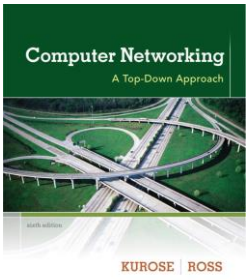
Chapter 2
Application Layer



Computer Networking: A Top Down Approach
6th edition
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Thanks and enjoy! JFK/KWR

Chapter 2: outline

2.1 principles of network applications
- app architectures
- app requirements

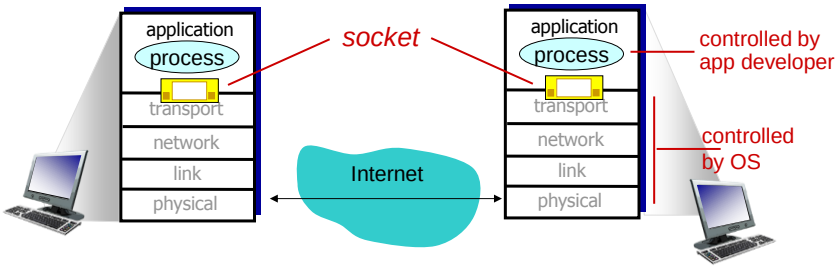
2.2 Web and HTTP
2.3 FTP
2.4 electronic mail
- SMTP, POP3, IMAP

2.5 DNS
2.6 P2P applications
2.7 socket programming with UDP and TCP

Socket programming

goal: learn how to build client/server applications that communicate using sockets

socket: door between application process and end-end-transport protocol



Socket programming

Two socket types for two transport services:

- *UDP:* unreliable datagram
- *TCP:* reliable, byte stream-oriented

Application Example:

1. Client reads a line of characters (data) from its keyboard and sends the data to the server.
2. The server receives the data and converts characters to uppercase.
3. The server sends the modified data to the client.
4. The client receives the modified data and displays the line on its screen.

Socket programming *with UDP*

UDP: no "connection" between client & server

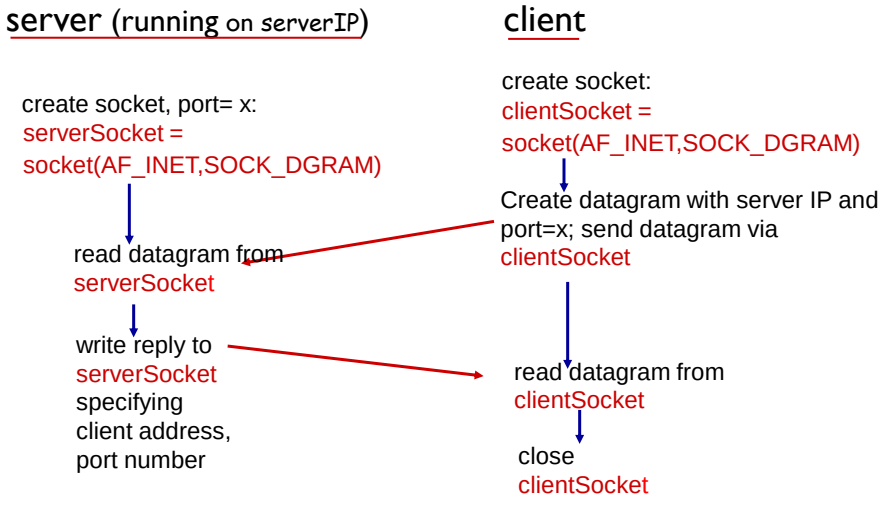
- no handshaking before sending data
- sender explicitly attaches IP destination address and port # to each packet
- rcvr extracts sender IP address and port# from received packet

UDP: transmitted data may be lost or received out-of-order

Application viewpoint:

- UDP provides *unreliable* transfer of groups of bytes ("datagrams") between client and server

Client/server socket interaction: UDP



Example app: UDP client

Python UDPClient

include Python's socket library → `from socket import *`

`serverName = 'hostname'`

`serverPort = 12000`

create UDP socket for server → `clientSocket = socket(socket.AF_INET,`
`socket.SOCK_DGRAM)`

get user keyboard input → `message = raw_input('Input lowercase sentence:')`

Attach server name, port to message; send into socket → `clientSocket.sendto(message,(serverName, serverPort))`

read reply characters from socket into string → `modifiedMessage, serverAddress =`
`clientSocket.recvfrom(2048)`

print out received string and close socket → `print modifiedMessage`

`clientSocket.close()`

Example app: UDP server

Python UDPServer

```
from socket import *
serverPort = 12000
```

create UDP socket → `serverSocket = socket(AF_INET, SOCK_DGRAM)`

bind socket to local port number 12000 → `serverSocket.bind(('', serverPort))`

`print "The server is ready to receive"`

loop forever → `while 1:`

Read from UDP socket into message, getting client's address (client IP and port) →
```
    message, clientAddress = serverSocket.recvfrom(2048)
    modifiedMessage = message.upper()
```

send upper case string back to this client → `serverSocket.sendto(modifiedMessage, clientAddress)`

Socket programming *with TCP*

client must contact server

- server process must first be running
- server must have created socket (door) that welcomes client's contact

client contacts server by:

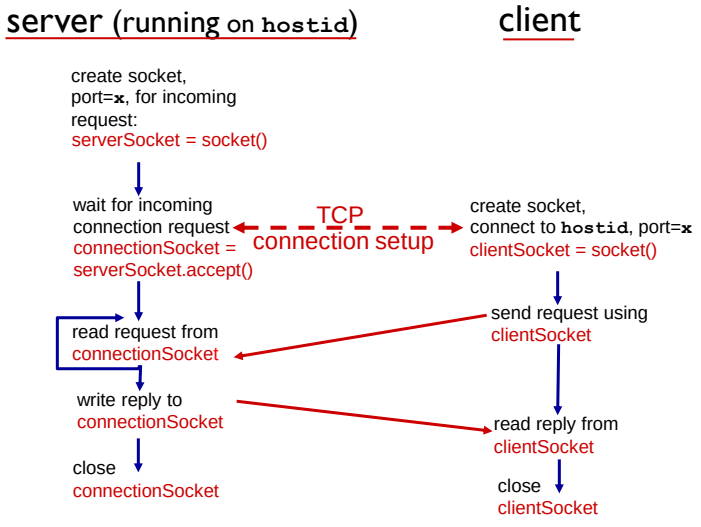
- Creating TCP socket, specifying IP address, port number of server process
- *when client creates socket:* client TCP establishes connection to server TCP

- when contacted by client, *server TCP creates new socket* for server process to communicate with that particular client
  - allows server to talk with multiple clients
  - source port numbers used to distinguish clients (more in Chap 3)

application viewpoint:

TCP provides reliable, in-order byte-stream transfer ("pipe") between client and server

Client/server socket interaction: TCP



Example app: TCP client

Python TCPClient

```
from socket import *
serverName = 'servername'
serverPort = 12000
clientSocket = socket(AF_INET, SOCK_STREAM)
clientSocket.connect((serverName,serverPort))
sentence = raw_input('Input lowercase sentence:')
clientSocket.send(sentence)
modifiedSentence = clientSocket.recv(1024)
print 'From Server:', modifiedSentence
clientSocket.close()
```

create TCP socket for server, remote port 12000

No need to attach server name, port

Example app: TCP server

Python TCPServer

```
from socket import *
serverPort = 12000
serverSocket = socket(AF_INET,SOCK_STREAM)
serverSocket.bind(('',serverPort))
serverSocket.listen(1)
print 'The server is ready to receive'
while 1:
    connectionSocket, addr = serverSocket.accept()
    sentence = connectionSocket.recv(1024)
    capitalizedSentence = sentence.upper()
    connectionSocket.send(capitalizedSentence)
    connectionSocket.close()
```

create TCP welcoming socket

server begins listening for incoming TCP requests

loop forever

server waits on accept() for incoming requests, new socket created on return

read bytes from socket (but not address as in UDP)

close connection to this client (but *not* welcoming socket)

Chapter 2: summary

our study of network apps now complete!

- application architectures
  - client-server
  - P2P
- application service requirements:
  - reliability, bandwidth, delay
- Internet transport service model
  - connection-oriented, reliable: TCP
  - unreliable, datagrams: UDP
- specific protocols:
  - HTTP
  - FTP
  - SMTP, POP, IMAP
  - DNS
  - P2P: BitTorrent, DHT
- socket programming: TCP, UDP sockets

Chapter 2: summary

most importantly: learned about protocols!

- typical request/reply message exchange:
  - client requests info or service
  - server responds with data, status code
- message formats:
  - headers: fields giving info about data
  - data: info being communicated

important themes:

- control vs. data msgs
  - in-band, out-of-band
- centralized vs. decentralized
- stateless vs. stateful
- reliable vs. unreliable msg transfer
- "complexity at network edge"