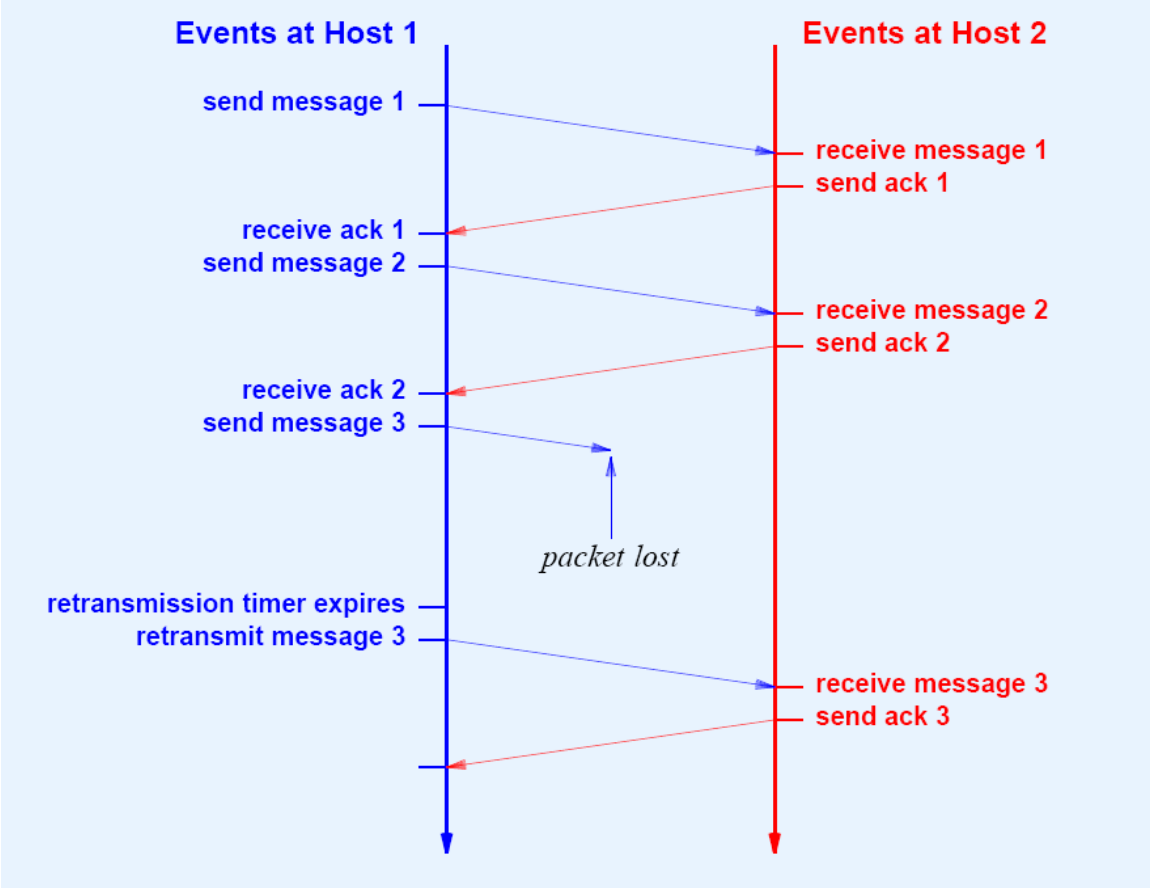
Reliable Data Transmission

- Positive acknowledgment
  - Receiver returns short message when data arrives
  - Called acknowledgment
- Retransmission
  - Sender starts timer whenever message is transmitted
  - If timer expires before acknowledgment arrives, sender
- retransmits message

Illustration Of Retransmission



How Long Should TCP Wait Before Retransmitting?

- Time for acknowledgment to arrive depends on
  - Distance to destination
  - Current traffic conditions
- Multiple connections can be open simultaneously
- Traffic conditions change rapidly

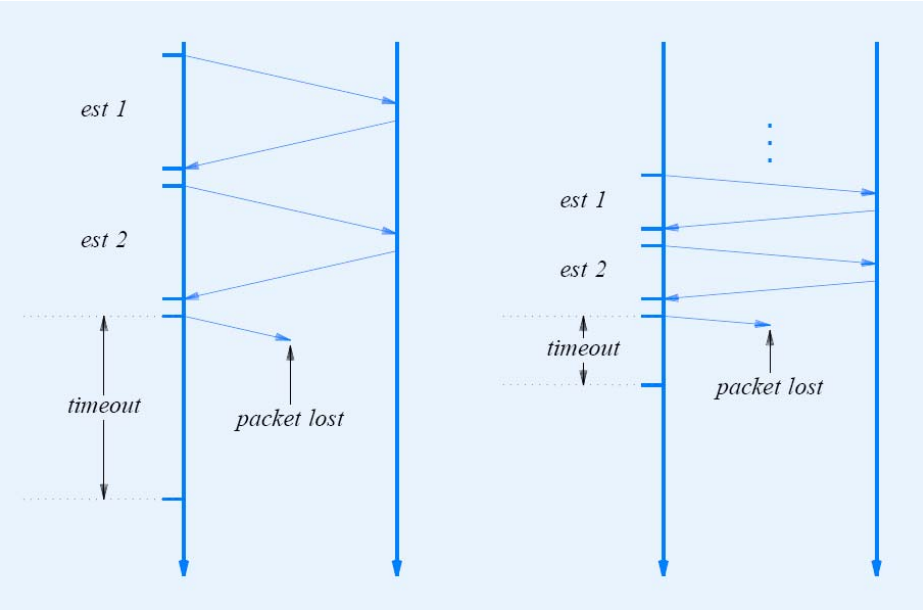
Important Point

The delay required for data to reach a destination and an acknowledgment to return depends on traffic in the internet as well as the distance to the destination. Because it allows multiple application programs to communicate with multiple destinations concurrently, TCP must handle a variety of delays that can change rapidly.

Solving The Retransmission Problem

- Keep estimate of round trip time on each connection
- Use current estimate to set retransmission timer
- Known as adaptive retransmission
- Key to TCP's success

Illustration Of Adaptive Retransmission



- Timeout depends on current round-trip estimate

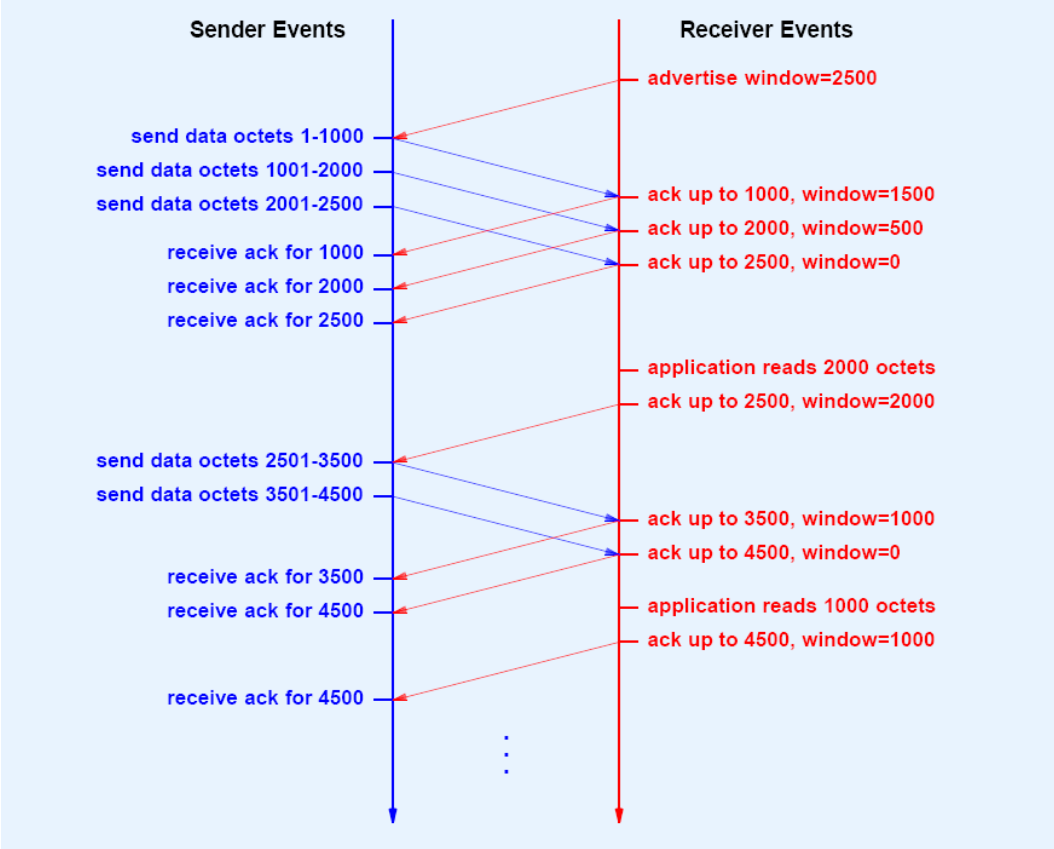
TCP Flow Control

- Receiver
  - Advertises available buffer space
  - Called window
- Sender
  - Can send up to entire window before ack arrives

Window Advertisement

- Each acknowledgment carries new window information
  - Called window advertisement
  - Can be zero (called closed window)
- Interpretation: have received up through X, and can take Y more octets

Illustration Of Window Advertisement



Startup And Shutdown

- Connection startup
  - Must be reliable
- Connection shutdown
  - Must be graceful
- Difficult

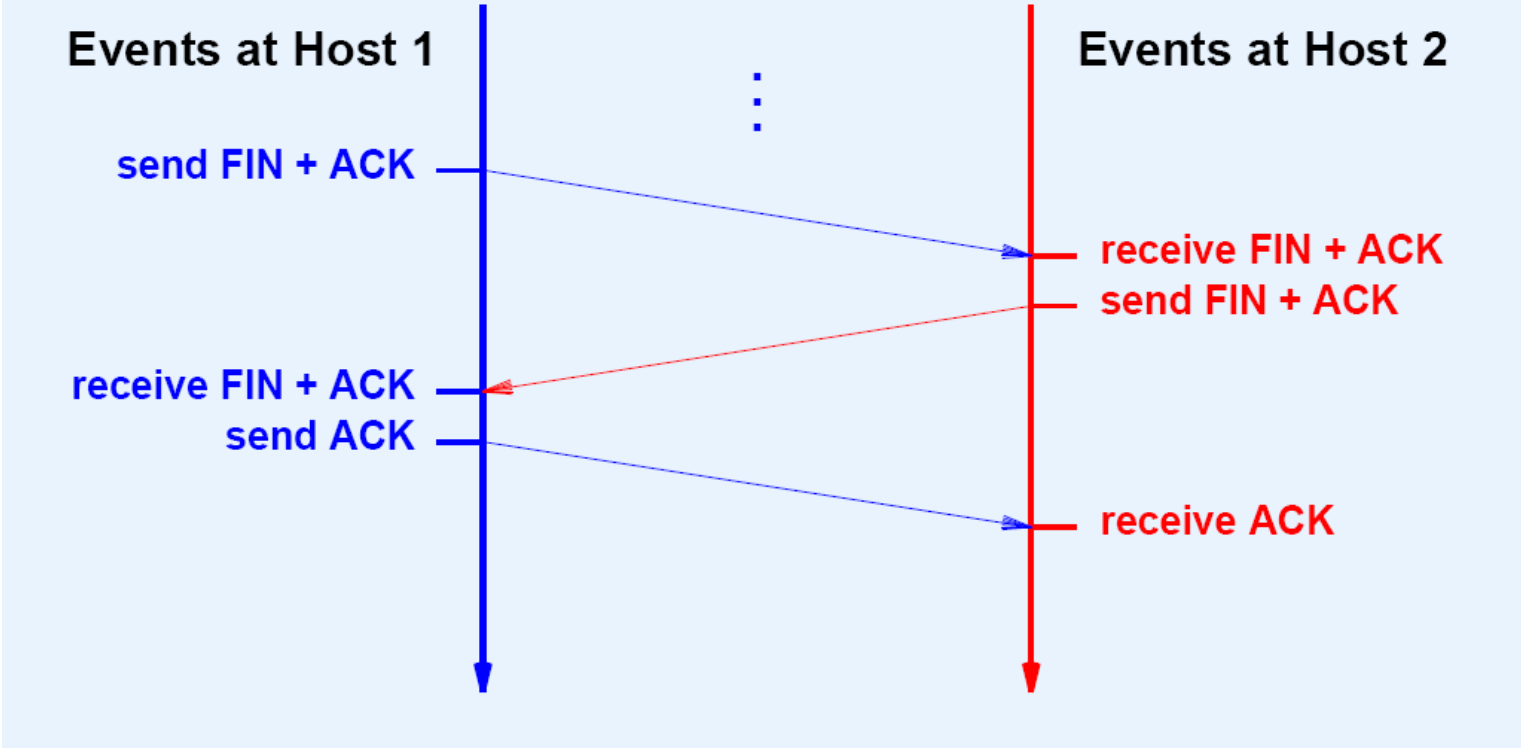
Why Startup And Shutdown Are Difficult

- Segments can be
  - Lost
  - Duplicated
  - Delayed
  - Delivered out of order
  - Either side can crash
  - Either side can reboot
- Need to avoid duplicate shutdown message from affecting later connection

TCP's Solution For Startup/Shutdown

- Uses three-message exchange
- Known as 3-way handshake
- Necessary and sufficient for
  - Unambiguous, reliable startup
  - Unambiguous, graceful shutdown
- SYN used for startup
- FIN used for shutdown

Illustration Of 3-Way Handshake



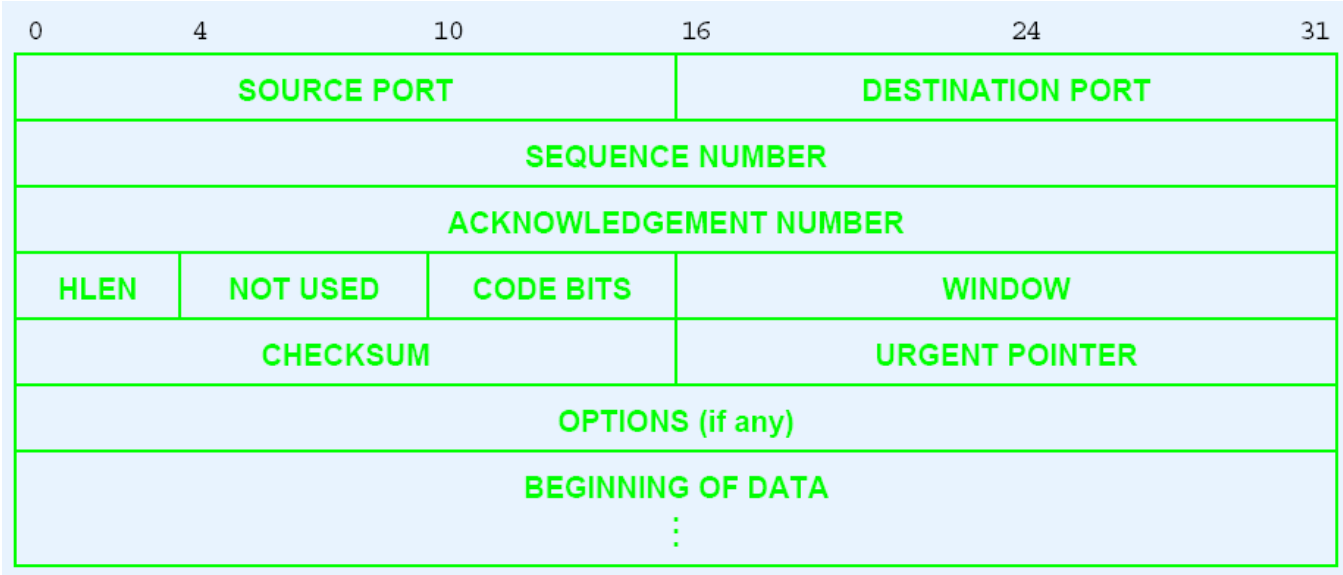
TCP Segment Format

- All TCP segments have same format
  - Data
  - Acknowledgment
  - SYN (startup)
  - FIN (shutdown)
- Segment divided into two parts
  - Header
  - Payload area (zero or more bytes of data)

TCP Segment Format (continued)

- Header contains
  - Protocol port numbers to identify
    - Sending application
    - Receiving application
  - Code bits to specify items such as
    - SYN
    - FIN
    - ACK
  - Fields for window advertisement, acknowledgment, etc.

Illustration Of TCP Segment



- Sequence number specifies where in stream outgoing data belongs
- Acknowledgment number refers to incoming data
- Few segments contain options

IP Telephony

- Send audio telephone communication over an IP network
- Network types
  - Local IP network (e.g., within an organization)
  - Global Internet
- Scope of communication
  - Work entirely within an IP network
  - Interoperate with Public Switched Telephone Network (PSTN)
- Also known as Voice over IP (VoIP)

IP Telephony Standards

- Two competing groups
  - Internet Engineering Task Force (IETF) sets TCP/IP standards
  - International Telecommunications Union (ITU) controls telephone standards
- Several proposed standards
  - Session Initiation Protocol (SIP) from IETF
  - H.323 from ITU
  - Megaco from IETF and ITU

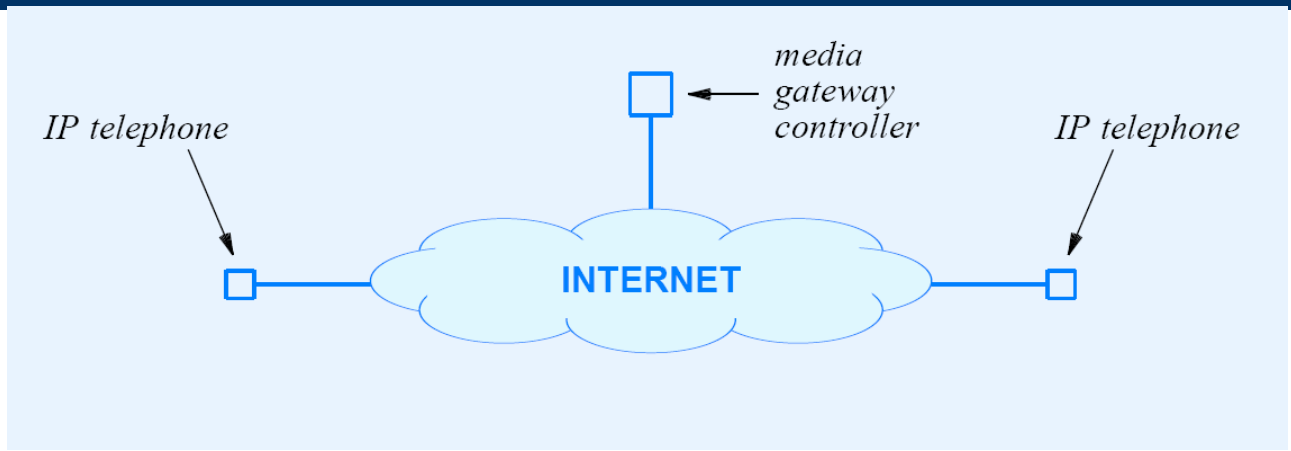
Encoding And Transmission

- General agreement
- Digital encoding
  - Use Pulse Code Modulation (PCM) standard
  - Same as existing telephone system
- Transmission
  - Use Real-time Transport Protocol (RTP)
  - Encapsulate RTP message in UDP datagram
  - Encapsulate UDP datagram in IP datagram

Signaling

- Telco term
- Refers to call setup, monitoring, and teardown
- Current telephone system standard is Signaling System 7 (SS7)
- May involve
  - Location of called party
  - Deciding whether to accept incoming call
  - Authentication and services such as caller ID
  - Accounting
- Requires active mechanism

Illustration Of Basic IP Telephone System



- Media gateway controller handles signaling
- Once call is established, IP telephones can communicate directly

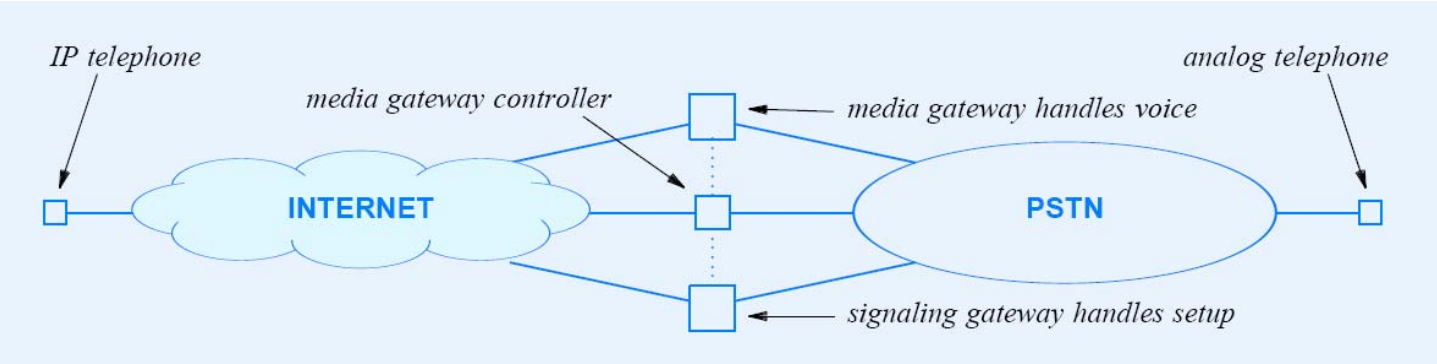
Interconnection With PSTN

- Difficult
- Must handle many possibilities
  - Calls that originate on IP telephone system and terminate on PSTN
  - Calls that originate on PSTN and terminate on IP telephone system
  - Mobile telephones
  - Services such as call forwarding
  - Islands (e.g., PSTN between two IP telephone systems)

Interconnection With PSTN (continued)

- Three conceptual functions
  - Media gateway passes encoded voice
  - Signaling gateway handles call setup
  - Media gateway controller coordinates

Illustration Of PSTN Interconnection



- Questions
  - What individual functions should be provided?
  - How should functions be divided among gateways?
- Each proposed standard defines a set of conceptual functions and implementation mechanisms

SIP Characteristics

- Distributed signaling system
- Uses DNS to store location information
- Defines multiple servers
  - User agent
  - Location server
  - Proxy server
  - Redirect server
  - Registrar server

H.323 Characteristics

- Uses more centralized model (similar to current telephone system)
- Defines
  - Terminal
  - Gatekeeper
  - Gateway
  - Multipoint Control Unit (to handle conferencing)

Examples Of Layering: H.323

<table>
<tr><th>Layer</th><th>Signaling</th><th>Registration</th><th>Audio</th><th>Video</th><th>Data</th><th>Security</th></tr>
<tr><td rowspan="2">5</td><td rowspan="2">H.225.0-Q.931
H.250-Annex G
H.245
H.250</td><td rowspan="2">H.225.9-RAS</td><td>G.711
H.263
G.722
G.723
G.728</td><td>H.261
H.323</td><td rowspan="2">T.120</td><td rowspan="2">H.235</td></tr>
<tr><td colspan="2">RTP, RTCP</td></tr>
<tr><td>4</td><td>TCP, UDP</td><td colspan="3">UDP</td><td>TCP</td><td>TCP, UDP</td></tr>
<tr><td>3</td><td colspan="5">IP, RSVP, and IGMP</td></tr>
</table>

- Many protocols
- Allows data and video to be transferred along with audio

Example Methods: SIP

Method	Purpose
INVITE	Session creation: an endpoint is invited to participate in the session.
ACK	Acknowledgment response to INVITE.
BYE	Session termination: call is ended.
CANCEL	Pending request cancellation (no effect if request has been completed).
REGISTER	Registration of user's location (i.e., a URL at which the user can be reached).
OPTIONS	Query to determine capabilities of called party.

Example SIP Session