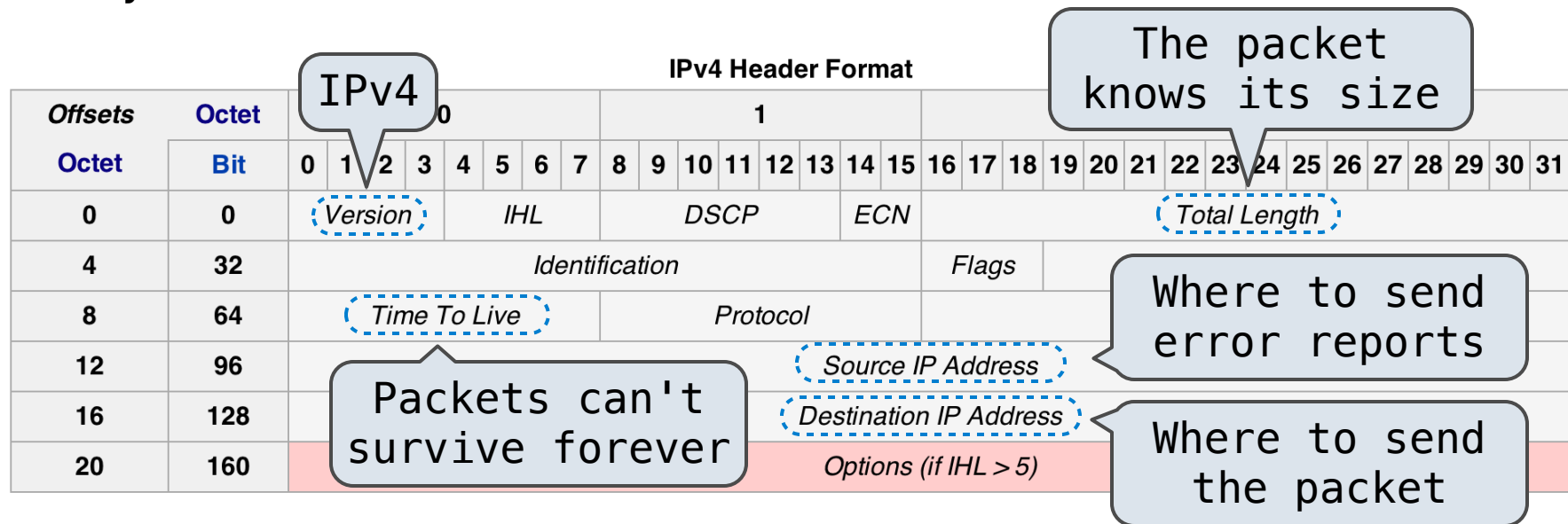
- Networks are inherently unreliable at any point.
- The structure of a network is dynamic.
- No system exists to monitor or track communications.



The Internet Protocol

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

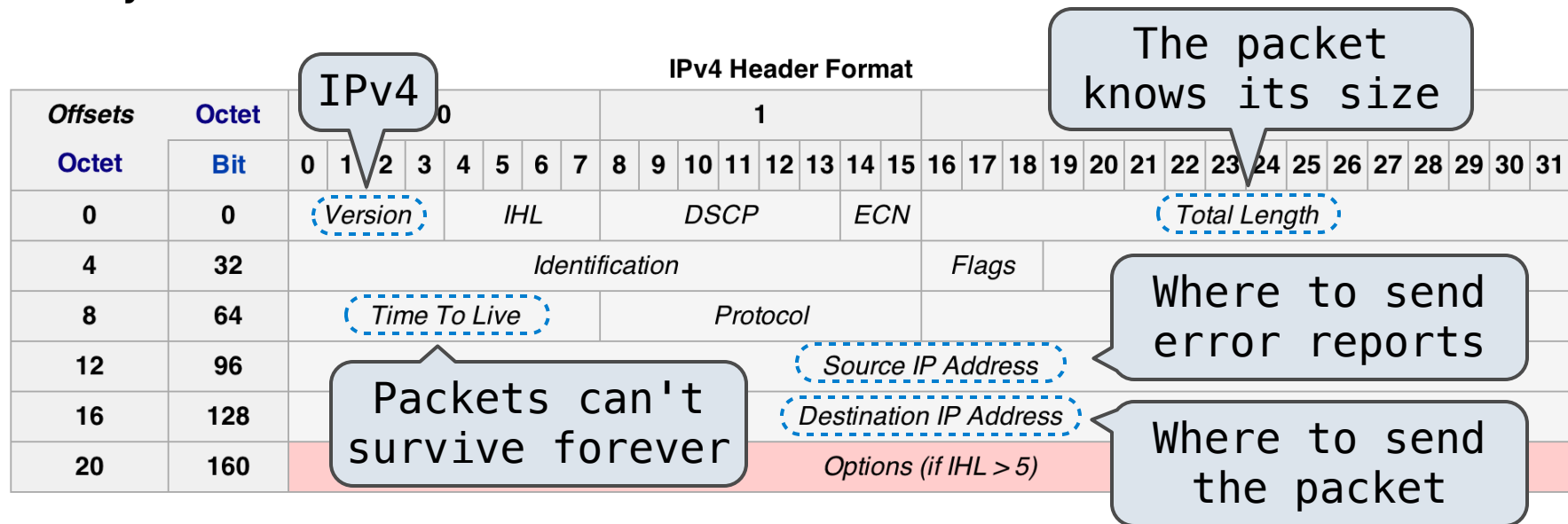
- Networks are inherently unreliable at any point.
- The structure of a network is dynamic.
- No system exists to monitor or track communications.



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

Transmission Control Protocol

The design of the **Internet Protocol** (IP) imposes constraints:

Transmission Control Protocol

The design of the **Internet Protocol** (IP) imposes constraints:

- Packets are limited to 65,535 bytes each.

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.

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.

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:

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.

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.

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.

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.

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.

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

Message Sequence of a TCP Connection

Computer A



A vertical dashed line extends downwards from the bottom center of the 'Computer A' box, representing a timeline or sequence of events.

Message Sequence of a TCP Connection

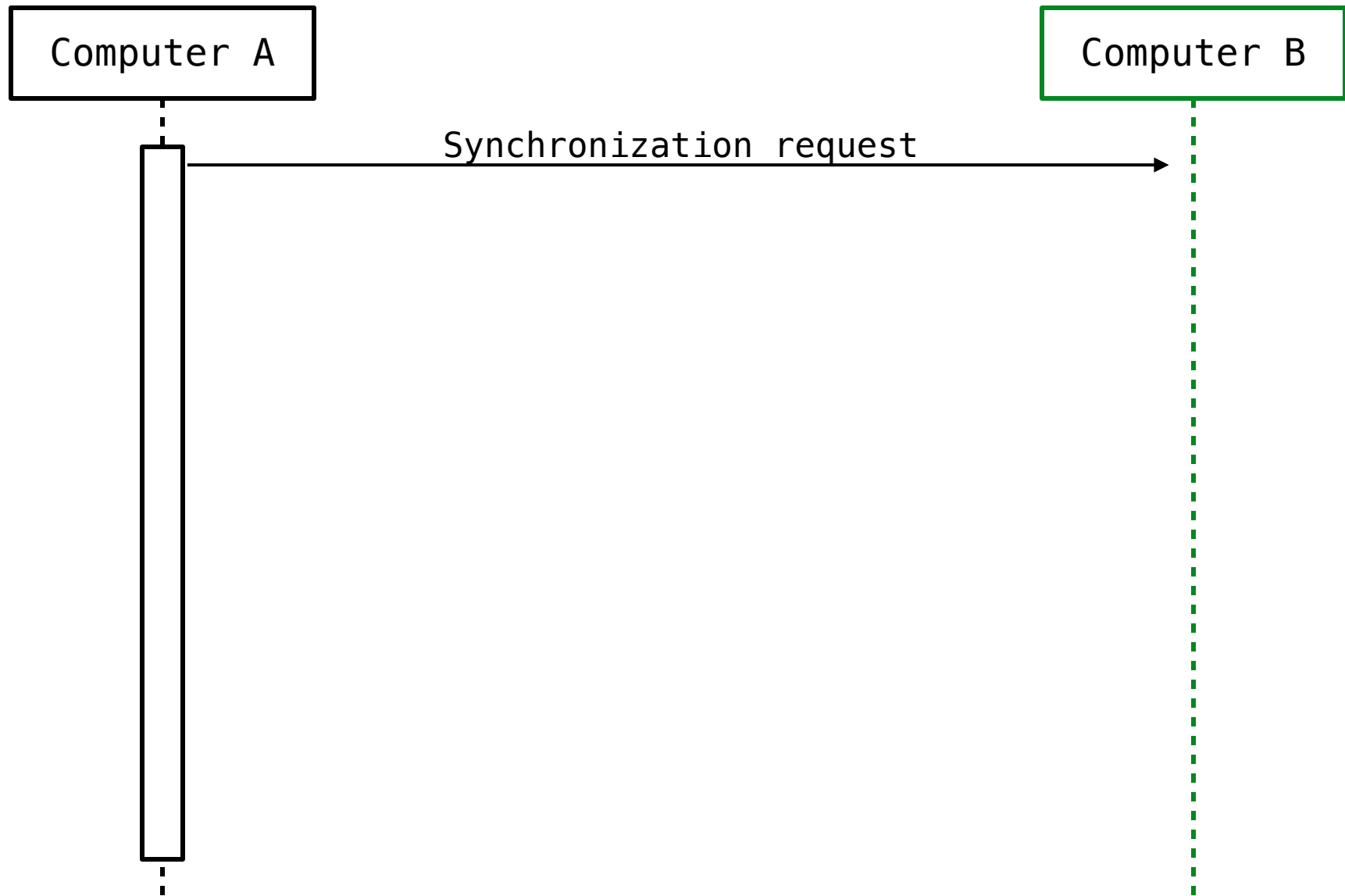
Computer A



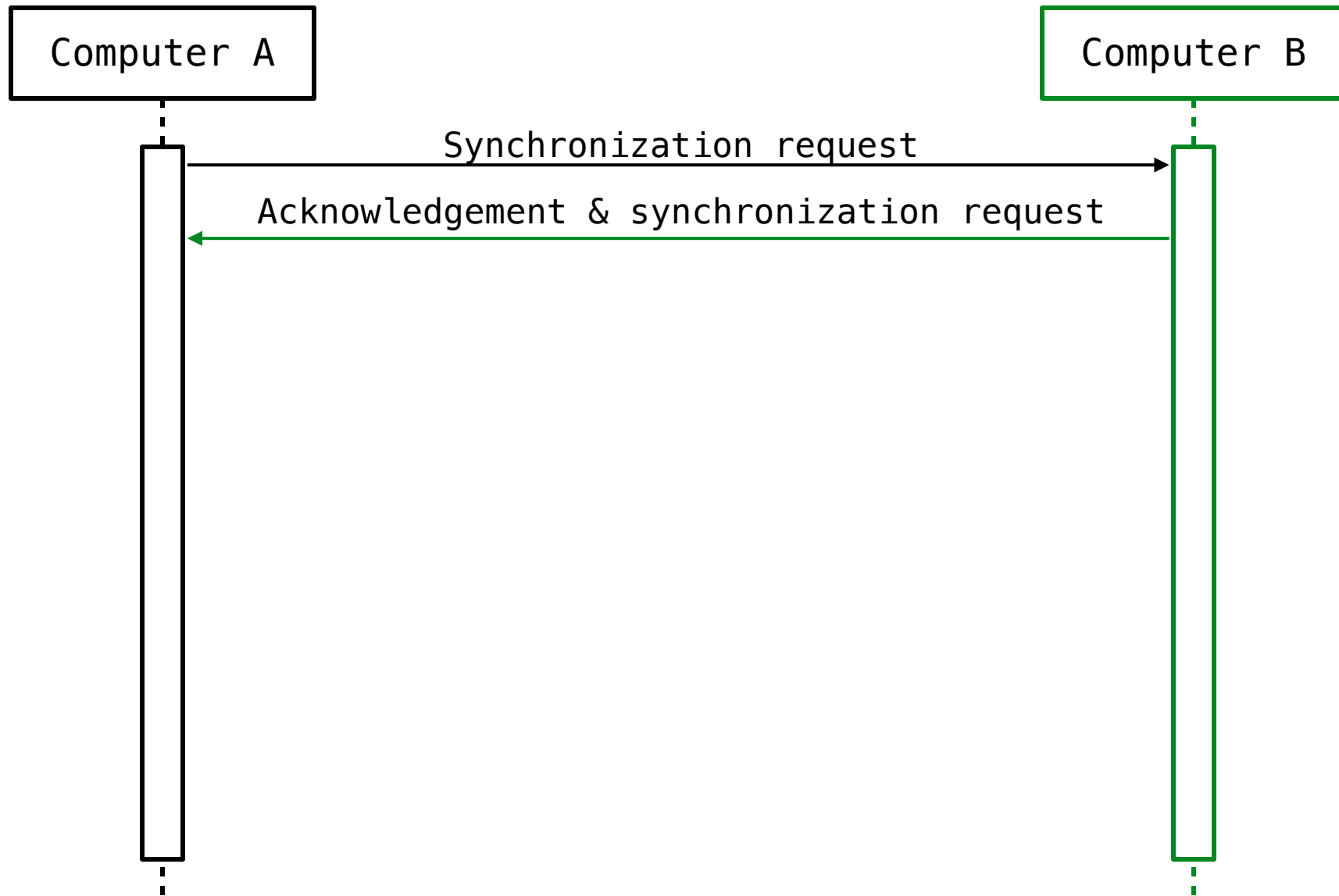
Computer B



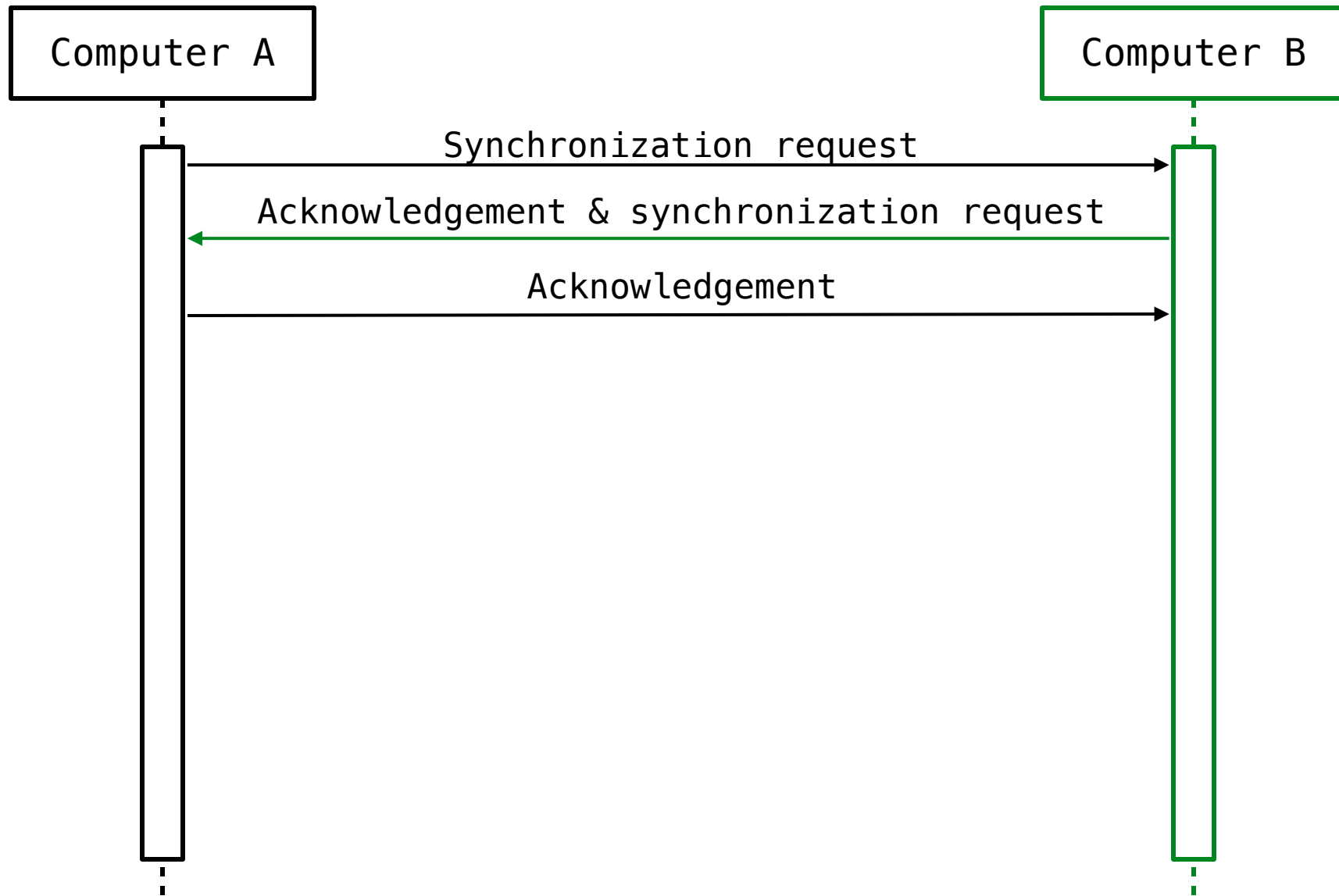
Message Sequence of a TCP Connection



Message Sequence of a TCP Connection



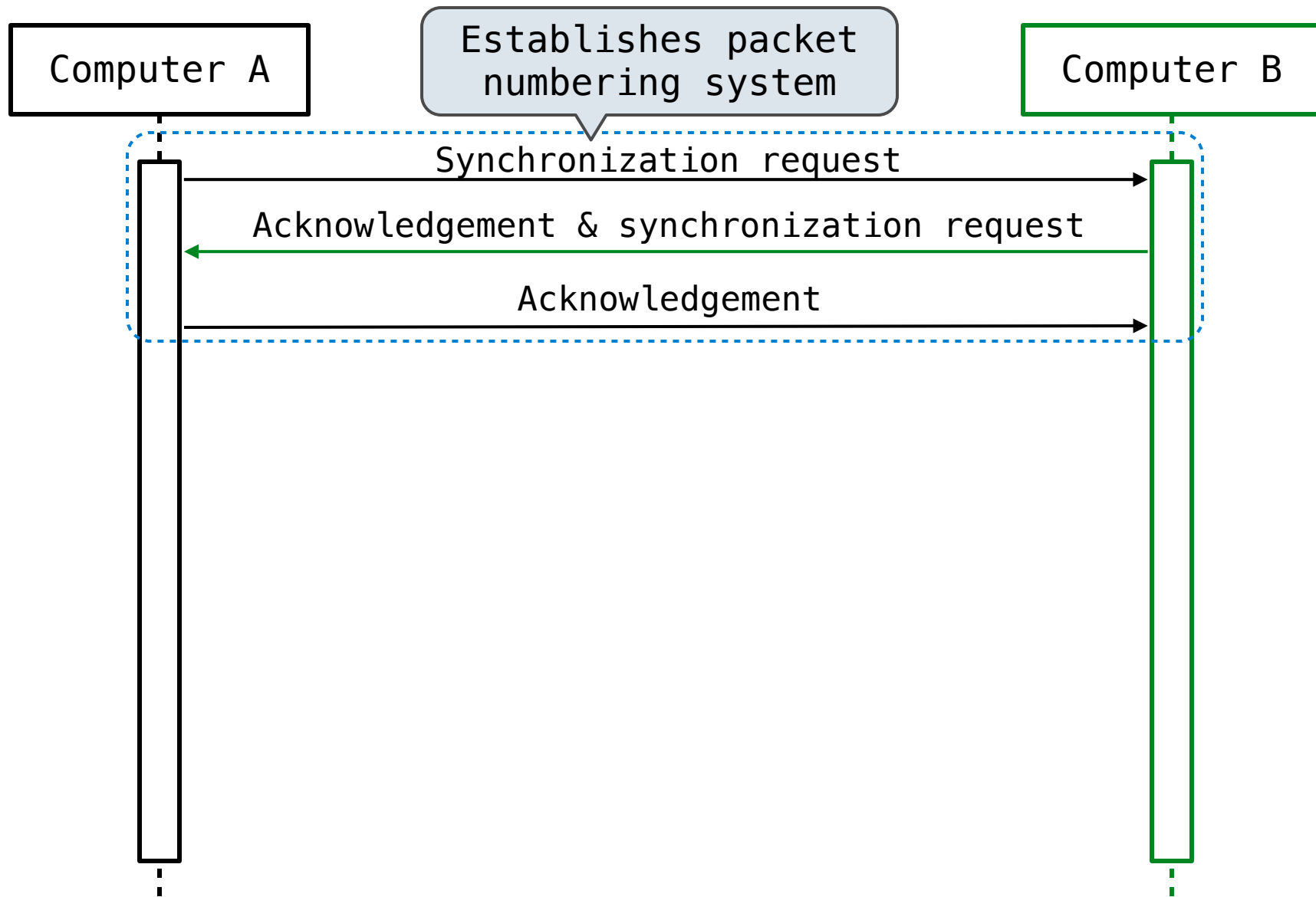
Message Sequence of a TCP Connection



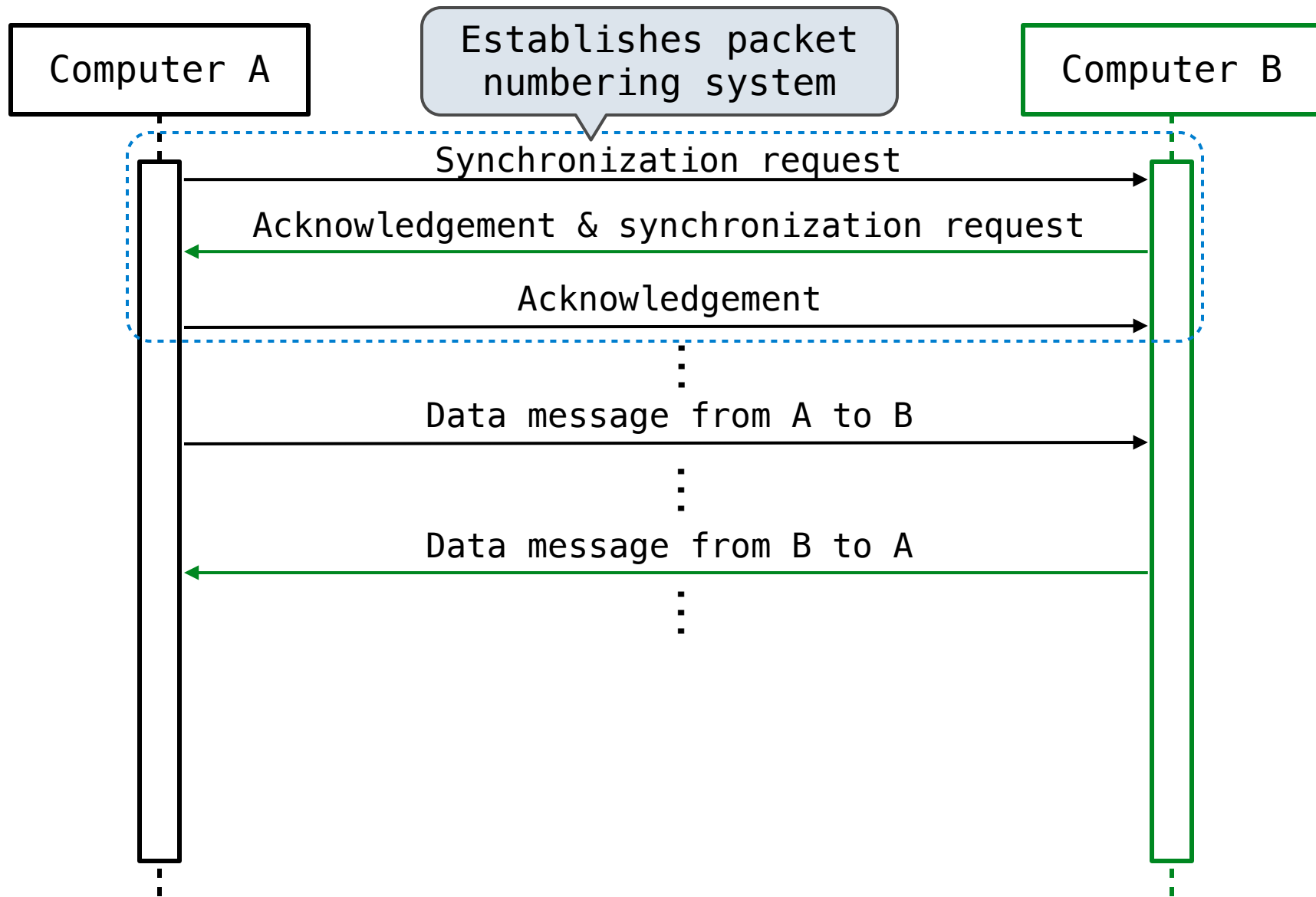
Message Sequence of a TCP Connection



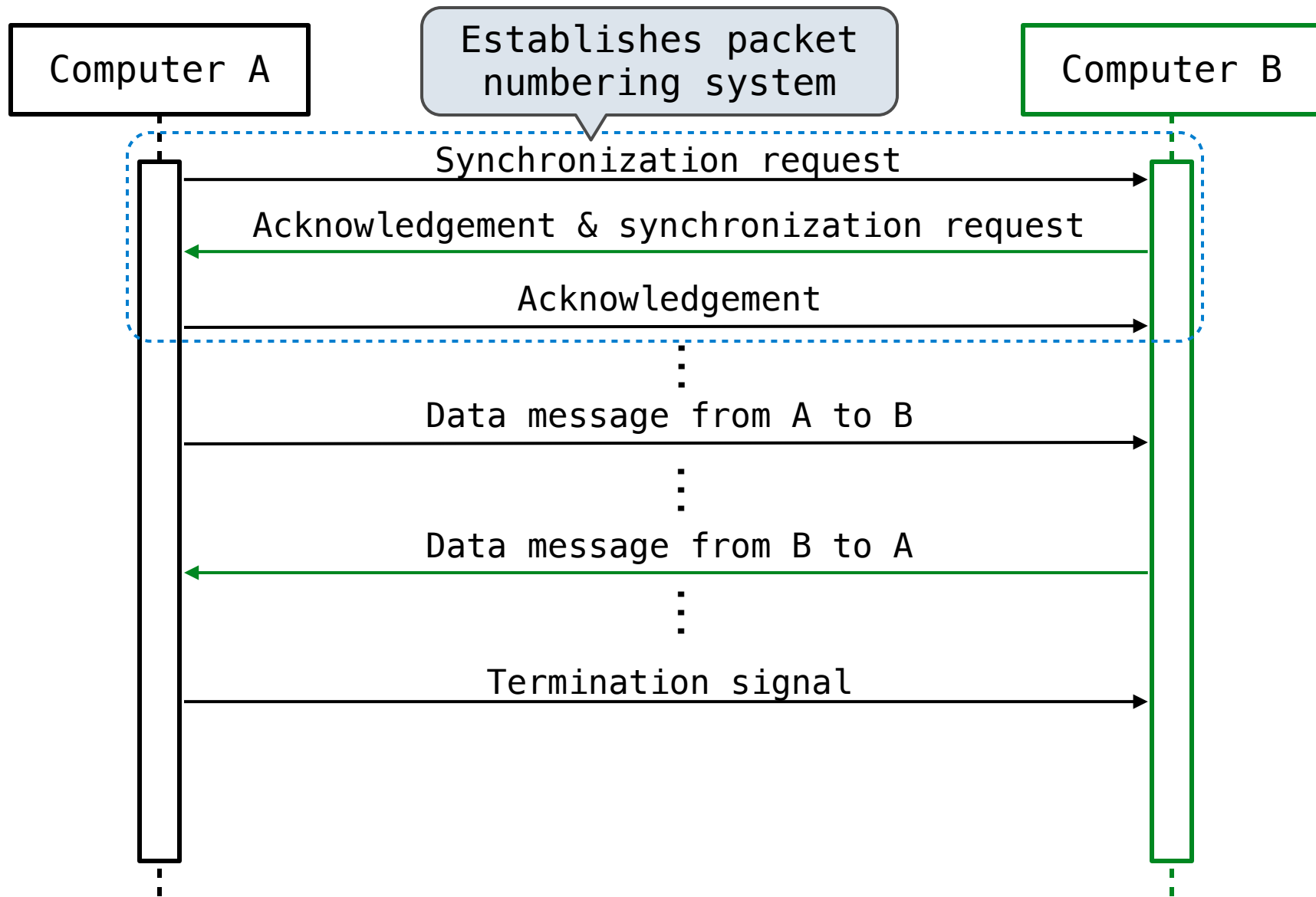
Message Sequence of a TCP Connection



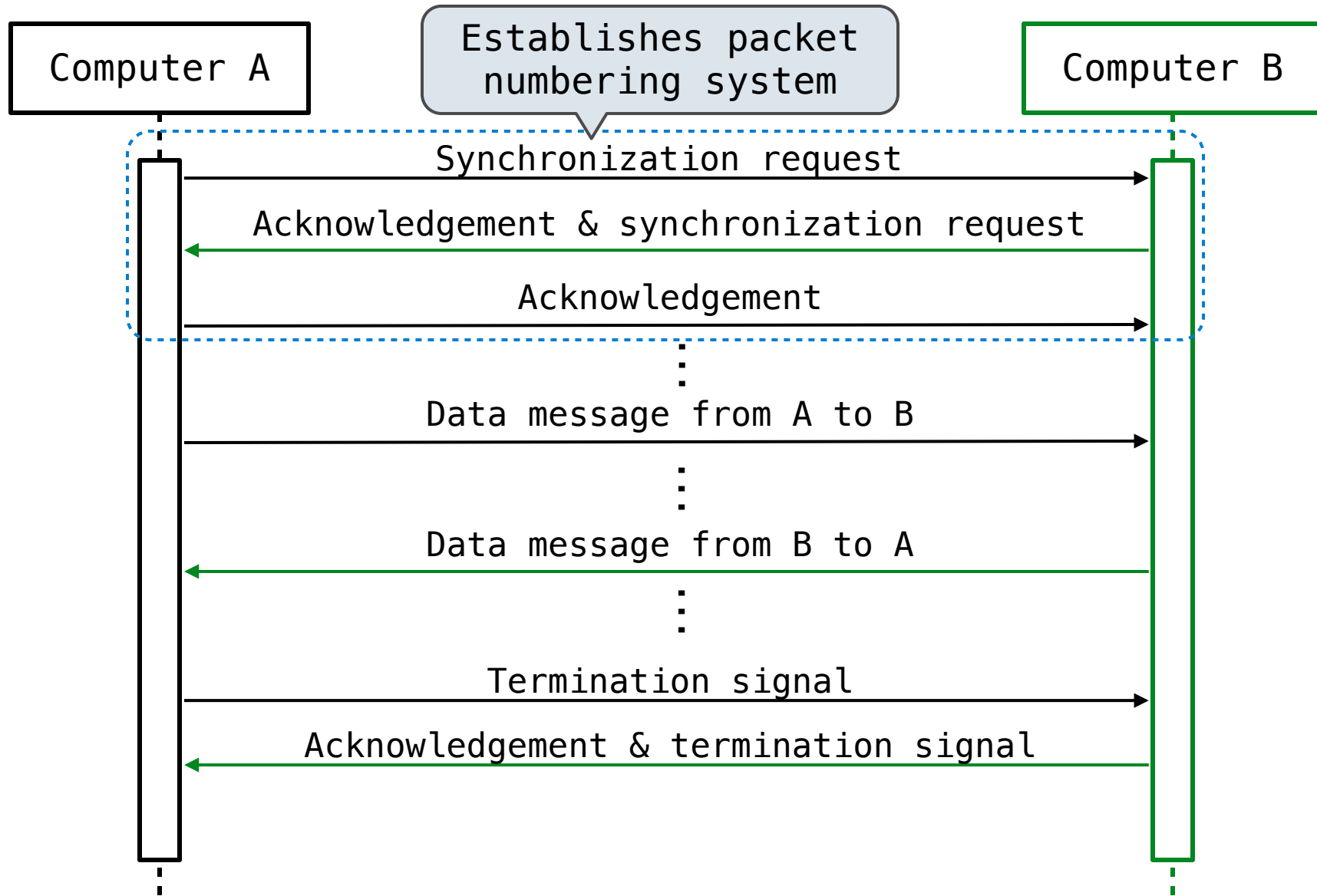
Message Sequence of a TCP Connection



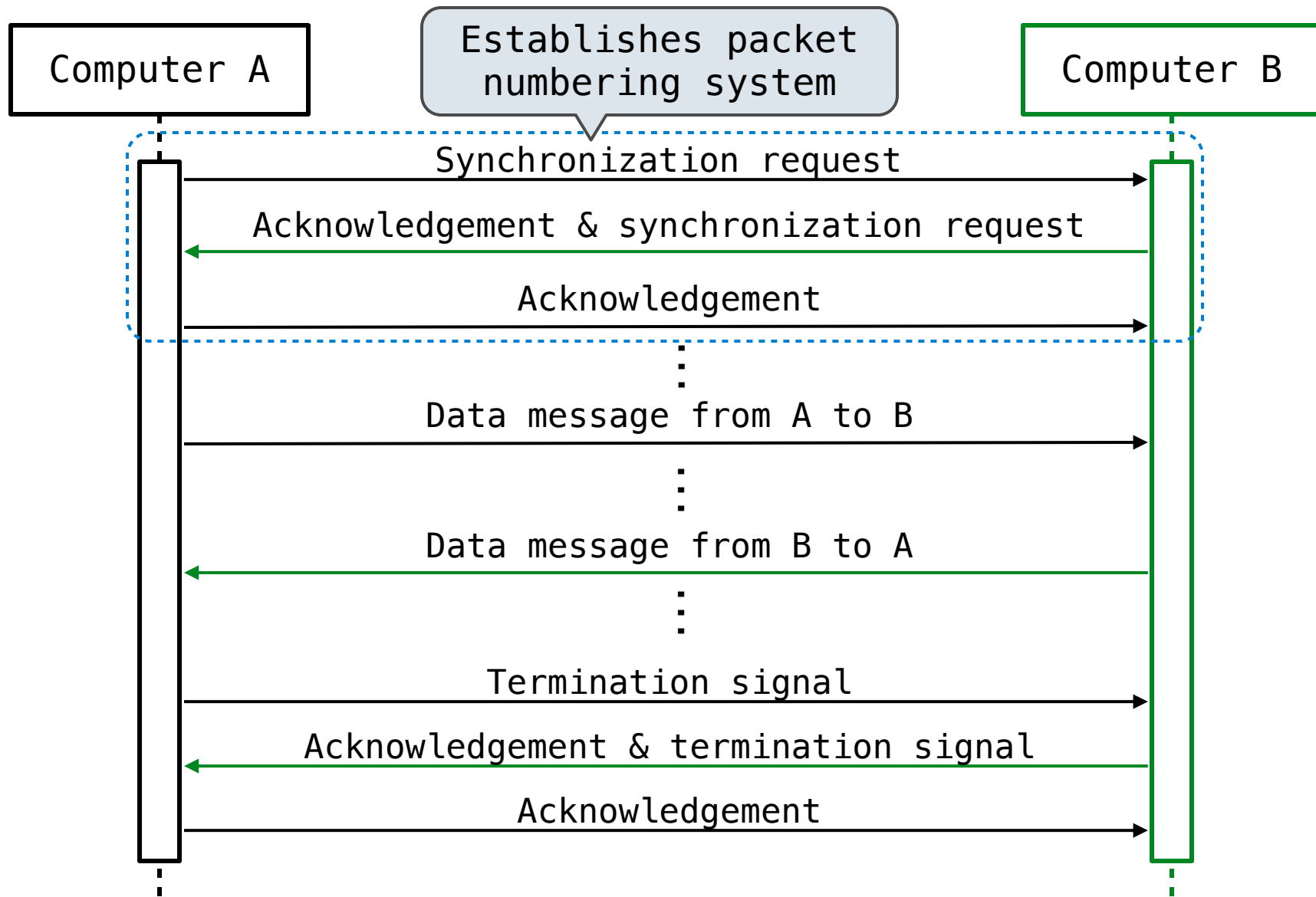
Message Sequence of a TCP Connection



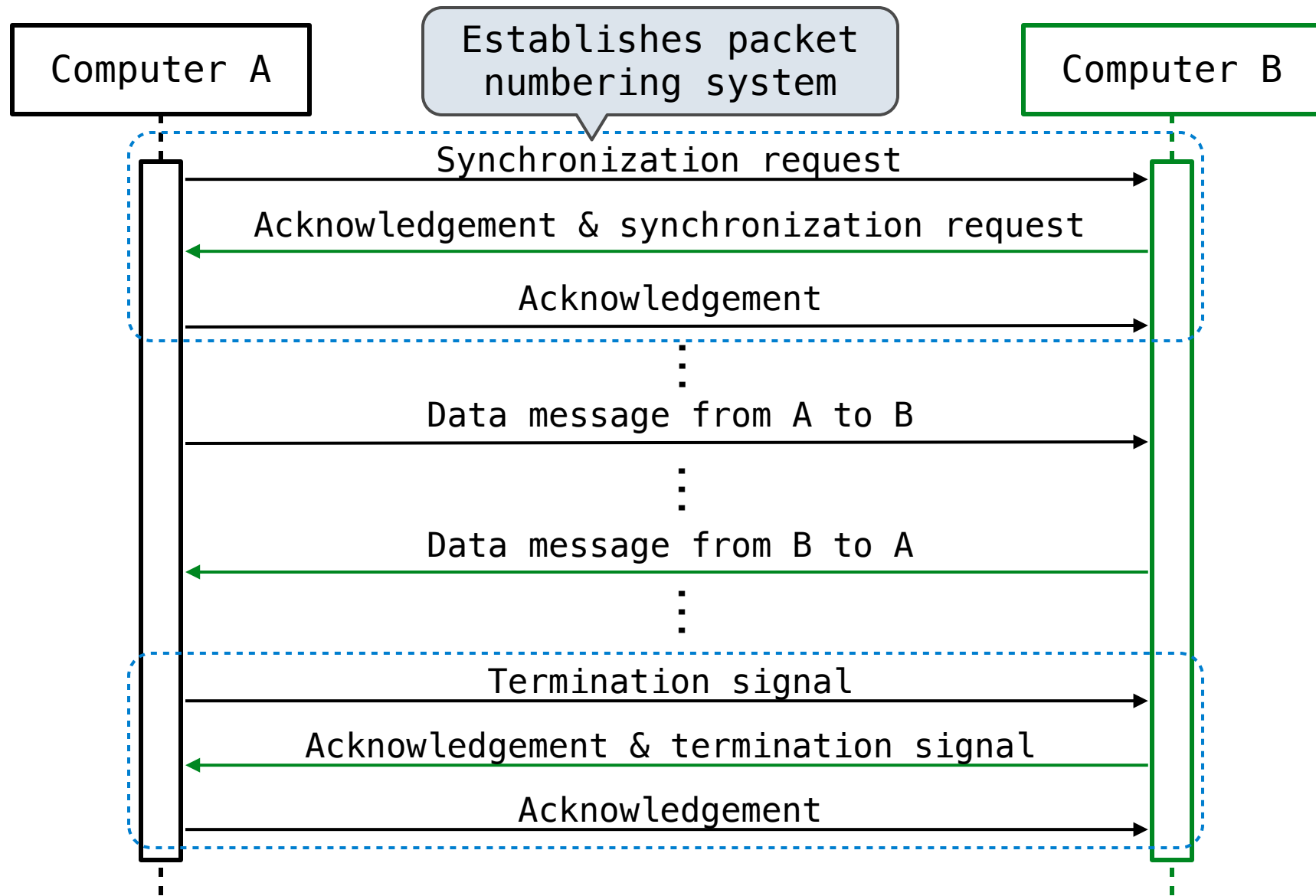
Message Sequence of a TCP Connection



Message Sequence of a TCP Connection



Message Sequence of a TCP Connection



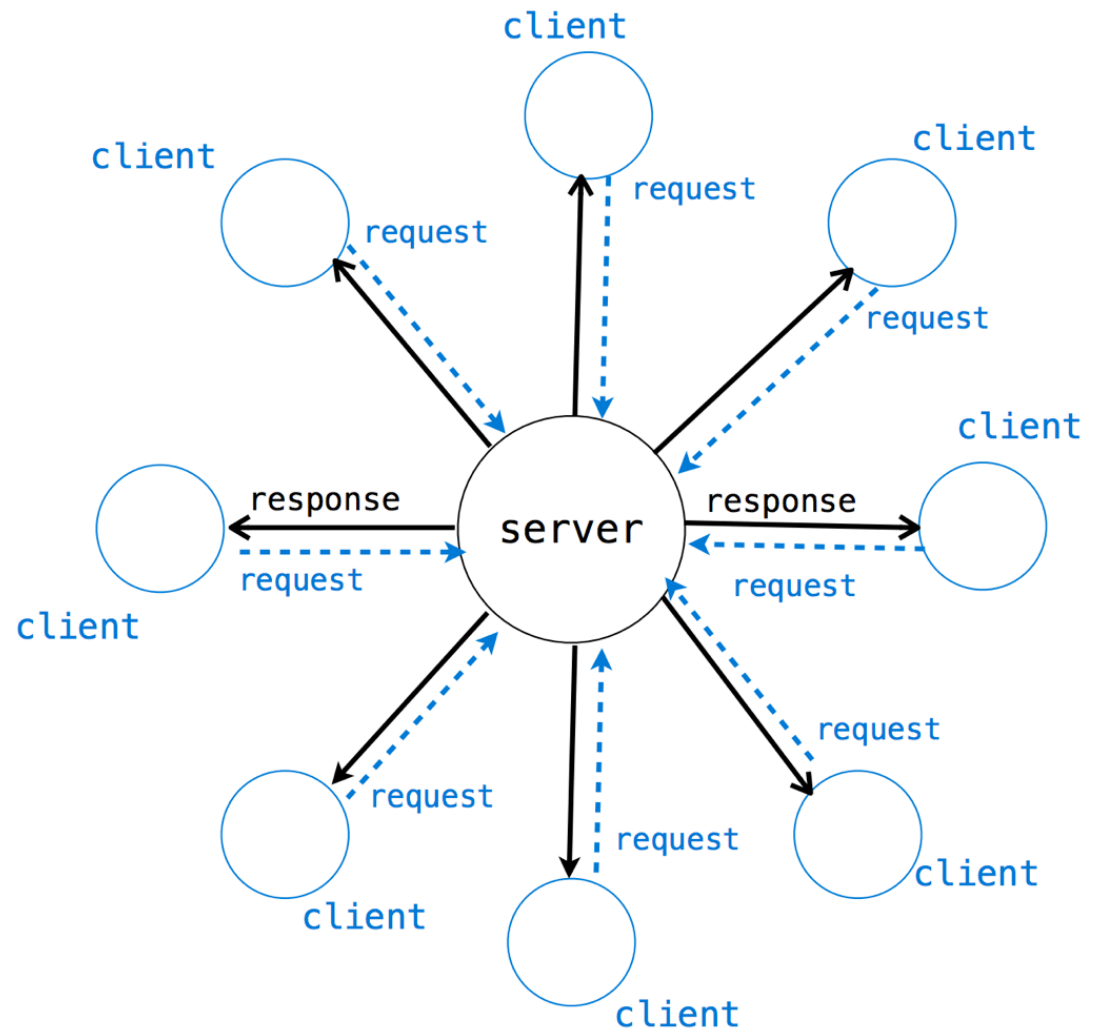
Client/Server Architecture

Client/Server Architecture

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

Client/Server Architecture

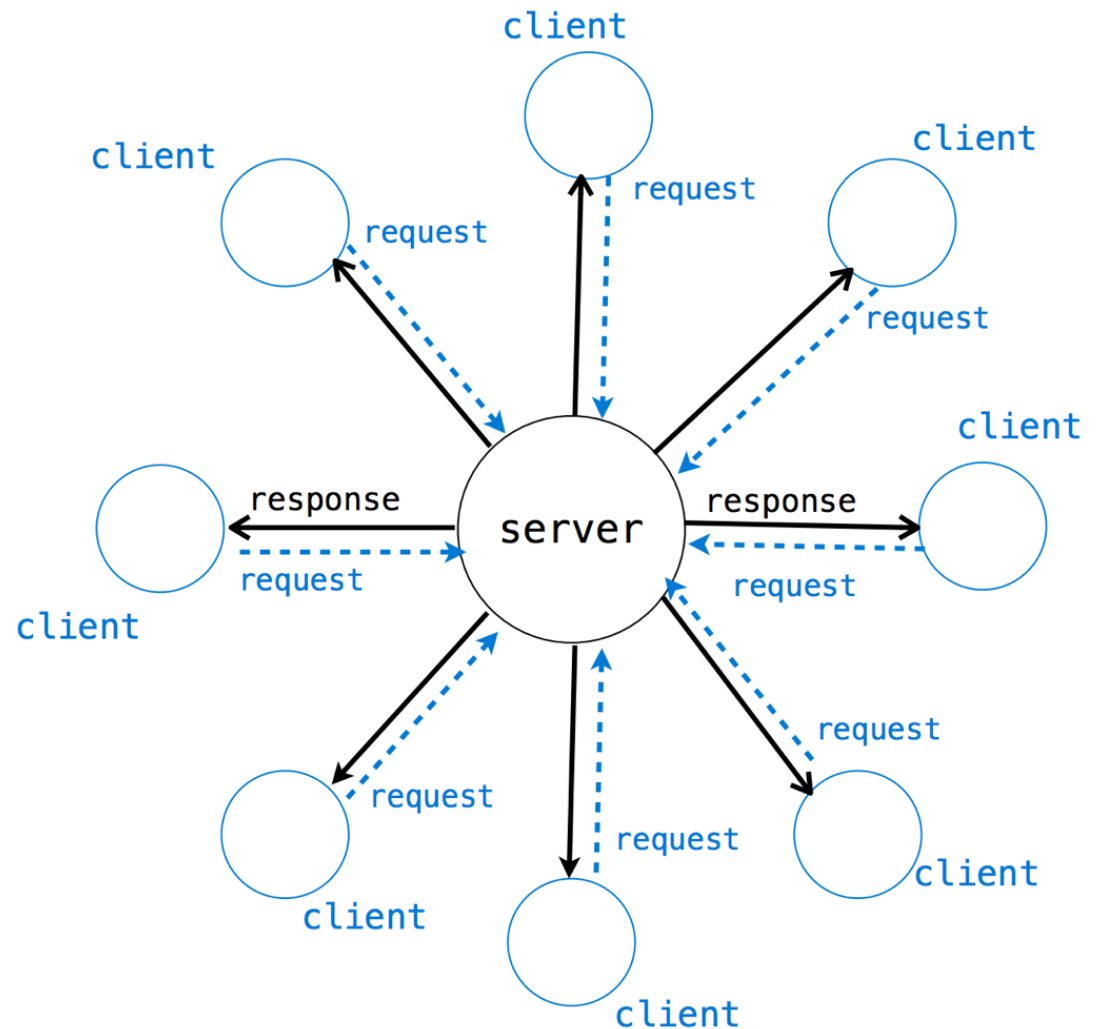
One server provides information to multiple clients through *request* and *response* messages.



Client/Server Architecture

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

Server role: Respond to service requests with requested information.

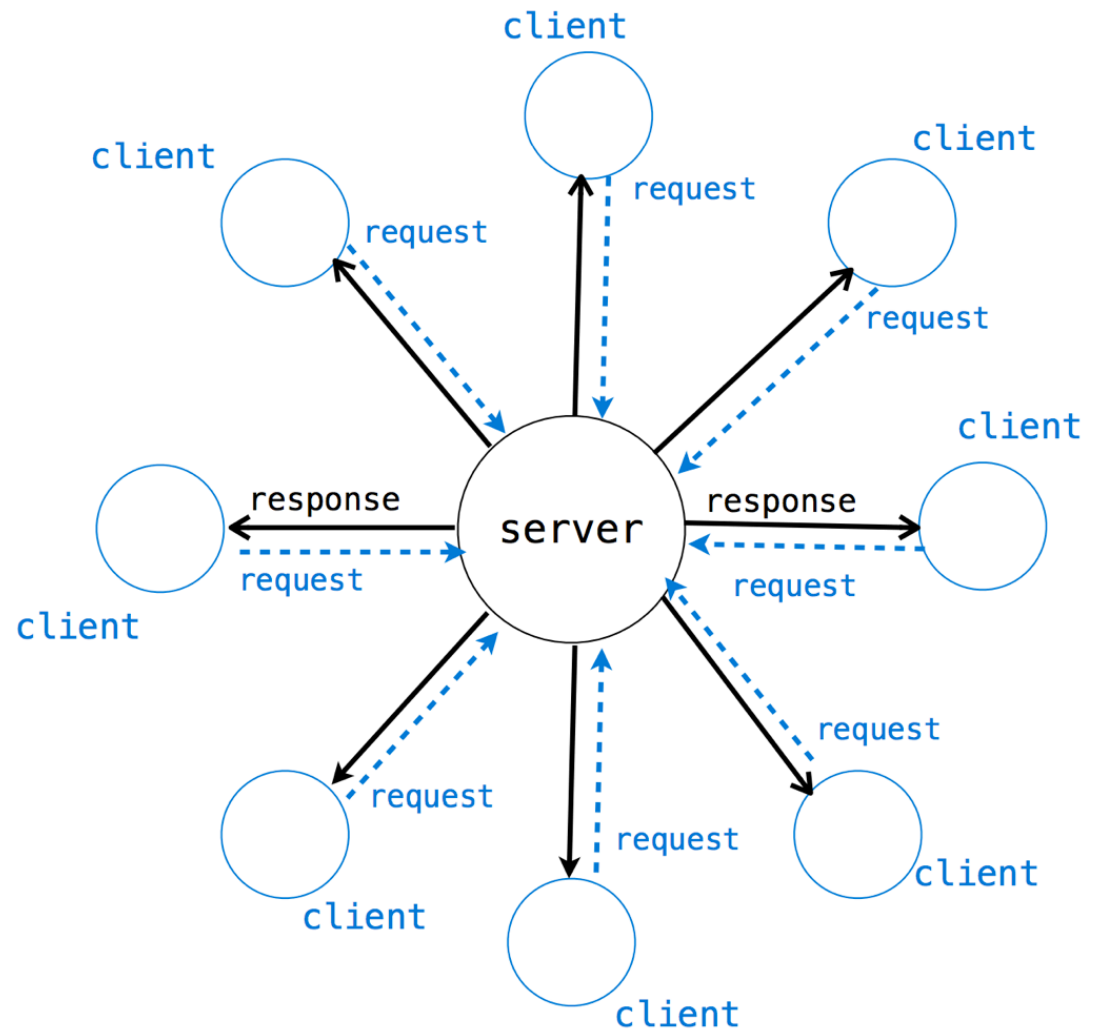


Client/Server Architecture

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.



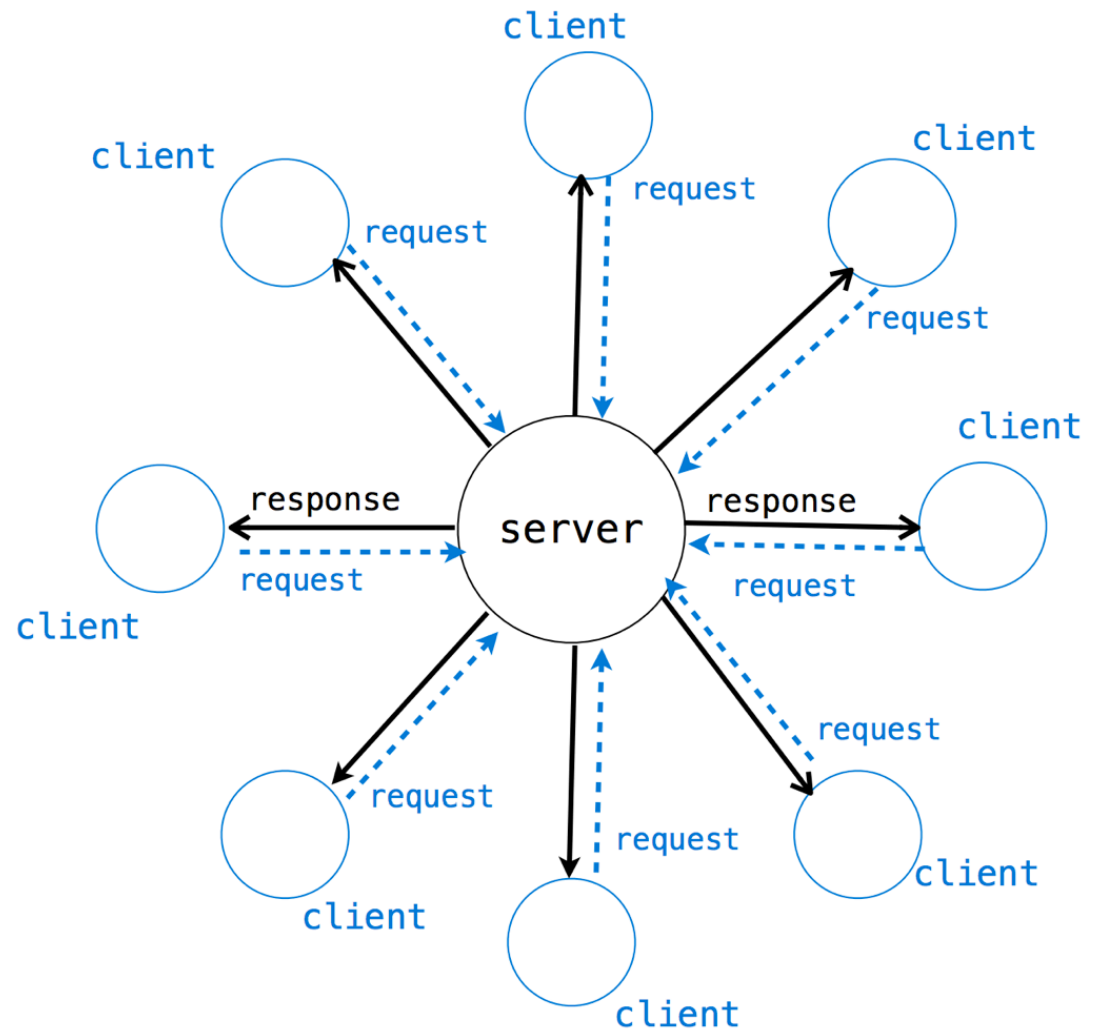
Client/Server Architecture

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

Client/Server Example: The World Wide Web

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

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.

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.

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)

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.

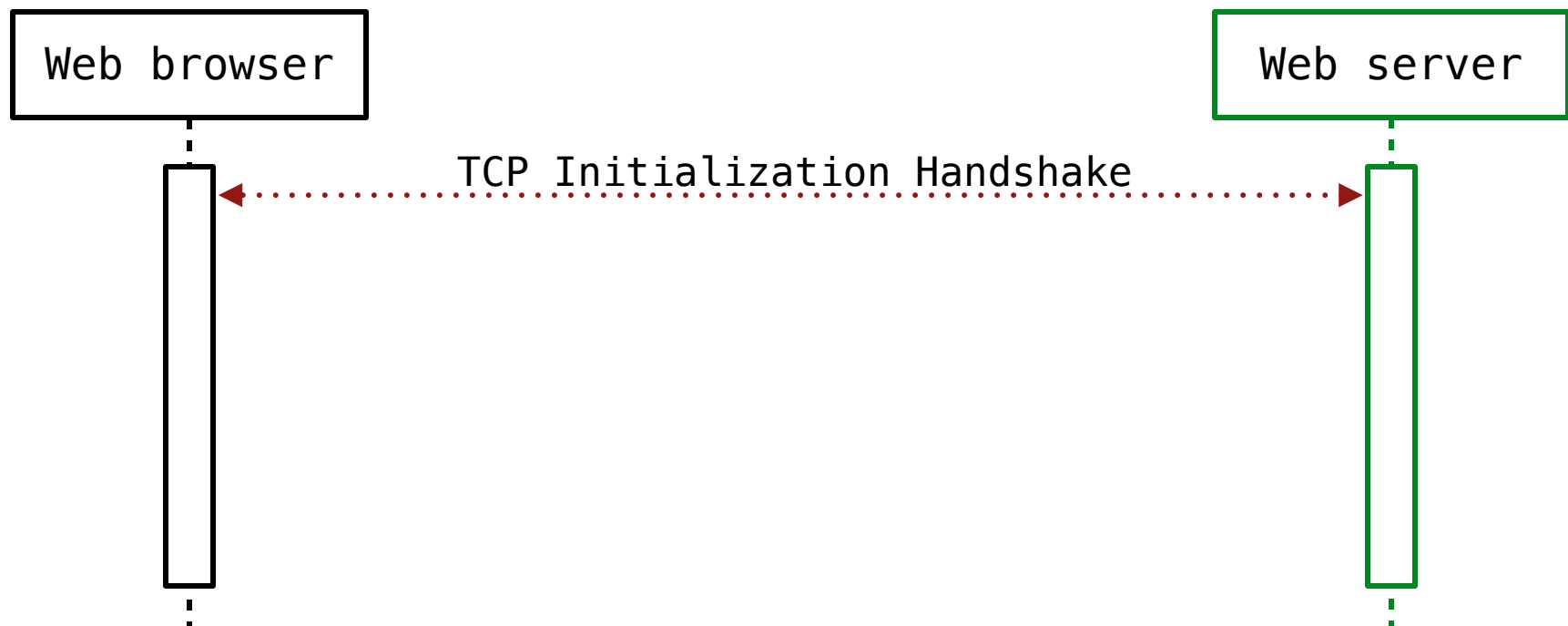
Client/Server Example: The World Wide Web

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.



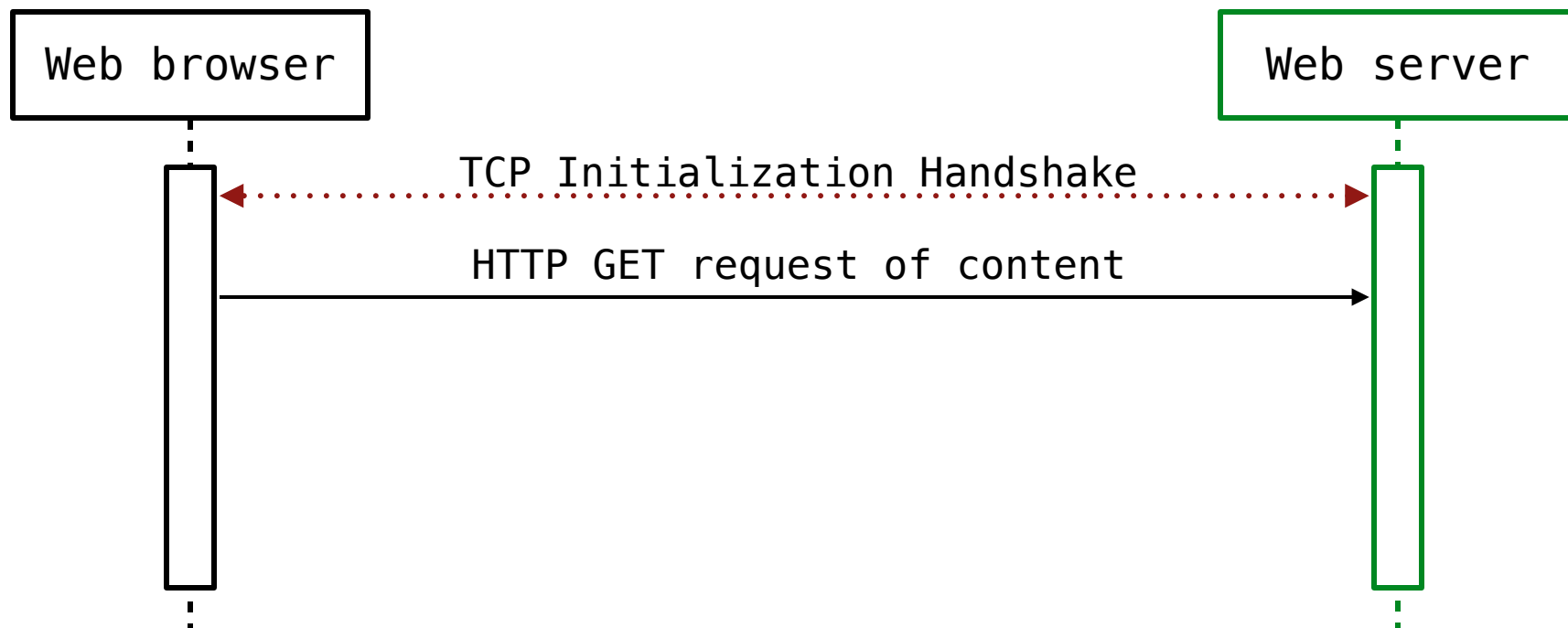
Client/Server Example: The World Wide Web

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.



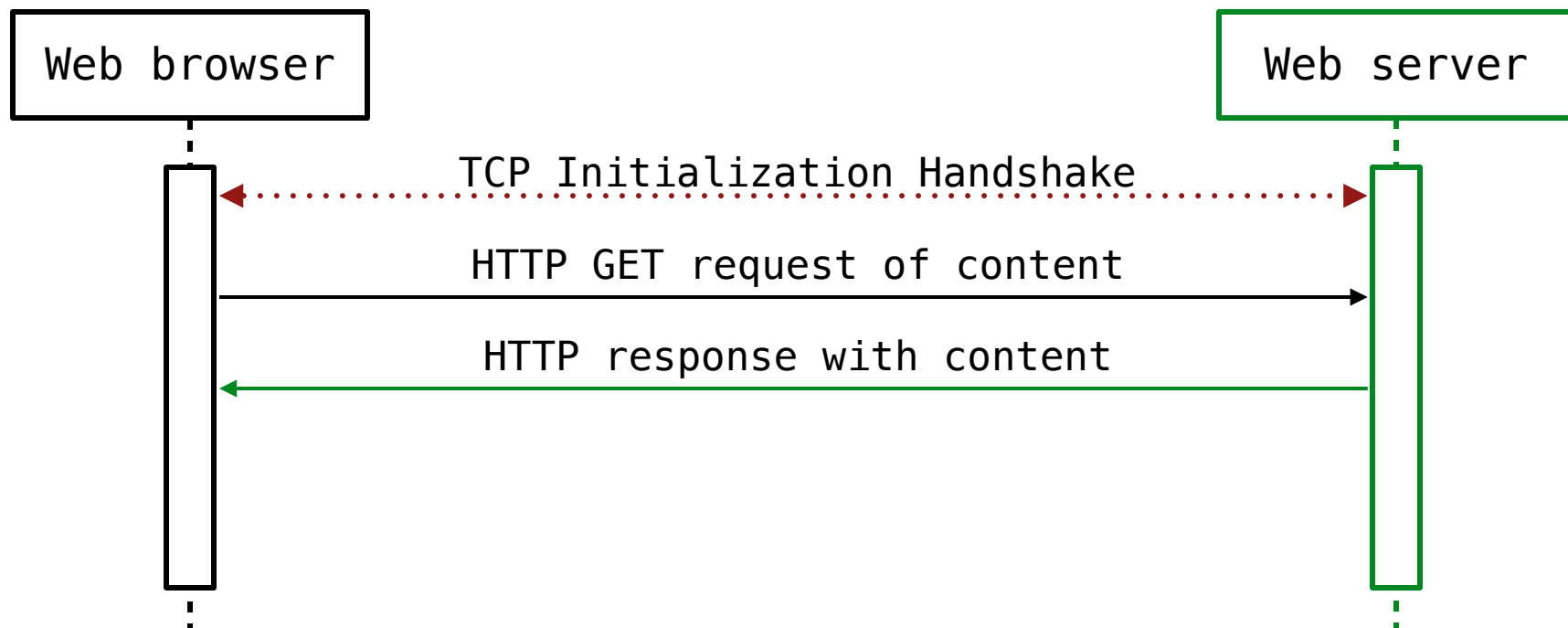
Client/Server Example: The World Wide Web

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.



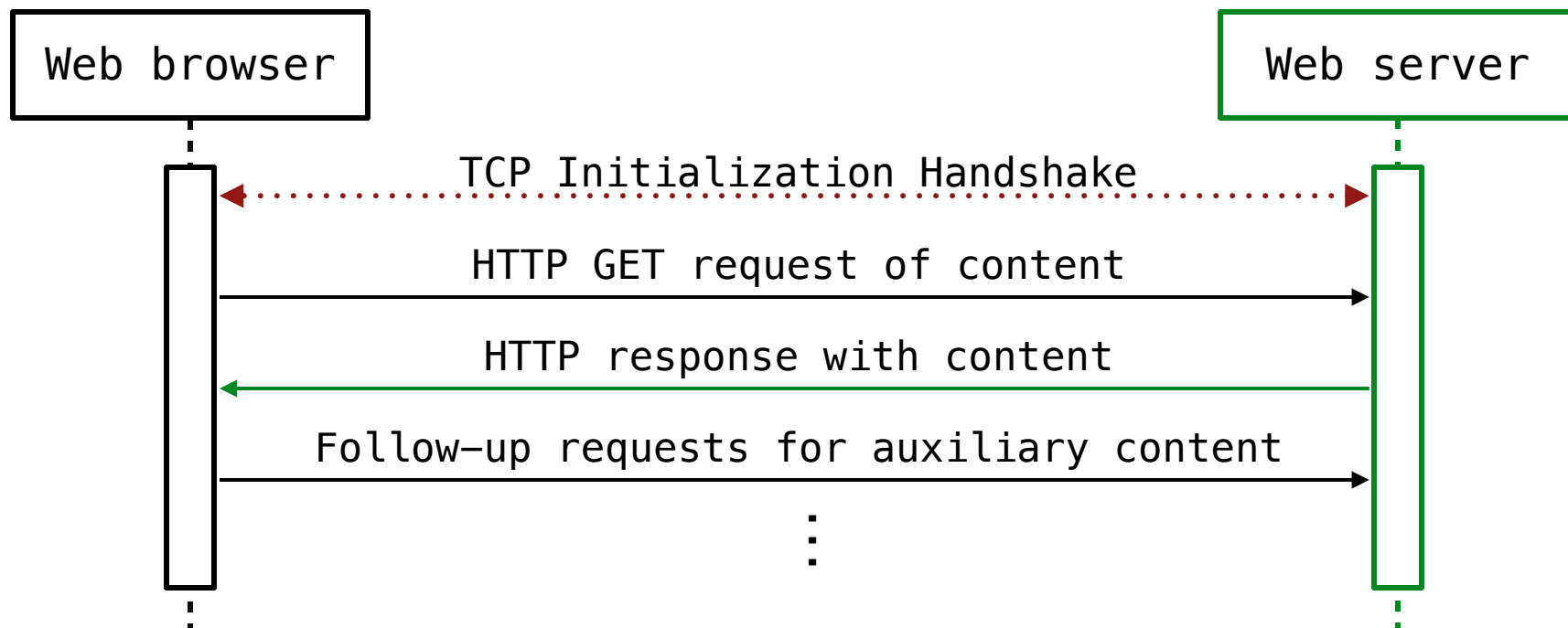
Client/Server Example: The World Wide Web

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.



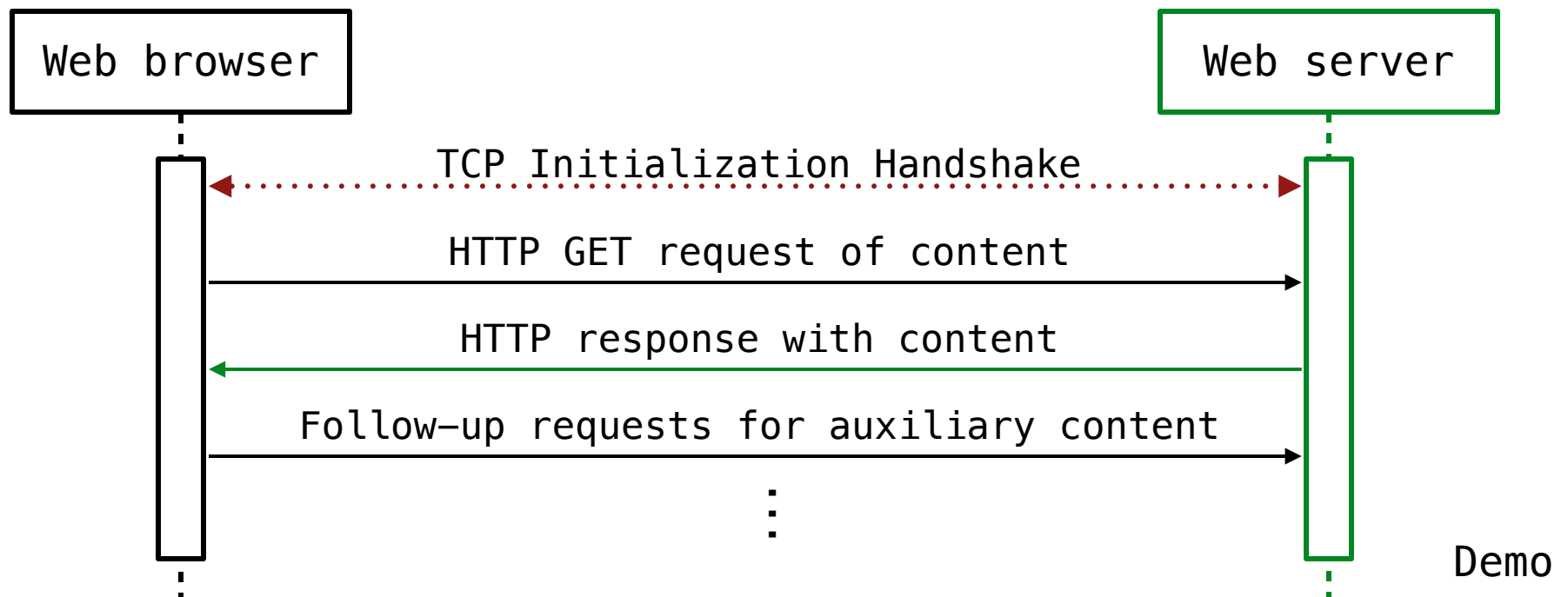
Client/Server Example: The World Wide Web

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

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

The Hypertext Transfer Protocol

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



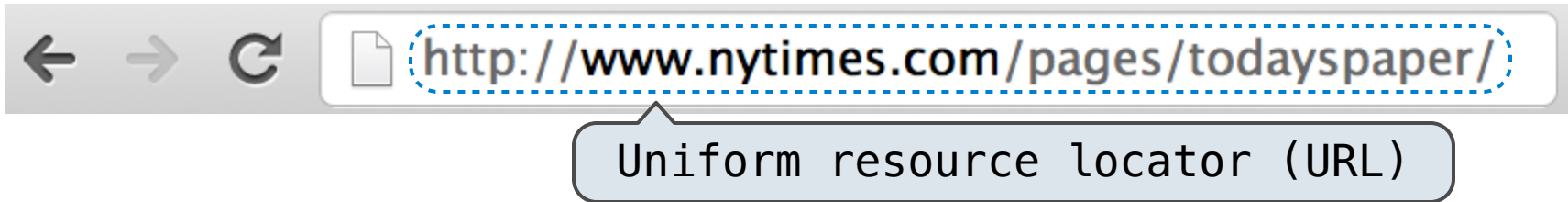
The Hypertext Transfer Protocol

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



The Hypertext Transfer Protocol

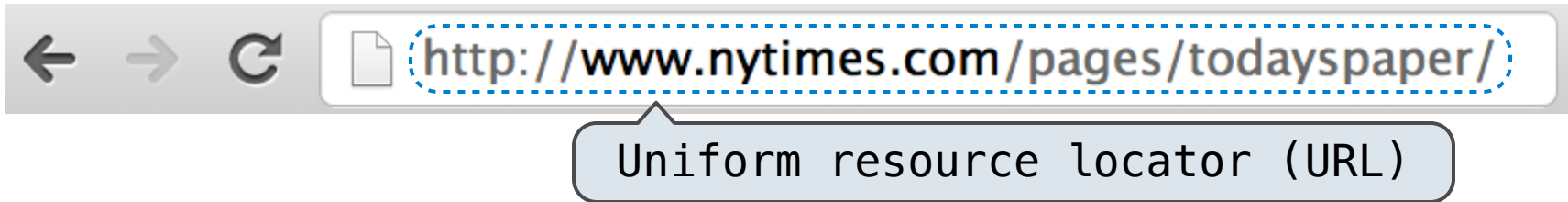
The Hypertext Transfer Protocol (HTTP) is a protocol designed to implement a Client/Server architecture.



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

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:

The Hypertext Transfer Protocol

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



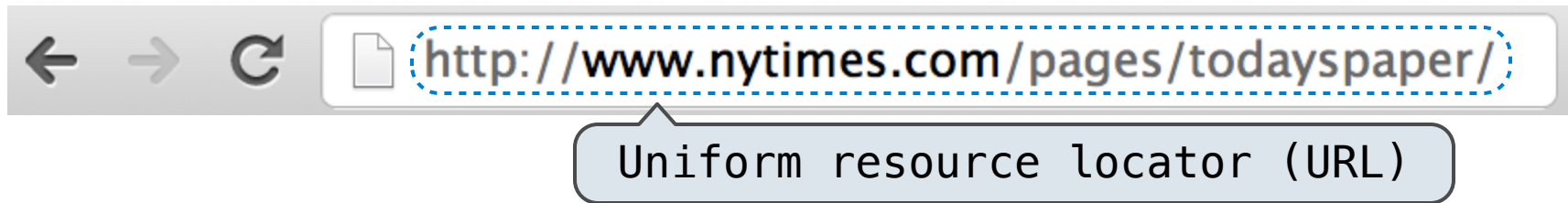
Browser issues a GET request to www.nytimes.com for the content (resource) at location "pages/todayspaper".

Server response contains more than just the resource itself:

- Status code, e.g. **200** OK, **404** Not Found, **403** Forbidden, etc.

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

The Hypertext Transfer Protocol

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



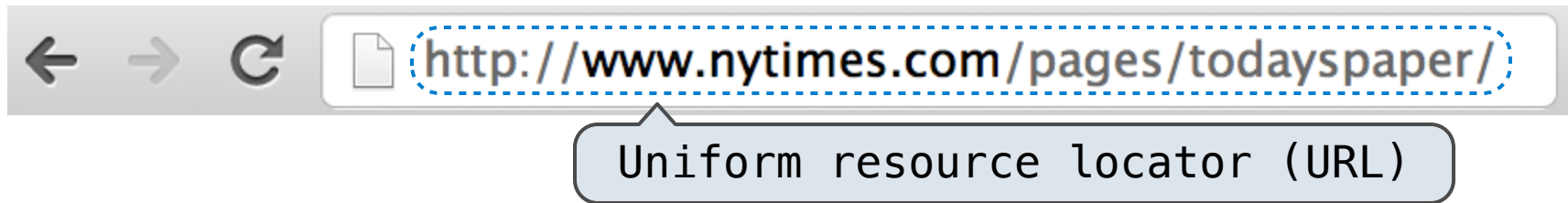
Browser issues a GET request to `www.nytimes.com` for the content (resource) at location "`pages/todayspaper`".

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

The Hypertext Transfer Protocol

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



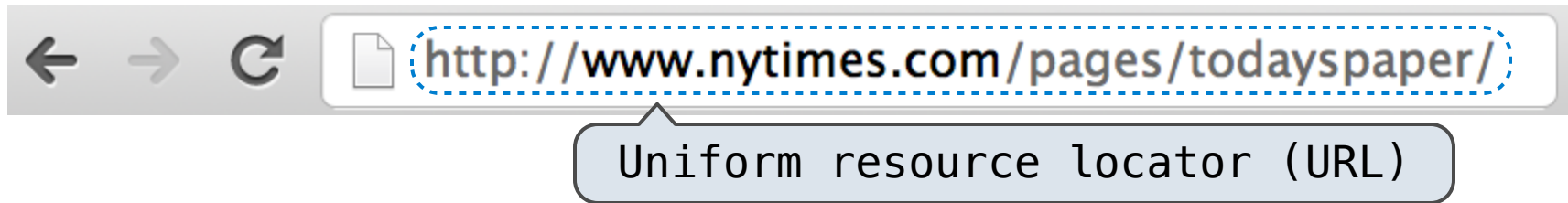
Browser issues a GET request to `www.nytimes.com` for the content (resource) at location "`pages/todayspaper`".

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

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

Properties of a Client/Server Architecture

Benefits:

Properties of a Client/Server Architecture

Benefits:

- Creates a separation of concerns among components.

Properties of a Client/Server Architecture

Benefits:

- Creates a separation of concerns among components.
- Enforces an abstraction barrier between client and server.

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.

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:

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.

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.

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:

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.

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).

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

Peer-to-Peer Architecture

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

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.

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.

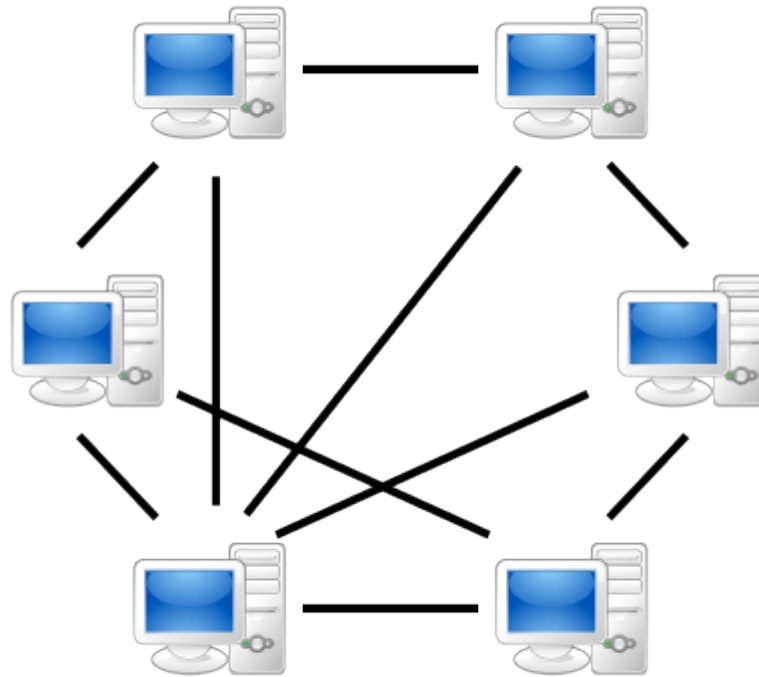
Each participant has only partial knowledge of the network.

Peer-to-Peer Architecture

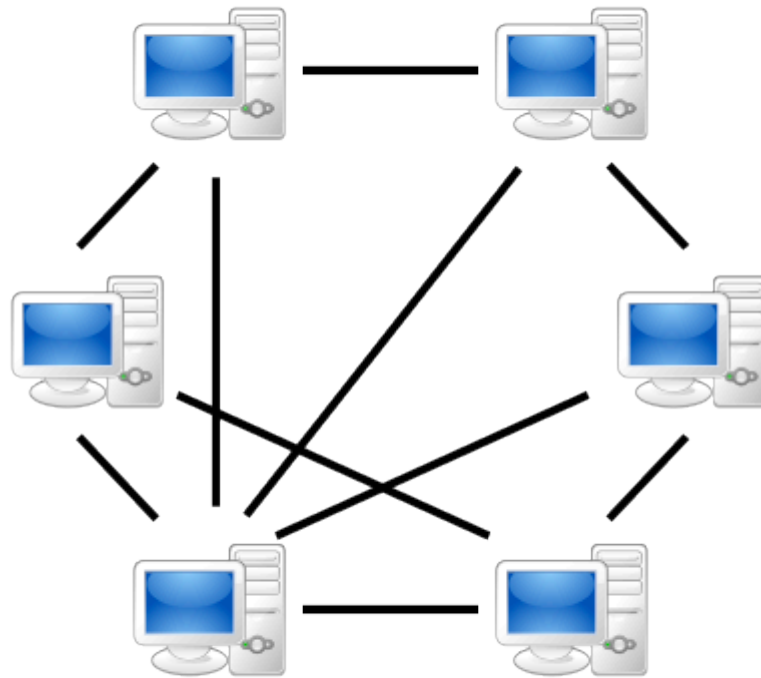
All participants in a distributed application contribute computational resources: processing, storage, and network.

Messages are relayed through a network of participants.

Each participant has only partial knowledge of the network.

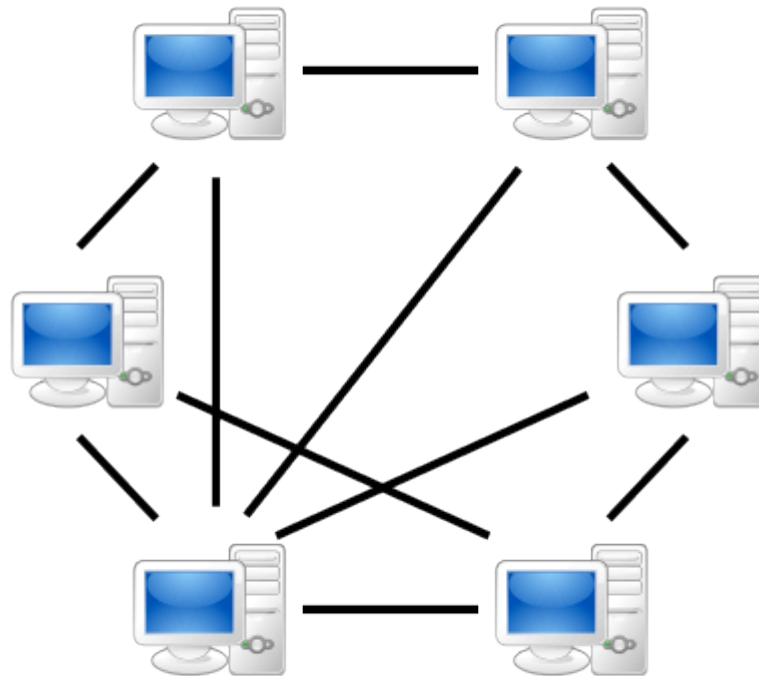


Network Structure Concerns



Network Structure Concerns

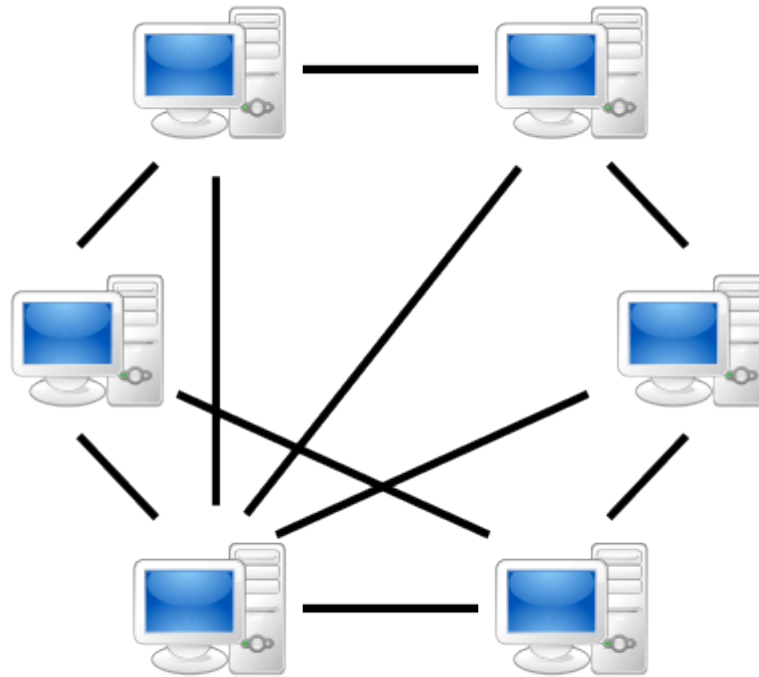
Some data transfers on the Internet are faster than others.



Network Structure Concerns

Some data transfers on the Internet are faster than others.

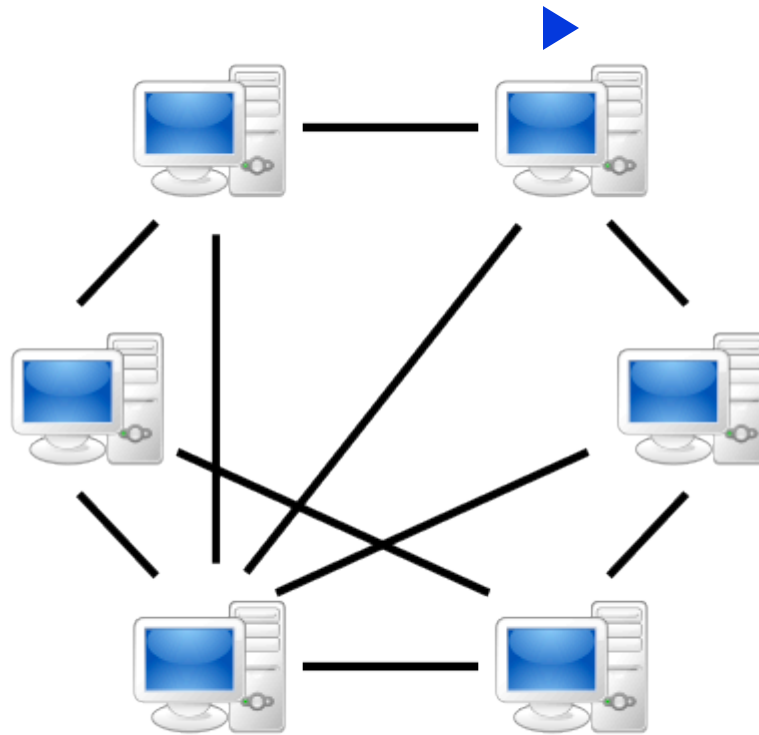
The time required to transfer a message through a peer-to-peer network depends on the route chosen.



Network Structure Concerns

Some data transfers on the Internet are faster than others.

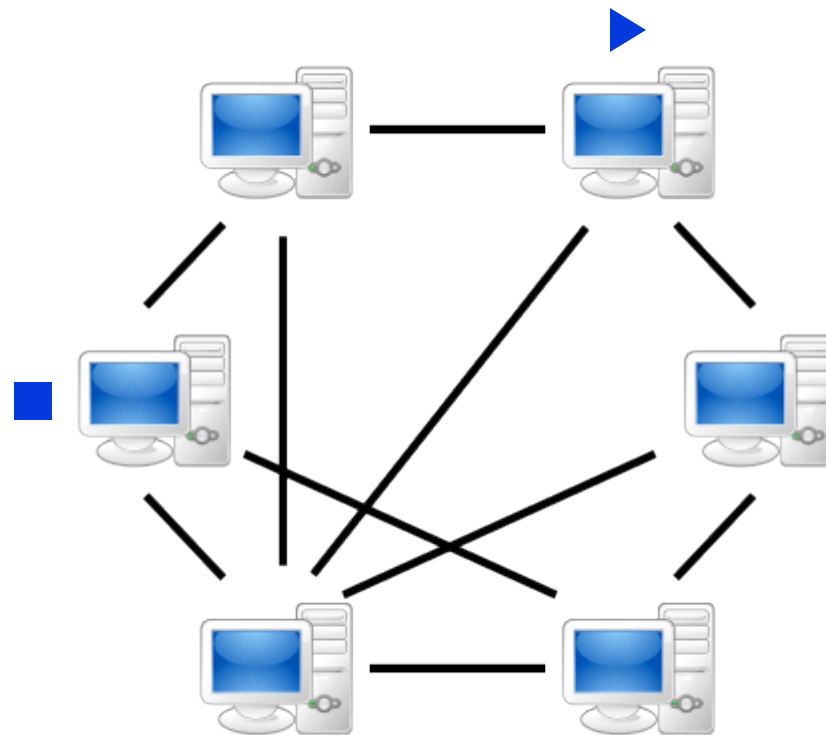
The time required to transfer a message through a peer-to-peer network depends on the route chosen.



Network Structure Concerns

Some data transfers on the Internet are faster than others.

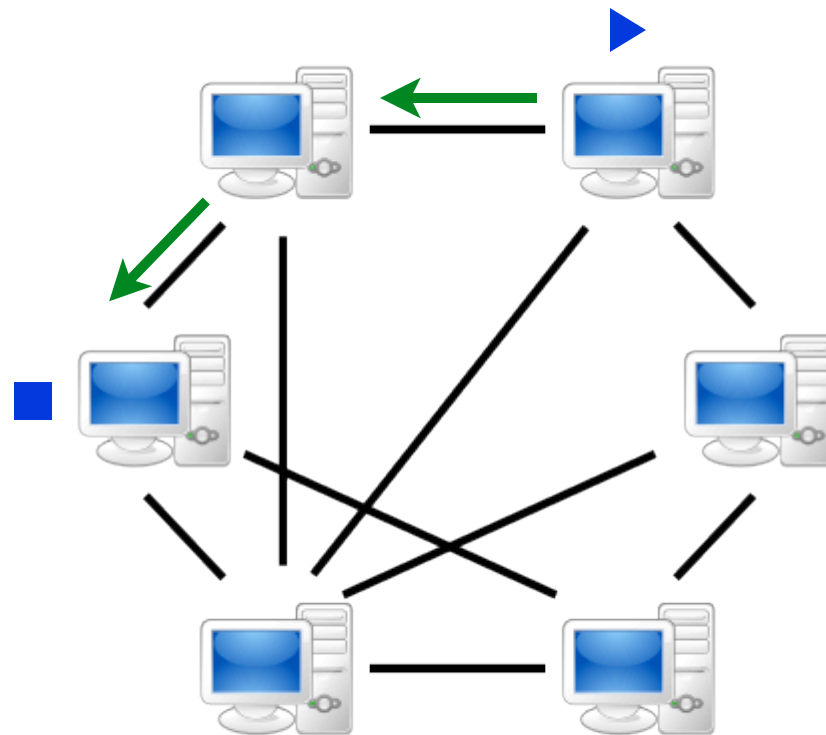
The time required to transfer a message through a peer-to-peer network depends on the route chosen.



Network Structure Concerns

Some data transfers on the Internet are faster than others.

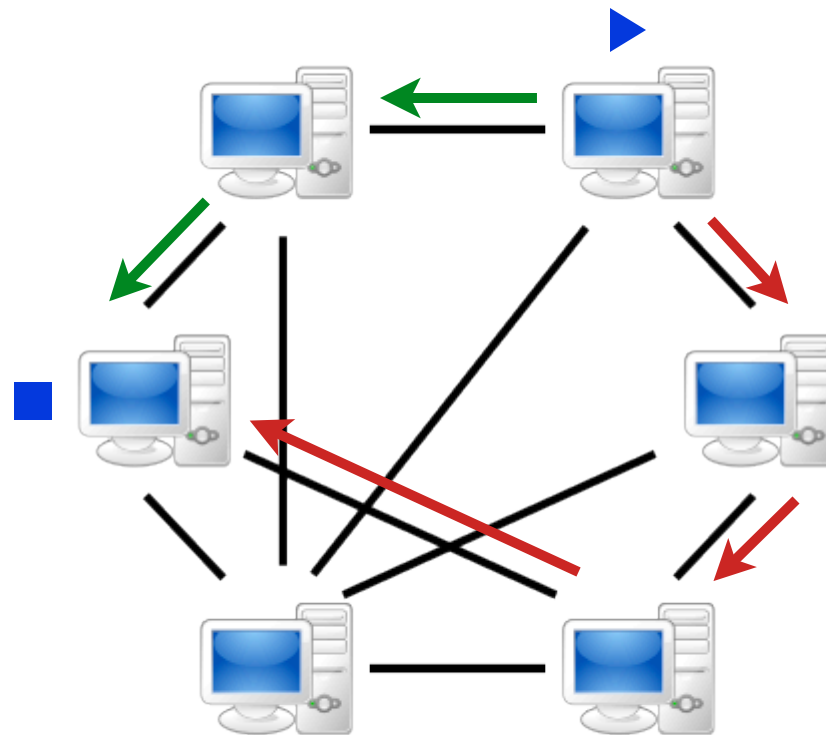
The time required to transfer a message through a peer-to-peer network depends on the route chosen.



Network Structure Concerns

Some data transfers on the Internet are faster than others.

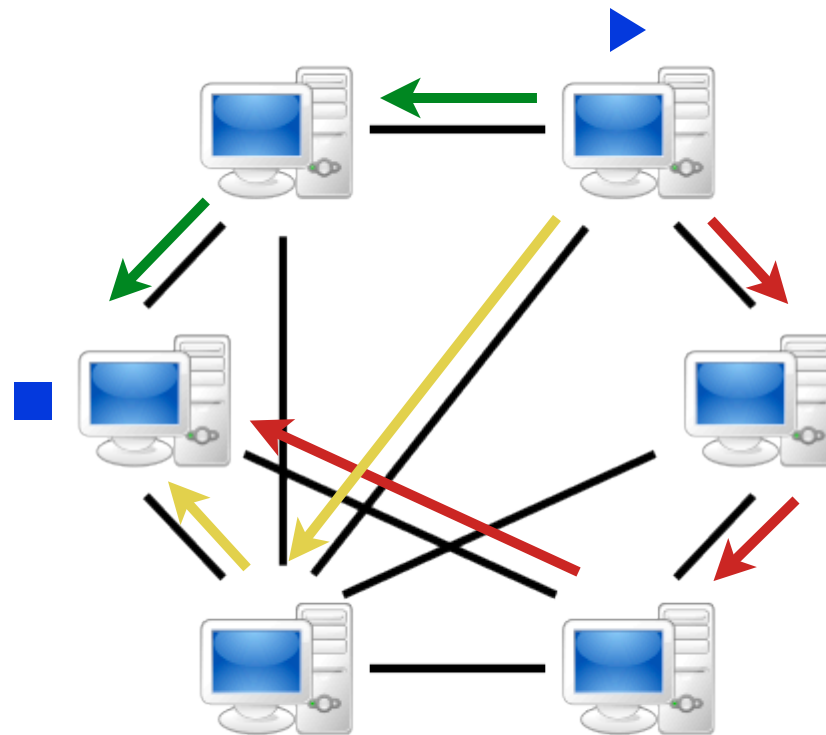
The time required to transfer a message through a peer-to-peer network depends on the route chosen.



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

Example: Skype

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

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.

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*.

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.

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.

Client A

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.

Client A

Client B

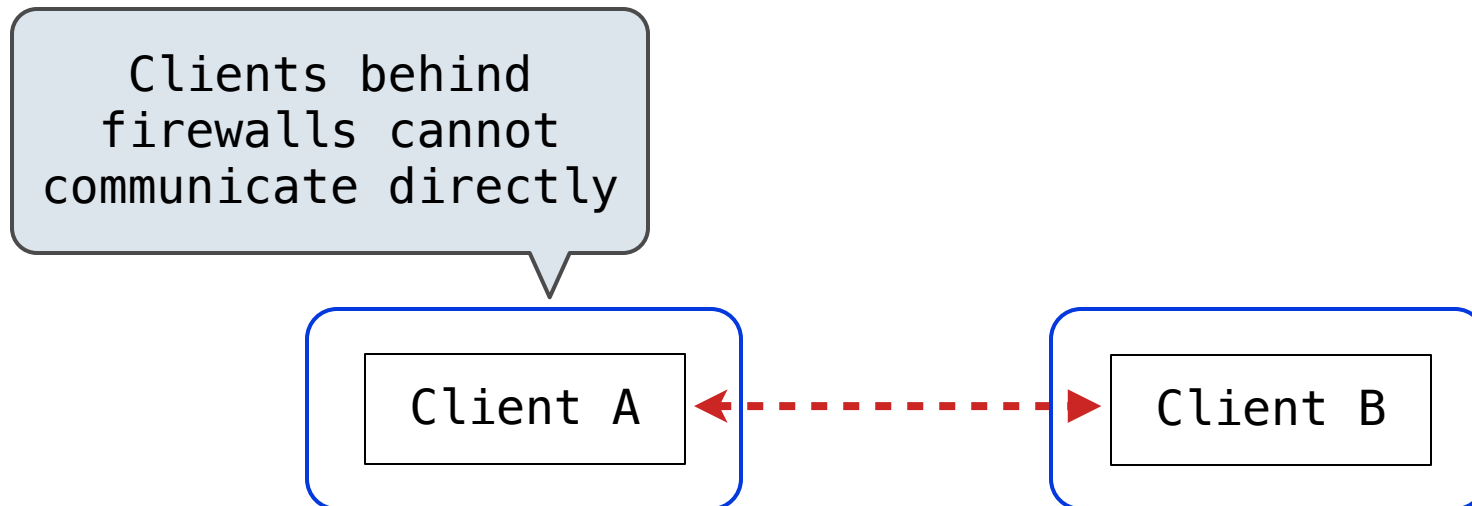
Example: Skype

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.



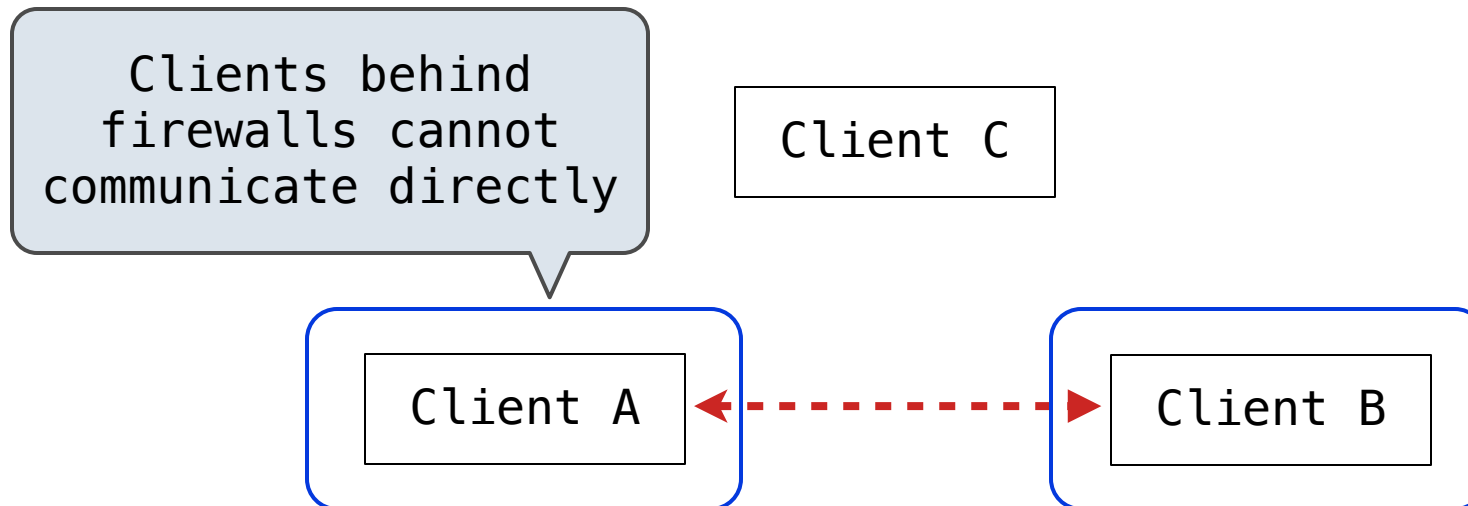
Example: Skype

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.



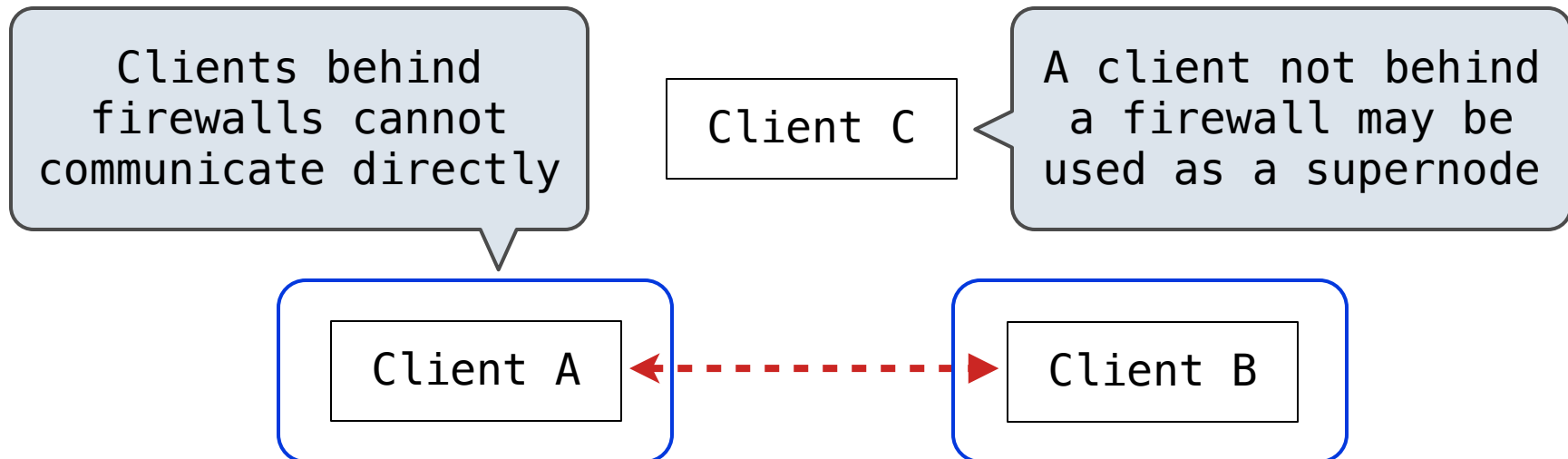
Example: Skype

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.



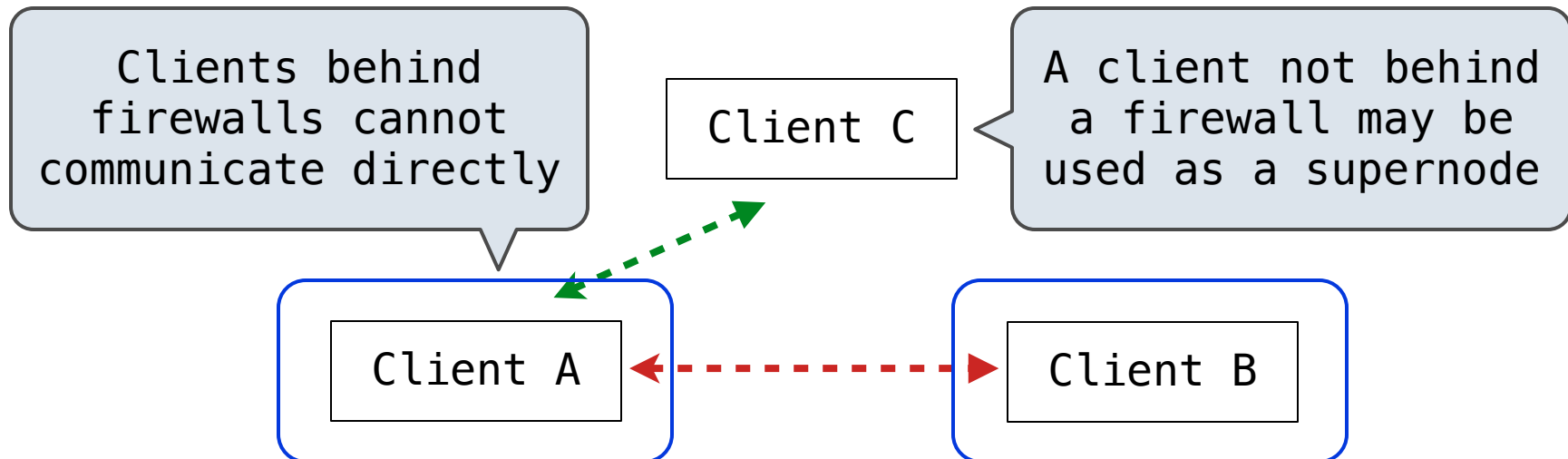
Example: Skype

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.



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.

