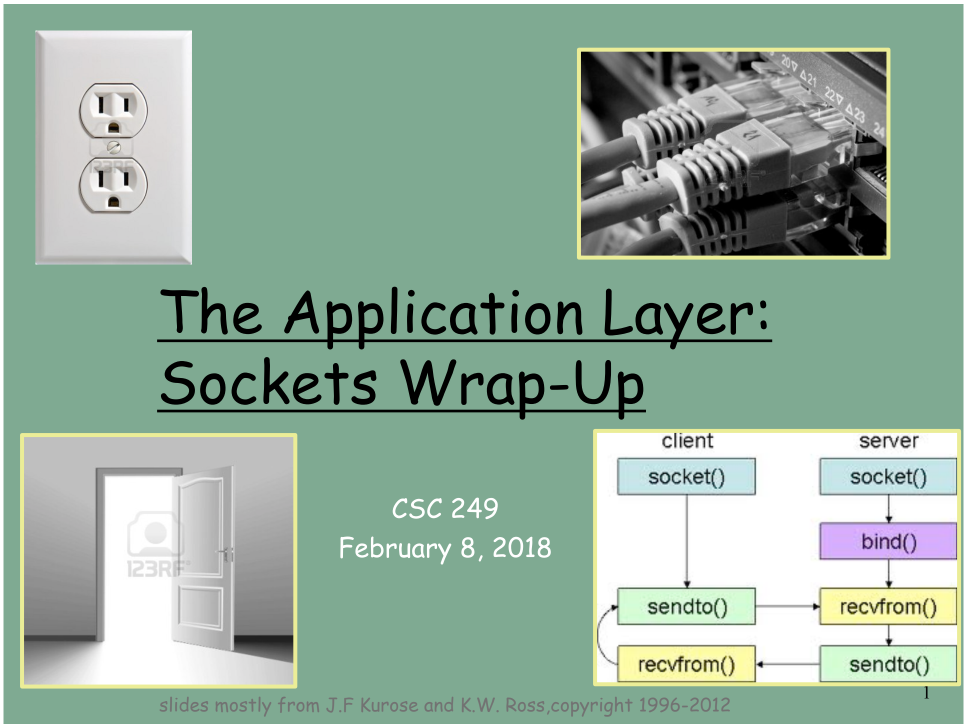


The Application Layer: Sockets Wrap-Up

CSC 249
February 8, 2018

client

server

socket()

socket()

bind()

sendto()

recvfrom()

recvfrom()

sendto()

slides mostly from J.F Kurose and K.W. Ross,copyright 1996-2012

Socket Overview

- ❑ Examples with socket-API programming
- ❑ Differences between TCP and UDP sockets
- ❑ Outline SMTP server program

Socket Programming

- ❑ Sockets are used to send data from one host to another
  - ❖ Sockets provide an interface between the application and the Internet
- ❑ Socket programming is analogous to simple file I/O
- ❑ In UNIX, all devices are file abstractions
  - ❖ Open, close, read, write
  - ❖ Sockets are simply one more file abstraction

3

Sockets

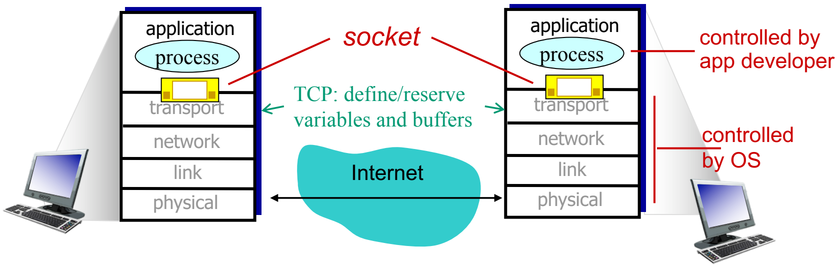
- ❑ The API is used for communicating between a Client and a Server
- ❑ Client
  - ❖ Active participant in communication
  - ❖ Initiates conversations and sends data
- ❑ Server
  - ❖ Passively listens and waits for data
- ❑ Socket
  - ❖ Protocol to use?
  - ❖ Identifier of the other machine (IP + port)?
  - ❖ Client or server?

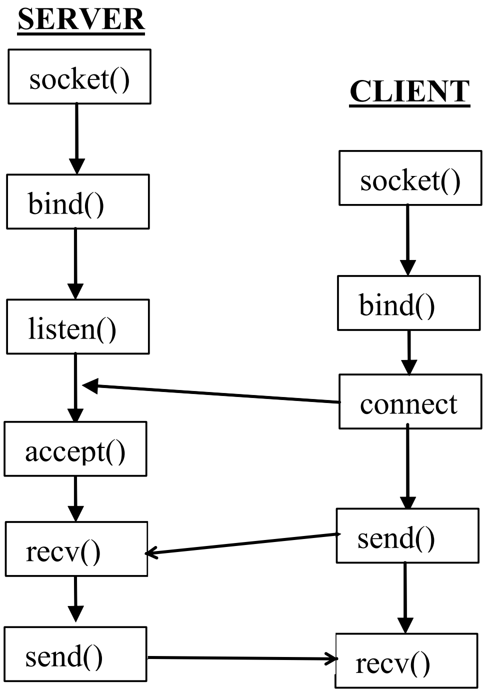
4

Socket-programming using TCP

Socket: an interface between application process and the transport protocol (UCP or TCP)

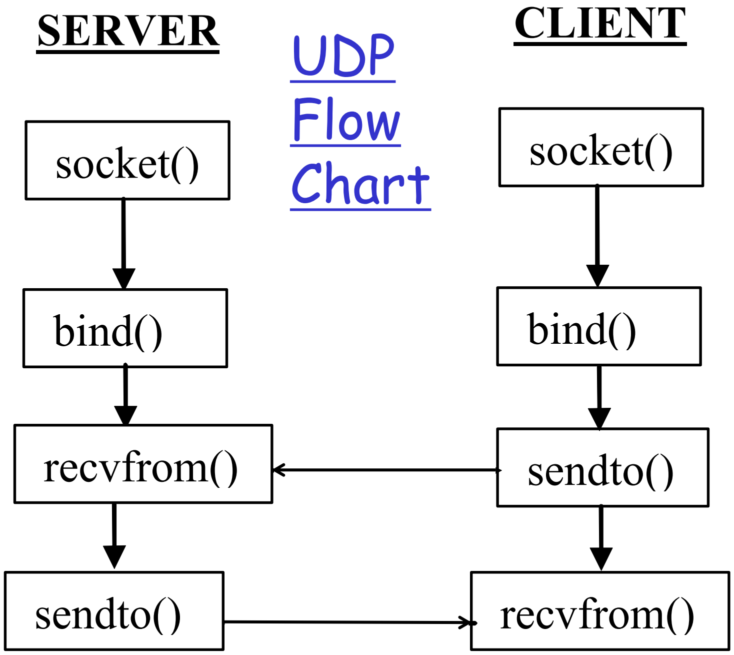
TCP service: reliable transfer of **bytes** from one process to another





TCP Flow Chart

UDP Flow Chart



SERVER

socket()

bind()

recvfrom()

sendto()

CLIENT

socket()

bind()

sendto()

recvfrom()

Creating a Socket()

- descriptor = socket(protoFamily, type)
  - Creates a socket and returns an integer descriptor
  - ProtoFamily – refers to Family of protocols that this protocol belongs to, for TCP/IP use AF_INET
  - Type – SOCK_STREAM, SOCK_DGRAM
    - *SOCK_STREAM – Connection Oriented (TCP)*
    - *SOCK_DGRAM – Connectionless (UDP)*

A first, simple socket example

Client-server simple application:

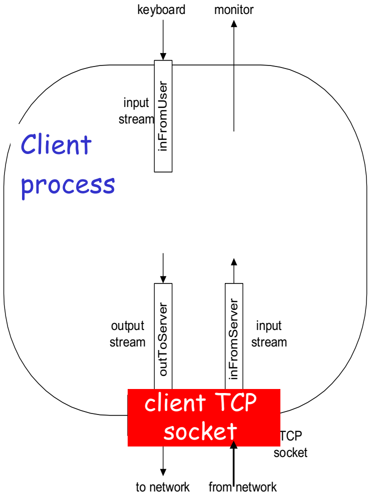
1) The client reads a line from standard input (**inFromUser** stream), sends it to server via socket (**outToServer** stream)

2) The server reads the line from its socket

3) The server converts the line to uppercase, and sends it back to the client

4) The client reads the modified line from its socket (**inFromServer** stream) and prints it to standard output

* Identify application vs. socket programming tasks *



Client/server socket interaction: TCP

1) Client contacts server

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

2) Client contacts server by:

- Creating TCP socket,
  - Reserve required memory
  - Specify server IP address and port number
- Client TCP layer establishes a connection to server TCP layer (via TCP handshaking, chapter 3)

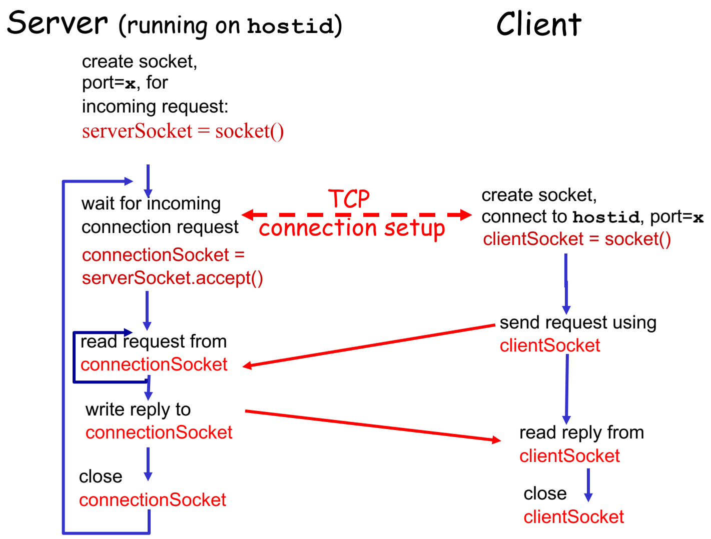
3) Server creates *new* socket

- when contacted by client, 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 Chapter 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

create TCP socket for server, remote port 12000

No need to attach server name, port (compare to UDP client… to come)

```
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()
```

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, dedicated socket created on return

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

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

Socket programming *with UDP*

UDP: no "connection" between client and server

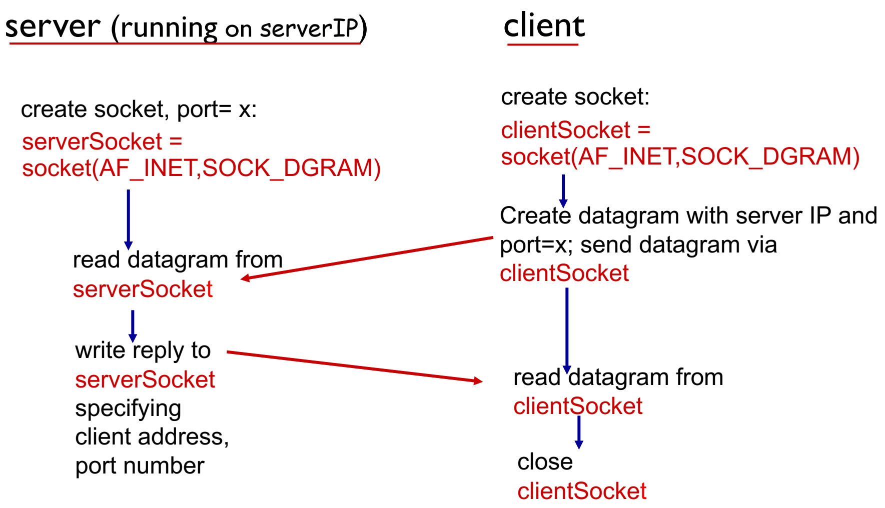
- no handshaking
- sender explicitly attaches IP address and port of destination to each packet
- server must extract IP address, port of sender from received packet

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

application viewpoint

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

Client/server socket interaction: UDP



server (running on serverIP)

create socket, port= x:
serverSocket =
socket(AF_INET,SOCK_DGRAM)

read datagram from
serverSocket

write reply to
serverSocket
specifying
client address,
port number

client

create socket:
clientSocket =
socket(AF_INET,SOCK_DGRAM)

Create datagram with server IP and
port=x; send datagram via
clientSocket

read datagram from
clientSocket

close
clientSocket

Example: UDP client

Python UDPClient

include Python's socket library

create UDP socket for server

get user keyboard input

Attach server name, port to message; send into socket

read reply characters from socket into string

print out received string and close socket

```
from socket import *
serverName = 'hostname'
serverPort = 12000
clientSocket = socket(socket.AF_INET,
                      socket.SOCK_DGRAM)
message = raw_input('Input lowercase sentence:')
clientSocket.sendto(message,(serverName, serverPort))
modifiedMessage, serverAddress =
                      clientSocket.recvfrom(2048)
print modifiedMessage
clientSocket.close()
```

Example: UDP server

Python UDPServer

create UDP socket

bind socket to local port number 12000

loop forever

Read from UDP socket into message, getting client's address (client IP and port)

send upper case string back to this client

```
from socket import *
serverPort = 12000
serverSocket = socket(AF_INET, SOCK_DGRAM)
serverSocket.bind((", serverPort))
print "The server is ready to receive"
while 1:
    message, clientAddress = serverSocket.recvfrom(2048)
    modifiedMessage = message.upper()
    serverSocket.sendto(modifiedMessage, clientAddress)
```

Connection-Oriented → TCP

- The message is only transferred after a connection has been made
  - Connection creates a virtual pipe between the client and the server such that each knows the other's IP address and protocol port number
- Both parties know that a message will be communicated
- No need to tell destination (IP address and port number) in subsequent messages
  - Because there is a connection!

Connectionless → UDP

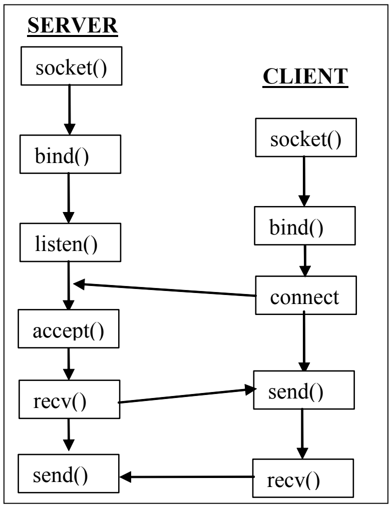
- ❑ Send Individual Messages
  - ❖ as opposed to a continuous byte stream
- ❑ Socket has to be told where to send the message every time
  - ❖ Destination IP address and Port number
- ❑ Overhead data flow can get excessive if a large number of messages need to be sent between the same hosts

Class Example: SMTP Client (5 minutes now, to come back to toward end of class)

- ❑ Develop a simple mail client that sends email to any recipient → a first attempt
  1) Recall the telnet practice with SMTP
  2) Connect to a mail server, dialogue with the mail server using the SMTP protocol
  3) Send an email message to the mail server.
     - Python provides smtplib, with built in methods, but this hides the details of SMTP and socket programming → so do not use this
- ❑ To limit spam, mail servers do not accept TCP connections from arbitrary sources.

Socket Flowcharts

- TCP vs. UDP



SERVER

socket()

bind()

listen()

accept()

recv()

send()

CLIENT

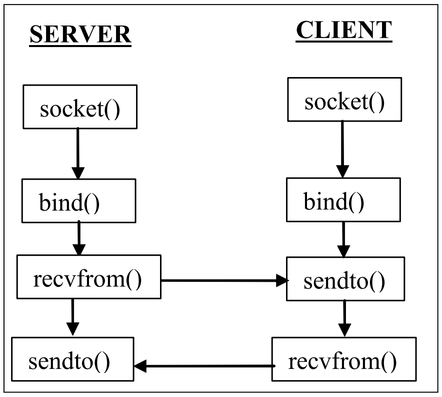
socket()

bind()

connect

send()

recv()



SERVER

socket()

bind()

recvfrom()

sendto()

CLIENT

socket()

bind()

sendto()

recvfrom()

Review Server steps

- All servers begin by making a function call to “socket()” to create a socket and “bind()” to specify a protocol port number
- UDP: the server is now ready to accept messages
- TCP: additional steps to become ready are
  - Server calls listen() to place the socket in passive mode
  - Server calls accept() to accept a connection request if it comes in

```
# Example to connect to google
from socket import *

print ("Creating Socket...”)
s = socket(AF_INET, SOCK_STREAM)
print ("done.”)

print ("Looking up port number...”)
port = getservbyname('http', 'tcp')
print ("done.”)

print ("Connect to remote host on port %d" %port),
s.connect (("www.google.com", port))
print ("done.”)

print "Connected from", s.getsockname()
print "Connected to", s.getpeername()
```

```
# Client example 2: client2.py
# Run the client after the server is running

from socket import * # Import socket module

s = socket()          # Create a socket object
host = gethostname() # Get local machine name
port = 12345          # Assign a port

print ("Client host is ", host)

s.connect((host, port))
print (s.recv(1024))

s.close           # Close the socket when done
```

```
# Example 2: Server2.py
from socket import *

s = socket()          # Create a socket object
host = gethostname() # Get local machine name
port = 12345          # Assign a port number

s.bind((host, port)) # Bind to the port
print ("Server host is ", host)
s.listen(1)           # Wait for client conx

while True:
     c, addr = s.accept() # conx to client
     print ('Got connection from', addr)
     c.send('Thank you for connecting')
     c.close()        # Close the connection
```

```
# Example 3: client3.py
from socket import *

HOST = 'localhost'
PORT = 29876
ADDR = (HOST,PORT)
BUFSIZE = 4096

cli = socket(AF_INET,SOCK_STREAM)
cli.connect((ADDR))

data = cli.recv(BUFSIZE)
print (data)

cli.close()
```

```
# Example 3: server3.py
from socket import *

HOST = ''           # Use the local host
PORT = 29876        # Assign a port number
ADDR = (HOST,PORT)  # define a tuple for the address
BUFSIZE = 4096      # Define buffer for data

# Create a new socket object (serv)
serv = socket( AF_INET,SOCK_STREAM)

# Bind our socket to the address
serv.bind((ADDR))     # Define an address 'tuple'
serv.listen(5)        # Allow 5 connections
print ('listening...’)

conn,addr = serv.accept()
print ('...connected!’)
conn.send('TEST’)
conn.close()
```

Class Example: SMTP Client

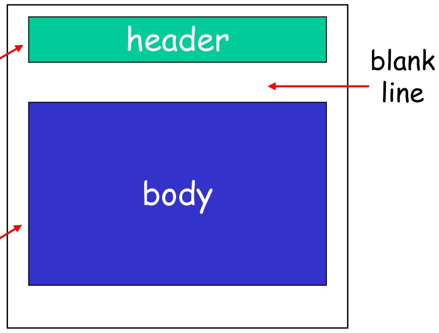
- ❑ Develop a simple mail client that sends email to any recipient → a first attempt
  1) Recall the telnet practice with SMTP
  2) Connect to a mail server, dialogue with the mail server using the SMTP protocol,
  3) Send an email message to the mail server. Python provides smtplib, with built in methods, but this hides the details of SMTP and socket programming → so do not use this
- ❑ To limit spam, mail servers do not accept TCP connection from arbitrary sources.
  - ❖ You could try connecting both to both the Smith mail server and to a popular Webmail server, such as an AOL mail server, gmail…

Mail message format

* Example of the actual message - NOT part of the SMTP handshaking process

- header lines, e.g.,
  - To:
  - From:
  - Subject:

  different from SMTP commands!
- body
  - the "message", ASCII characters only



```
   fcapmaster:~ jcardell$ telnet smtp.smith.edu 25
   Trying 131.229.64.236...
   Connected to baton.smith.edu.
   Escape character is '^]'.

   220 baton.smith.edu ESMTP Sendmail …

C: HELO jbc.edu
S: 250 baton.smith.edu Hello [131.229.102.128], pleased to meet you
C: MAIL FROM: <judy@jbc.edu>
S: 250 2.1.0 <judy@jbc.edu>... Sender ok
C: RCPT TO: <jcardell@smith.edu>
S: 250 2.1.5 <jcardell@smith.edu>... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: to: Easter@Bunny.hop
C: from: Tooth@Fairy.fly
C: subject: How's Business?
C:
C: Hello Hoppy
C: Checking in to see how you're doing.
C: .
S: 250 2.0.0 s8GFb0Q4007216 Message accepted for delivery
C: QUIT
S: 221 2.0.0 baton.smith.edu closing connection
```

```
#Sample SMTP client program -> server refuses contact
from socket import *

# Messages to send
msg = '\r\nHello World!’     endmsg = '\r\n.\r\n'

# Choose a mail server and call it mailserver
mailserver = 'smtp.smith.edu'

# Create socket, establish a TCP conx with mailserver
clientSocket = socket(AF_INET, SOCK_STREAM)

# Port number may change according to the mail server
clientSocket.connect((mailserver, 25))
recv = clientSocket.recv(1024)
print (recv)
if recv[:3] != '220':
      print ('220 reply not received from server.’)
```

```
# Send HELO command and print server response.
heloCommand = 'HELO smith.edu\r\n'
clientSocket.send(heloCommand)
recv1 = clientSocket.recv(1024)
print recv1
if recv1[:3] != '250':
      print ('250 reply not received from server.’)
…

# Send DATA command and print server response.
data = 'DATA\r\n'
clientSocket.send(data)
recv4 = clientSocket.recv(1024)
…

# Message ends with a single period.
clientSocket.send(endmsg)
…

# Send QUIT command and get server response.
quitcommand = 'QUIT\r\n'
clientSocket.send(quitcommand)
```

HW: Web Server

- Develop a web server that handles one HTTP request at a time.
  - Accept and parse the HTTP request message,
  - Get the requested file from the server’s file system
  - Create an HTTP response message consisting of the requested file and the appropriate header lines
  - Send the response directly to the client.
  - Use any web browser for the client

HW: Web Server Due Dates

- Feb 22
  - Python (or other) working code in 2 weeks
  - Web server code, beautifully commented with meaningful variable and object names
  - Screen shots of output
- * For Feb 15 *
  - The HTML code that your web server will serve up to your requesting web browser
  - (you will use a commercial web browser to contact your own web server)
  - BE SURE to be working on your web server this first week as well!

Appendix – Socket functions

36

Socket API Overview –

details in appendix to these slides

- Socket Programming Procedures
  - Socket()
  - Bind()
  - Listen()
  - Accept()
  - Connect()
  - Along with send and receive procedures
  - Close()
- And for DNS…
  - getHostByName
  - getServByName
  - getProtoByName

37

Procedures: Socket()

- descriptor = socket(protoFamily, type)
  - Creates a socket and returns an integer descriptor
  - ProtoFamily – refers to Family of protocols that this protocol belongs to, for TCP/IP use PF_INET
  - Type – SOCK_STREAM, SOCK_DGRAM
    - SOCK_STREAM – Connection Oriented (TCP)
    - SOCK_DGRAM – Connectionless (UDP)

Accept() – Server Procedure

- Newsock = accept(socket, caddr, caddrlen)
  - Accept() fills the fields of the struct caddr with the address of the client that formed the connection
  - Accept() creates a new socket for this connection and returns the descriptor of this new socket
  - The server's original "listen()" socket remains unchanged
- A request has come to the server
  - → The phone is ringing
- Accept picks up the connections (only TCP)

Bind()

- ❑ Bind(socket, localAddr, addrLen)
  - Call after socket() has been called to bind the socket to a protocol port number
  - Used to assign the port at which the client/server will be waiting for connections/messages
    - The port number is part of the address structure
    - s.bind(('', 80)) specifies that the socket is reachable by any address the machine happens to have
  - Socket – descriptor
  - localAddr – socket address structure → including the port number
  - addrLen – length of the address

Close()

- ❑ The socket is no longer going to be used
- ❑ Close(sock)
  - Sock – the descriptor

- ❑ Note: For a connection oriented socket, connection is terminated before socket is closed

Connect() – Client Procedure

- Connect(socket, saddr, saddrlen)
  - Arguments ‘socket’ is the desciptor of a socket on the client’s computer to use for the connection
  - ‘saddr’ and len specify the *server’s* info
  - With TCP, this initiates the connection to the specified server
- This is used to make the “phone call”
- Two uses
  - Connection-oriented transport – make the call
  - Possible use - Connectionless – identify the server to send the many, independent messages

Listen() – Server Procedure

- Listen(socket, queuesize)
  - Called at server
  - socket – descriptor at server
  - queueSize – buffering of requests
- This procedure tells the server to leave a socket running, in passive mode, at this port

Recv() and Recvfrom()

- ❑ Used to receive messages in a connection oriented communication
  - ❖ Recv(socket, buffer, length, flags)
    - Buffer – memory location/structure to store the data
    - Length – the length of buffer
- ❑ Recvfrom() is used in connectionless communication
  - ❖ Recvfrom(socket, buffer, flags, sndraddr, saddrlen)
    - Sndraddr – sender's address
    - Saddrlen – length of sender's address

Send() and Sendto()

- ❑ Used to send packets from one host to another
  - ❖ Send(socket, data, length, flags)
    - Socket – descriptor
    - Data – pointer to buffer in memory with the data
    - Length – of data to be sent
    - Flags – for debugging, not general use (typ = 0)
- ❑ Sendto() is used with an unconnected socket
  - ❖ Sendto (socket, data, length, flags, destAddress, addressLen)