Data Networks
Signaling

Prof. Anja Feldmann, Ph.D.

Design Principles

Goals:

- Identify, study common architectural components, protocol mechanisms, approaches do we find in network architectures?
- Synthesis: Big picture

Design Principles:

- Separation of data, control
- Hard state versus soft state
- Randomization
- Indirection
- Network virtualization / Overlays
- Resource sharing
- Design for scale

Signaling

Signaling: Exchange of messages among network entities to enable (provide service) to connection/call

Before, during, after connection/call

- Call setup and teardown
- Call maintenance
- Measurement, billing

Between

- End-user <-> network
- End-user <-> end-user
- Network element <-> network element

Signaling is about state!

“… exchange information between network components required to provide and maintain service”

Signaling is about state!

"… exchange information between network components required to provide and maintain service"

- Two principles:

Signaling is about state!

"… exchange information between network components required to provide and maintain service"

- Two principles:
  - Hard state: No periodic maintenance/explicit teardown

Signaling is about state!

"… exchange information between network components required to provide and maintain service"

- Two principles:
  - Hard state: No periodic maintenance/explicit teardown
  - Soft state: Expires timers

Signaling is about state!

"… exchange information between network components required to provide and maintain service"

- Two principles:
  - Hard state: No periodic maintenance/explicit teardown
  - Soft state: Expires timers

Huge debate

Signaling is about state!

"… exchange information between network components required to provide and maintain service"

- Two principles:
  - Hard state: No periodic maintenance/explicit teardown
  - Soft state: Expires timers

Huge debate

More after signaling

Signaling examples

- Internet
  - TCP handshake (connection setup/teardown)
  - RSVP (Resource Reservation Protocol, e.g., for QoS)
  - SIP (Session Initiation Protocol for Internet telephony)
- Telephone network
  - SS7 (Signaling System no. 7)

Signaling in the Internet

Signaling in the Internet

connectionless
(stateless) forwarding
by IP routers

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

- Yet: Transport protocols need state and variable initialization

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

- Yet: Transport protocols need state and variable initialization
- E.g.: Transport Control Protocol [RFCs 793, 1122, 1323, 2018, 2581]

TCP Connection Management

- Recall: TCP sender, rcvr setup "connection" before exchanging data
- Initialize TCP variables:
  - Seq. #s
  - Buffers, flow control info (e.g., RcvWindow)
  - MSS and other options
- Client: Connection initiator; Server: Contacted by client
    - Three-way handshake
      - Simultaneous open
    - TCP Half-Close (four-way handshake)
    - Connection aborts via RSTs

TCP Connection Management (2)

Three way handshake:

- Step 1: Client sends TCP SYN control segment to server
  - Specifies initial seq #
  - Specifies initial window #
- Step 2: Server receives SYN, replies with SYNACK
  - ACKs received SYN
  - Allocates buffers
  - Specifies server → receiver initial seq. #
  - Specifies initial window #
- Step 3: Client receives SYNACK

TCP Connection Management (3)

Closing a connection:

Client closes socket:

```
clientSocket.close();
```

Step 1: Client sends TCP FIN control segment to server

Step 2: Server receives FIN, replies with ACK. Closes connection, sends FIN.

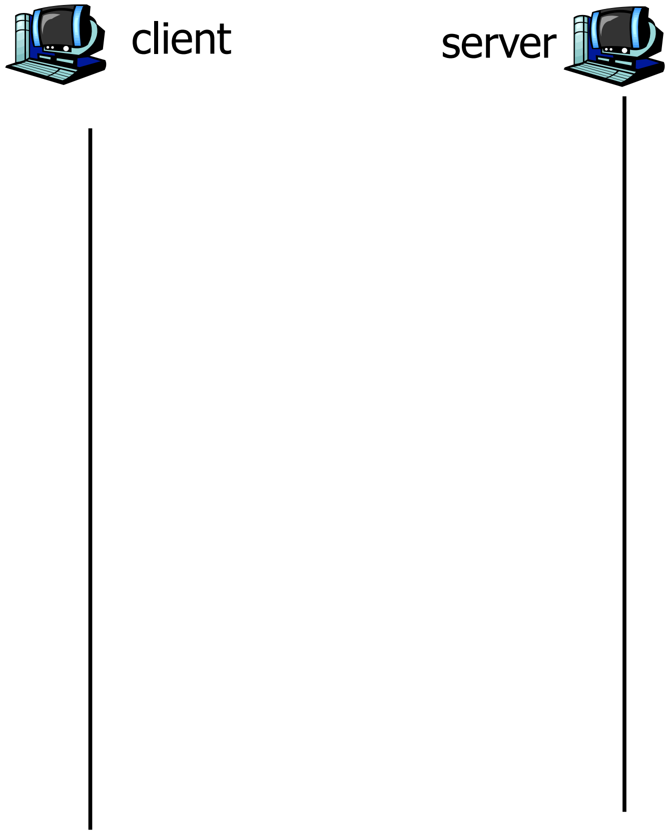
TCP Connection Management (3)

Closing a connection:

Client closes socket:
`clientSocket.close();`

Step 1: Client sends TCP FIN control segment to server

Step 2: Server receives FIN, replies with ACK. Closes connection, sends FIN.



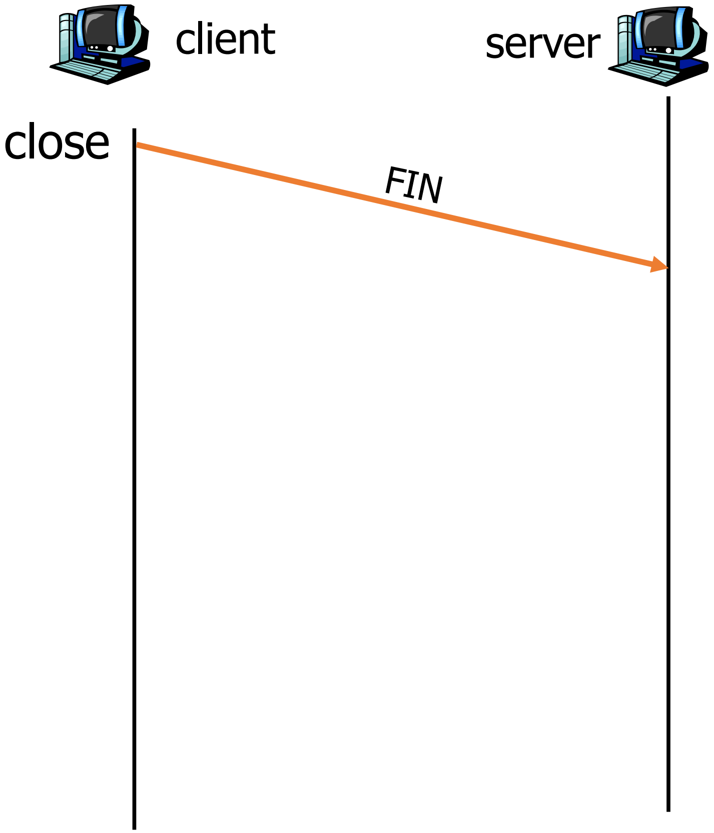
TCP Connection Management (3)

Closing a connection:

Client closes socket:
`clientSocket.close();`

Step 1: Client sends TCP FIN control segment to server

Step 2: Server receives FIN, replies with ACK. Closes connection, sends FIN.



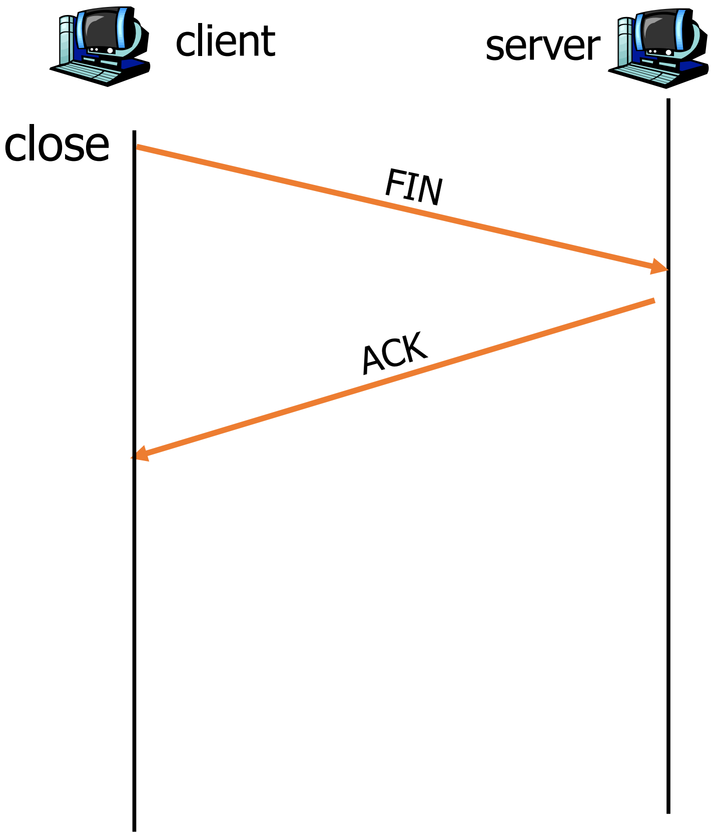
TCP Connection Management (3)

Closing a connection:

Client closes socket:
`clientSocket.close();`

Step 1: Client sends TCP FIN control segment to server

Step 2: Server receives FIN, replies with ACK. Closes connection, sends FIN.



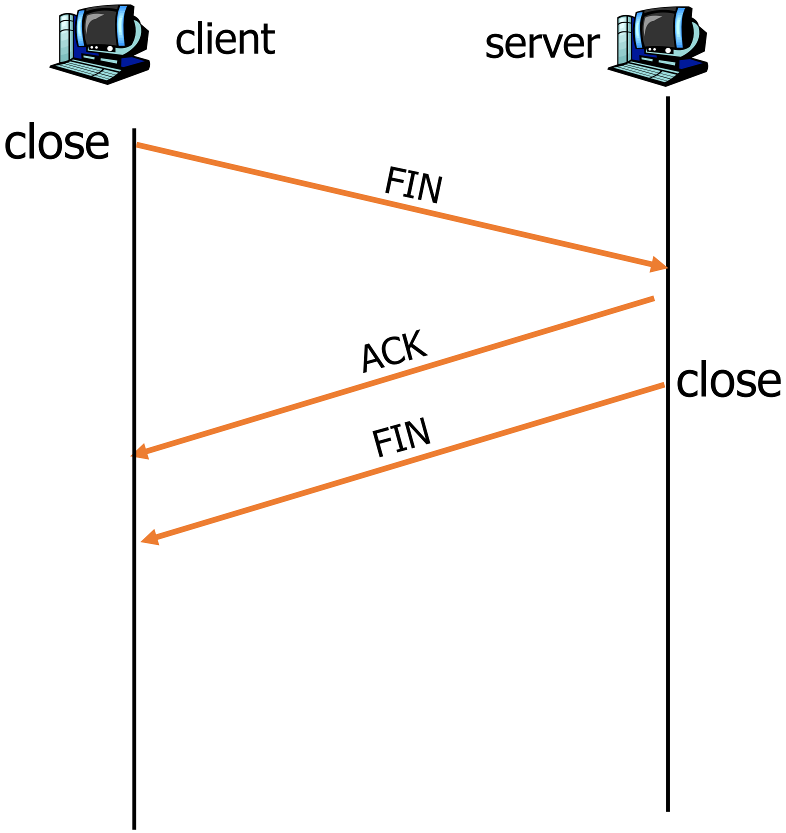
TCP Connection Management (3)

Closing a connection:

Client closes socket:
```
clientSocket.close();
```

Step 1: Client sends TCP FIN control segment to server

Step 2: Server receives FIN, replies with ACK. Closes connection, sends FIN.



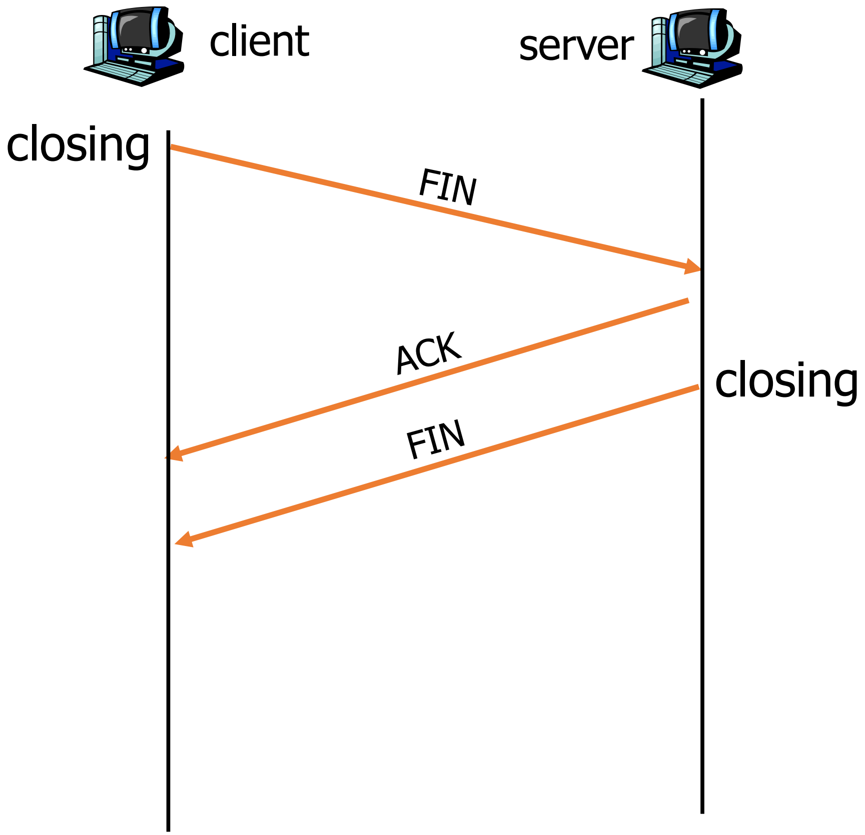
TCP Connection Management (4)

Step 3: Client receives FIN, replies with ACK.

- Enters “time wait” – will respond with ACK to received FINs

Step 4: Server, receives ACK. Connection closed.

Note: With small modification, can handle simultaneous FINs.



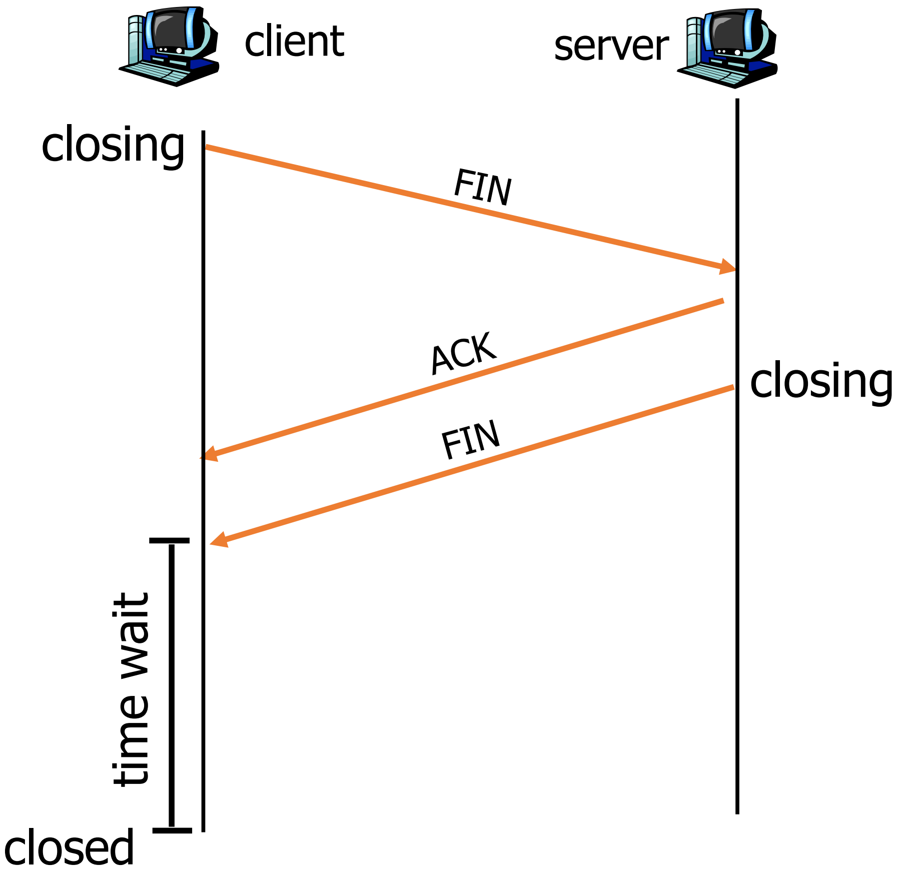
TCP Connection Management (4)

Step 3: Client receives FIN, replies with ACK.

- ❑Enters "time wait" – will respond with ACK to received FINs

Step 4: Server, receives ACK. Connection closed.

Note: With small modification, can handle simultaneous FINs.



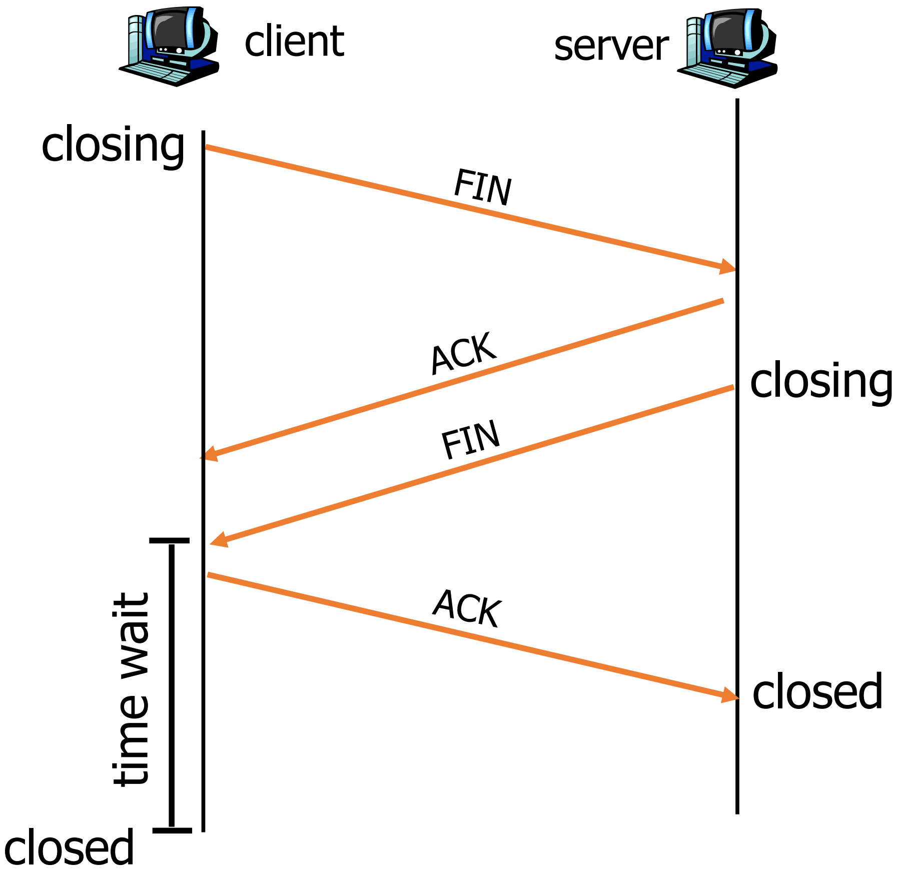
TCP Connection Management (4)

Step 3: Client receives FIN, replies with ACK.

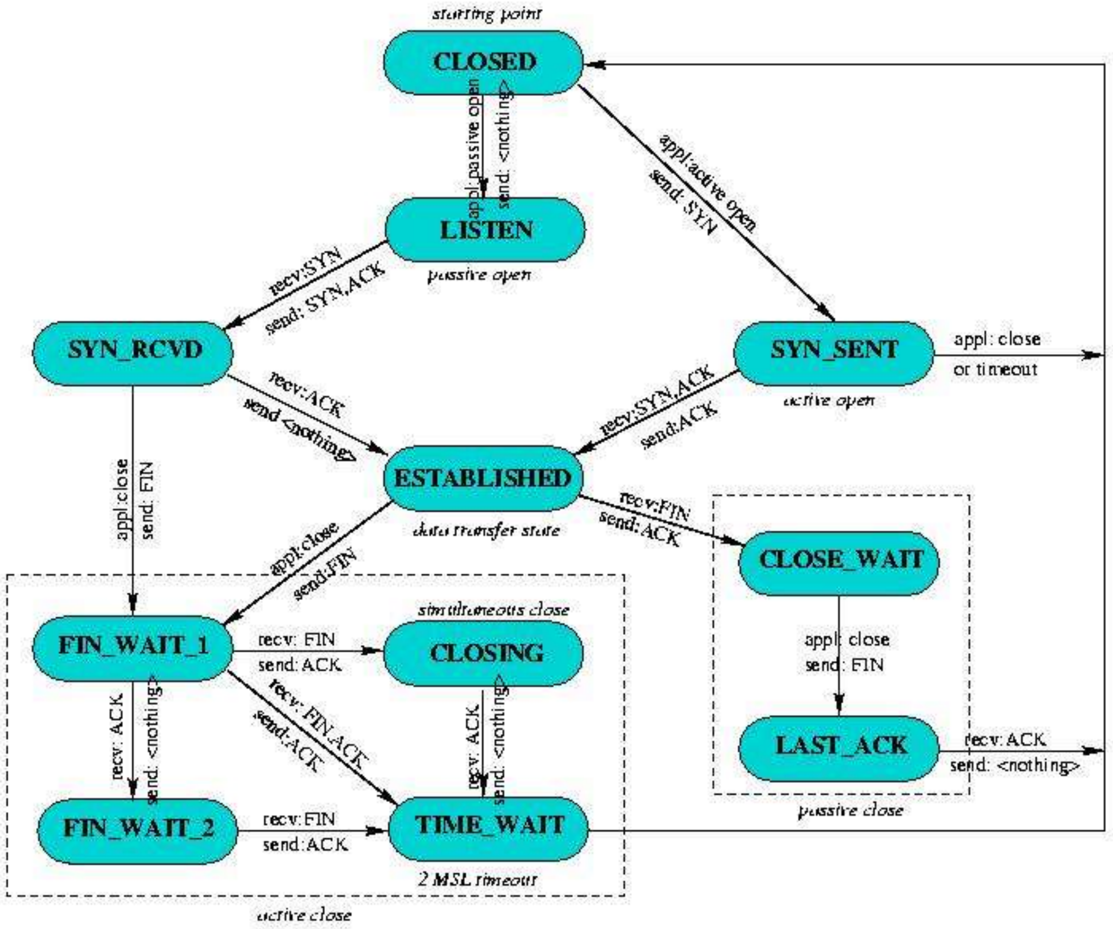
- ❑Enters "time wait" – will respond with ACK to received FINs

Step 4: Server, receives ACK. Connection closed.

Note: With small modification, can handle simultaneous FINs.

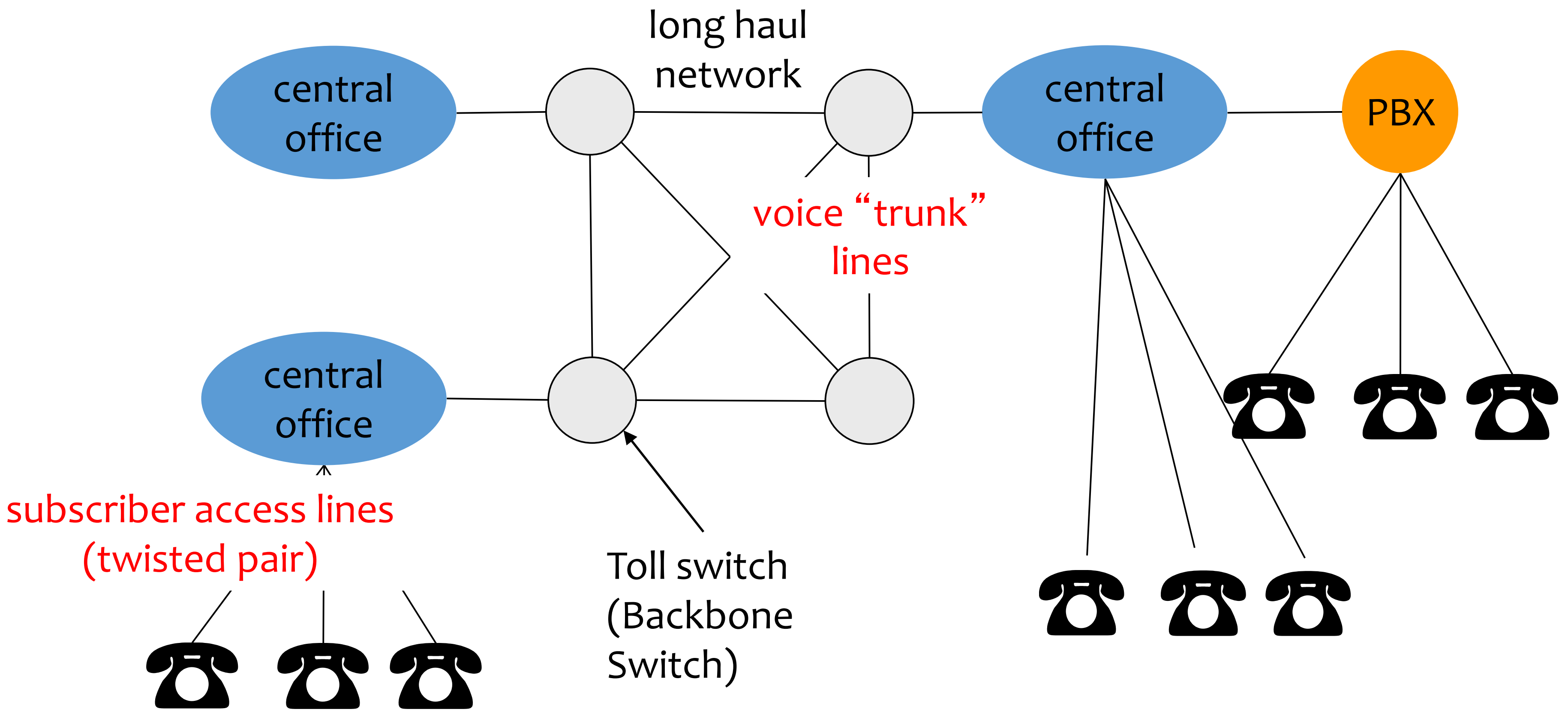


TCP state machine



Telephone network

- Created 1876
- A global Infrastructure



Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

- Yet, new requirement: App. layer protocol, enable users to be reachable independent of the device and his location

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

- Yet, new requirement: App. layer protocol, enable users to be reachable independent of the device and his location
- SIP: Session Initiation Protocol [RFC 3261]
  - IETF protocol
  - All telephone calls and video conference calls take place over the Internet
  - People are identified by names/e-mail addresses, rather than phone #
  - Callee reachable, no matter where the callee roams, no matter what IP device the callee is currently using

SIP Services

- Setting up a call
  - Provides mechanisms for caller to let callee know she wants to establish a call
  - Provides mechanisms so that caller and callee can agree on media type and encoding
  - Provides mechanisms to end call

- Determine current IP address of callee
  - Maps mnemonic identifier to current IP address
- Call management
  - Add new media streams during call
  - Change encoding during call
  - Invite others
  - Transfer and hold calls

SIP and IMS

- IMS – Internet Multimedia Subsystem

SIP and IMS

- IMS – Internet Multimedia Subsystem
- IMS uses SIP in order to provide functionality equivalent to SS7 and more
- IMS is heavily used to provide VoIP services
  - E.g., VoIP for LTE

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

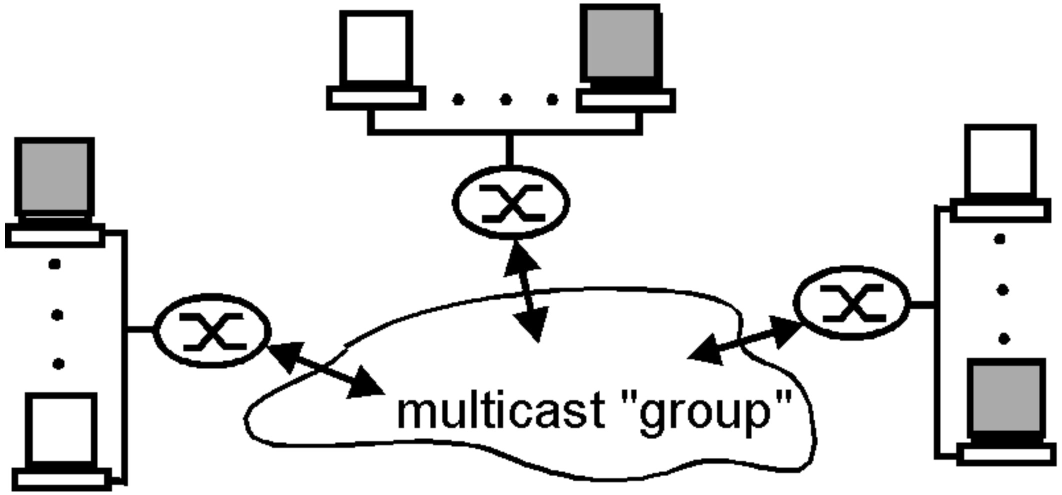
- Yet, new requirement: Reserve resources along end-to-end path (end system, routers) for QoS for multimedia applications

Signaling in the Internet

connectionless (stateless) forwarding by IP routers + best effort service = no network signaling protocols in initial IP design

- Yet, new requirement: Reserve resources along end-to-end path (end system, routers) for QoS for multimedia applications
- RSVP: Resource Reservation Protocol [RFC 2205]
  - " … allows users to communicate requirements to network in robust and efficient way." i.e., signaling!
  - Earlier Internet Signaling protocol: ST-II [RFC 1819]
  - Designed with multicast in mind

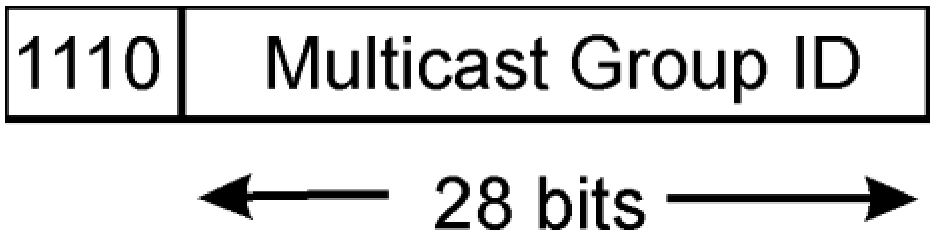
Internet multicast service model



- Multicast group concept:
  - Hosts send IP datagram pkts to multicast group
  - Hosts that have "joined" that multicast group will receive pkts sent to that group
  - Routers forward multicast datagrams to hosts

Multicast groups

- Class D Internet addresses reserved for multicast:



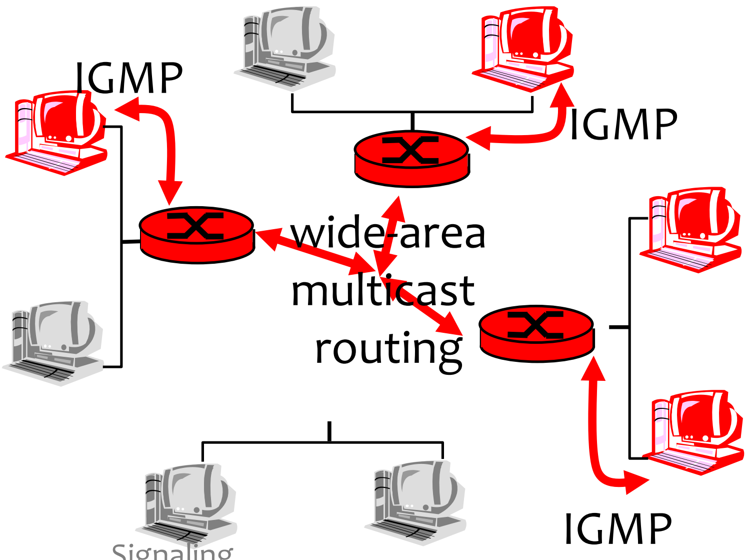
1110 | Multicast Group ID

28 bits

- Host group semantics:
  - Anyone can “join” (receive) multicast group
  - Anyone can send to multicast group
  - No network-layer identification to hosts of members
- Needs: Infrastructure to deliver mcast-addressed datagrams to all hosts that joined that multicast group

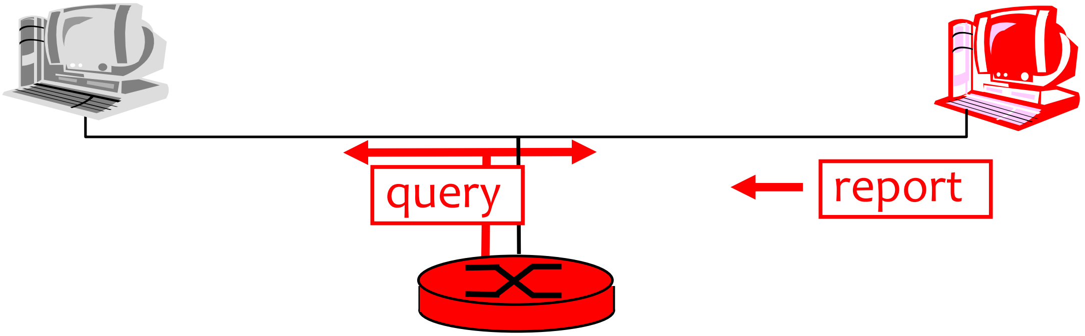
Joining a mcast group: Two-step process

- Local: Host informs local mcast router of desire to join group: IGMP (Internet Group Management Protocol)
- Wide area: Local router interacts with other routers to receive mcast datagram flow
  - Many protocol options (e.g., DVMRP, MOSPF, PIM)



IGMP: Internet Group Management Protocol

- Host: Sends IGMP report when application joins mcast group
  - IP_ADD_MEMBERSHIP socket option
  - Host need not explicitly "unjoin" group when leaving
- Router: Sends IGMP query at regular intervals
  - Host belonging to a mcast group must reply to query



IGMP

IGMP version 1

- Router: Host Membership Query msg broadcast on LAN to all hosts (for all groups)
- Host: Host Membership Report msg to indicate group membership
  - Randomized delay before responding
  - Implicit leave via no reply to Query
- RFC 1112

IGMP

IGMP version 1

- Router: Host Membership Query msg broadcast on LAN to all hosts (for all groups)
- Host: Host Membership Report msg to indicate group membership
  - Randomized delay before responding
  - Implicit leave via no reply to Query
- RFC 1112

IGMP v2: Additions include

- Group-specific query
- Leave Group msg
  - Last host replying to Query can send explicit Leave Group msg
  - Router performs group-specific query to see if any hosts left in group
  - RFC 2236

IGMP v3: Internet draft

IPv6: ICMP replaces IGMP