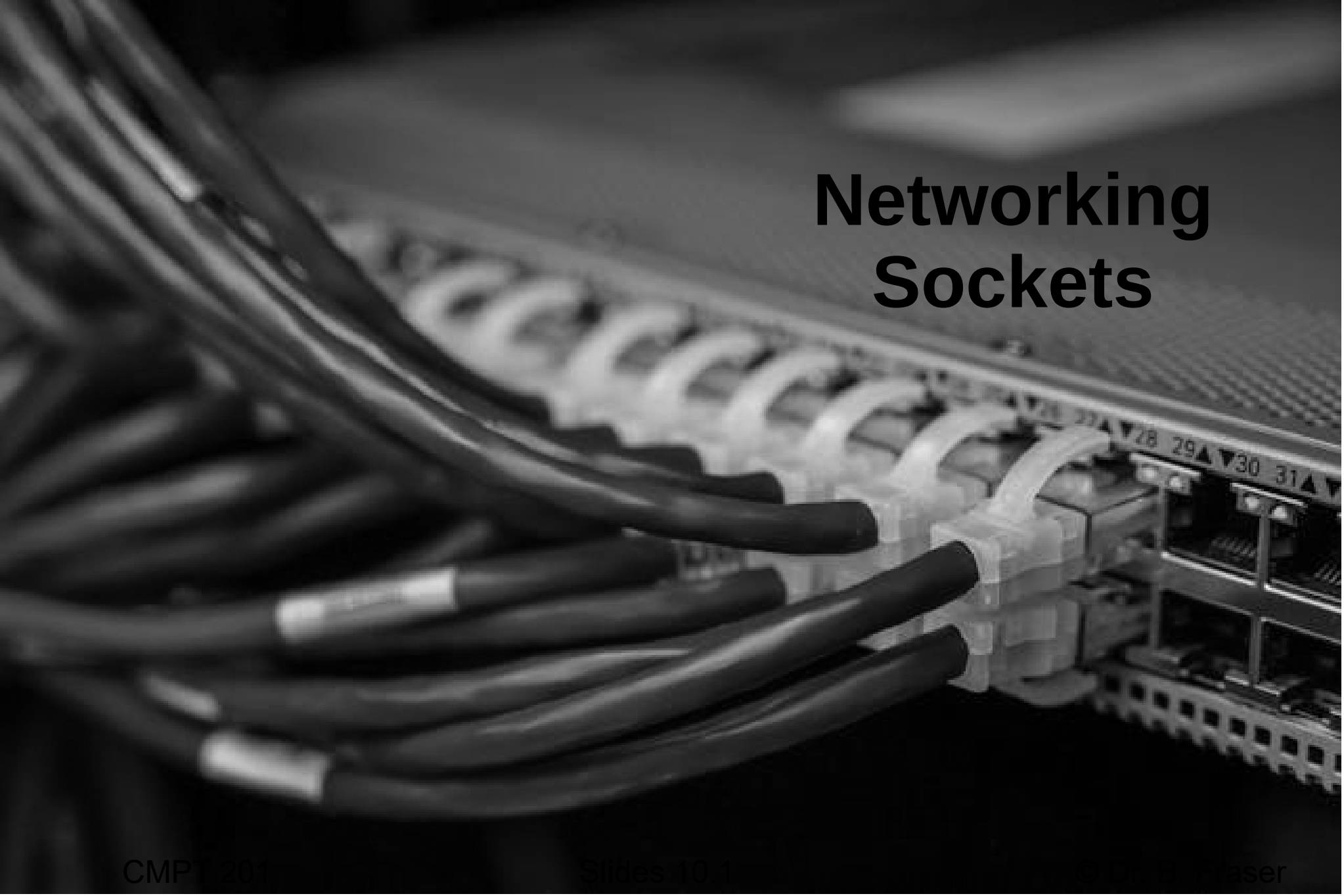

Networking
Sockets

Topics

- How does software do something complicated like networking? Layers!
- What are the two types of sockets?
- What syscalls can we use to work with sockets?

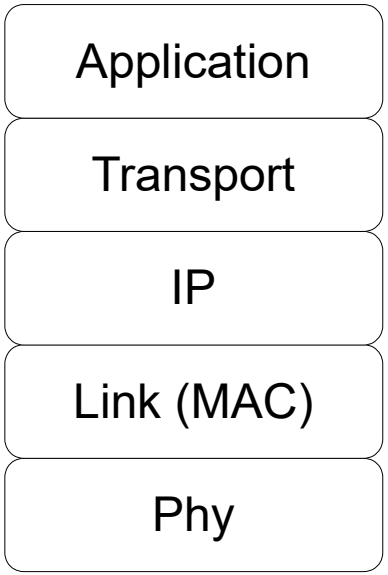
Networking

- Programs can communicate with each other via a network.
  - Can be across a network (wifi, wired, ...)
  - Can be on the same computer!
- More Resources
  - Beej's Guide to Network Programming https://beej.us/guide/bgnet/ is popular.
  - The Linux Programming Interface (our recommended text) is also great.

Basics of the Networking Stack

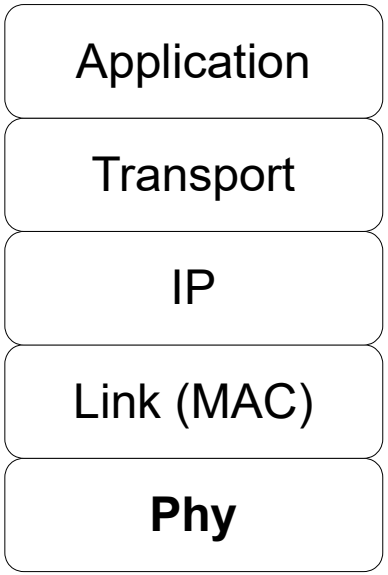
Networking Stack

- Stack
  - ..
  - Each layer provides a service to the layer above it.

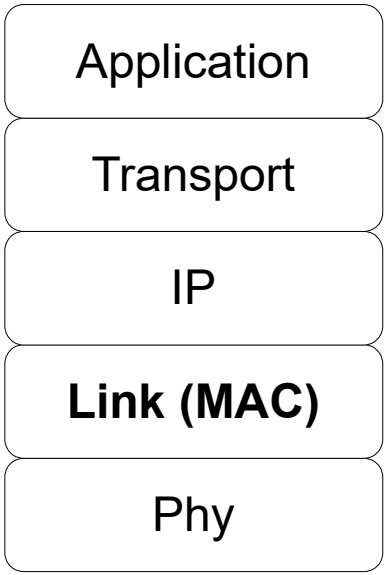


Physical Layer

- Phy (Physical) Layer:
  ..
  generates and receives signals.
  - Need to know how to physically send and receive data.
  - Focuses on voltage and signalling.
- Analogy:
  Amazon package delivery:
  ..



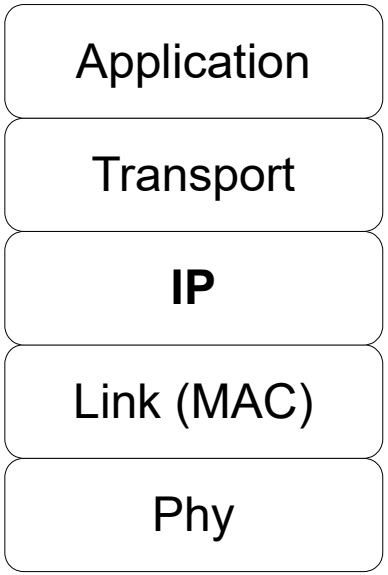
Link Layer



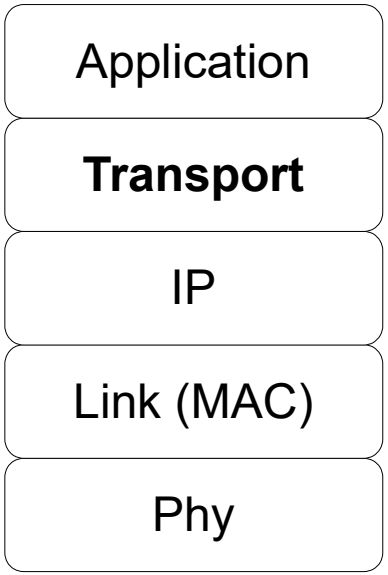
- Link (MAC) Layer:
  ..
  - This is only for a (small area) local network.
  - E.g., wired or wireless local network.
  - LAN = Local Area Network
- Link layer has MAC addresses for addressing.
  - MAC =..
    MAC address look like: 05:35:5a:30:f9:05
- Analogy: Amazon package delivery:
  - need an address and routes
    (how to get there).

IP (Network) Layer

- IP ("Network") Layer:
  - ..
  - IP =.. Internet Protocol
- What if you want to connect a wired local network with a wireless local network?
  - Still need addressing and routing but it needs to be something common for both wired and wireless.
- ..
  - IP addresses look like: 192.168.7.53

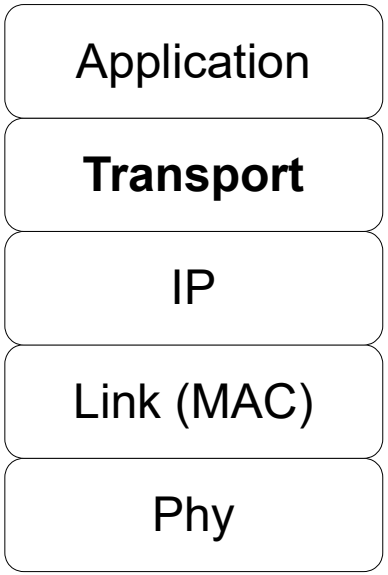


Transport Layer



- Transport Layer:
  ..
- Imagine sending/receiving lots of packages:
  3 problems can occur:
  - ..
    Think car crash; or human errors like losing a package in a warehouse.
  - ..
    They may be delivered by different trucks via different routes.
  - ..
    If the sender mistakenly thinks the package is lost and re-sends.

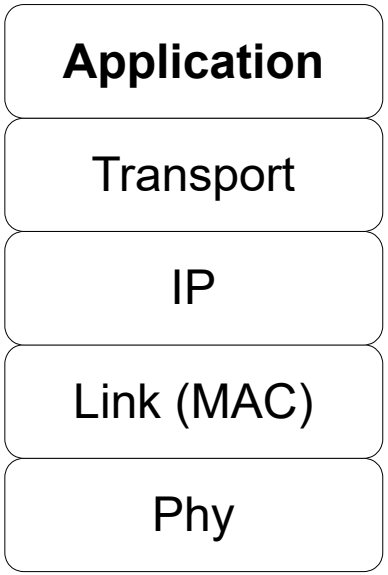
Transport Layer (cont)



- Some applications require an in-order reliable byte stream.
- Need a way to control these things:
  - ..
    provides protection against these things:
    ..
  - ..
    does not provide any protection!
    Raw datagrams = packets.
- Port Number
  - Use a socket port number to identify
    ..
    to send a packet
  - E.g., port 80, or 443

Application Layer

- Application Layer:
  ..
  - Often features a well-known protocol such as: HTTP and FTP.



ABCD Spot the Address

- Which of the following is _____?
  1) an IP Address
  2) a MAC Address
  3) Port Number

  a) `8001`
  b) `19:02:16:08:07:01`
  c) `153.10.23.103`
  d) `0xF532 5E85 0005 235F`

Socket Interface

Socket Syscalls

- An application can use a socket to communicate with another process (local or remote)

- There are five key syscalls
  - socket()
  - bind()
  - listen()
  - accept()
  - connect()

socket()

int socket(int domain, int type, int protocol)

- ..
- Functions to send/receive
  - socket-specific calls: send(), recv(), sendto(), recvfrom()
  - file I/O calls: read(), write()

- int domain
  - Specifies what protocol is used. What is a protocol?
    - ..
  - Domain examples
    - AF_UNIX: Local communication (this computer)
    - AF_INET: IPv4 Internet protocols
    - AF_INET6: IPv6 Internet protocols

socket() cont

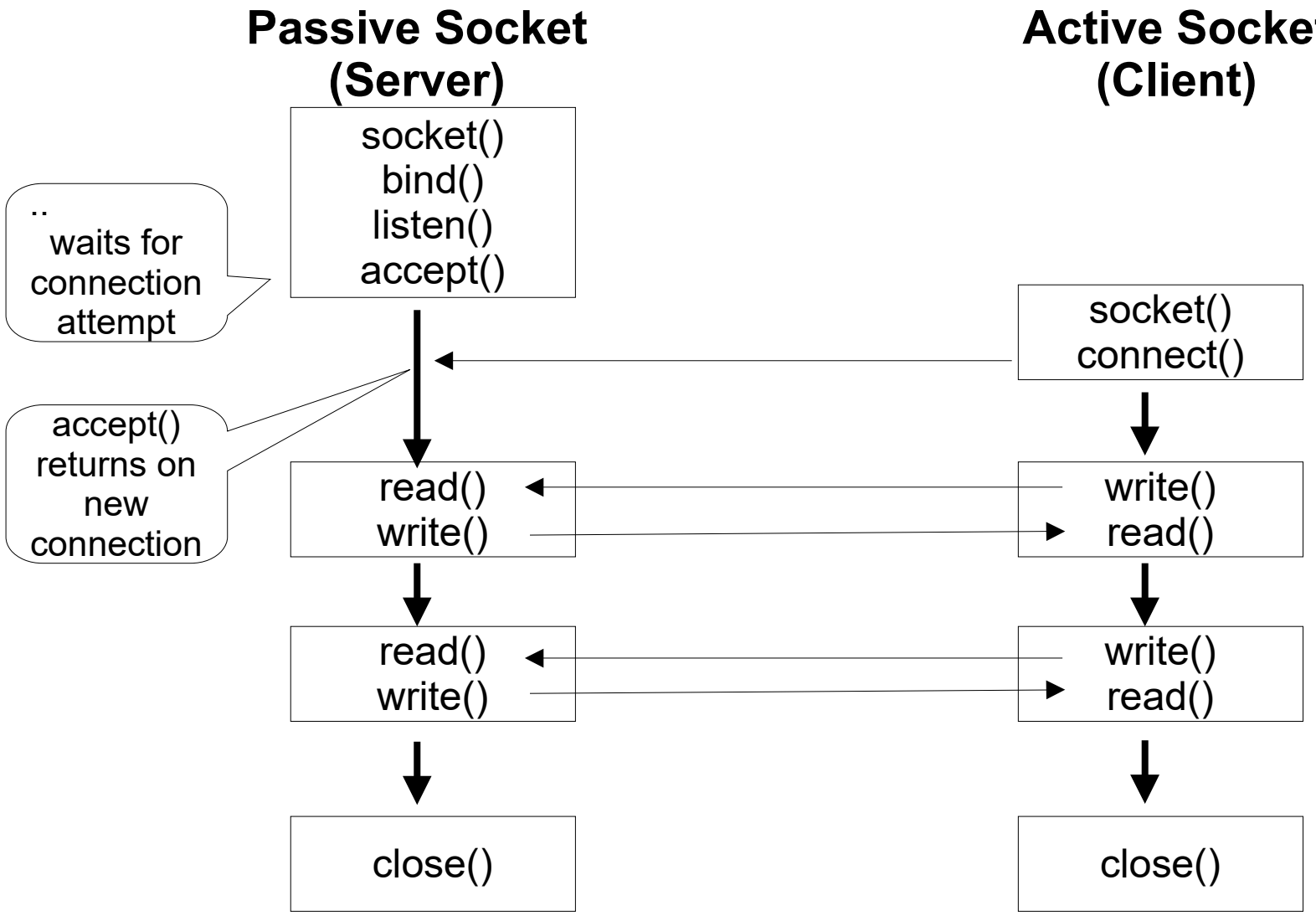
int socket(int domain, int type, int protocol)

- int type
  - SOCK_STREAM: TCP

    ..
    - Connection-based / connection-oriented: will explain later
  - SOCK_DGRAM: UDP

    ..
    - Connectionless: will explain later.
- int protocol
  - Always 0 for us; not used for AF_UNIX, AF_INET, and AF_INET6.
  - Some domains allow different protocols.

Stream Socket Sequence (TCP)



TCP Explanation: bind()

- socket() creates a socket.
- bind()..
  - Uses a generic address struct.

```
struct sockaddr {
    sa_family_t sa_family;
    char        sa_data[14];
    // size varies.
    // bind() given struct size.
```

  - Different protocols use different structs
    (with different-yet-similar names, and different fields).

TCP Explanation: listen(), accept()

- listen()..
  - i.e., it's used to wait for a connection to come (a server).
  - By default, a socket is active.
- accept()..
  - Returns a **new socket** to use for the new connection.
  - The original socket is only used to accept new connections.
- connect()..
  - "connection-oriented" means we establish a connection first.

ABCD TCP Call Sequence

- Which of the following is the most likely sequence of calls for a TCP server?

a)

```
socket()
bind()
listen()
read()
accept()
write()
close()
```

b)

```
socket()
bind()
listen()
accept()
read()
write()
close()
```

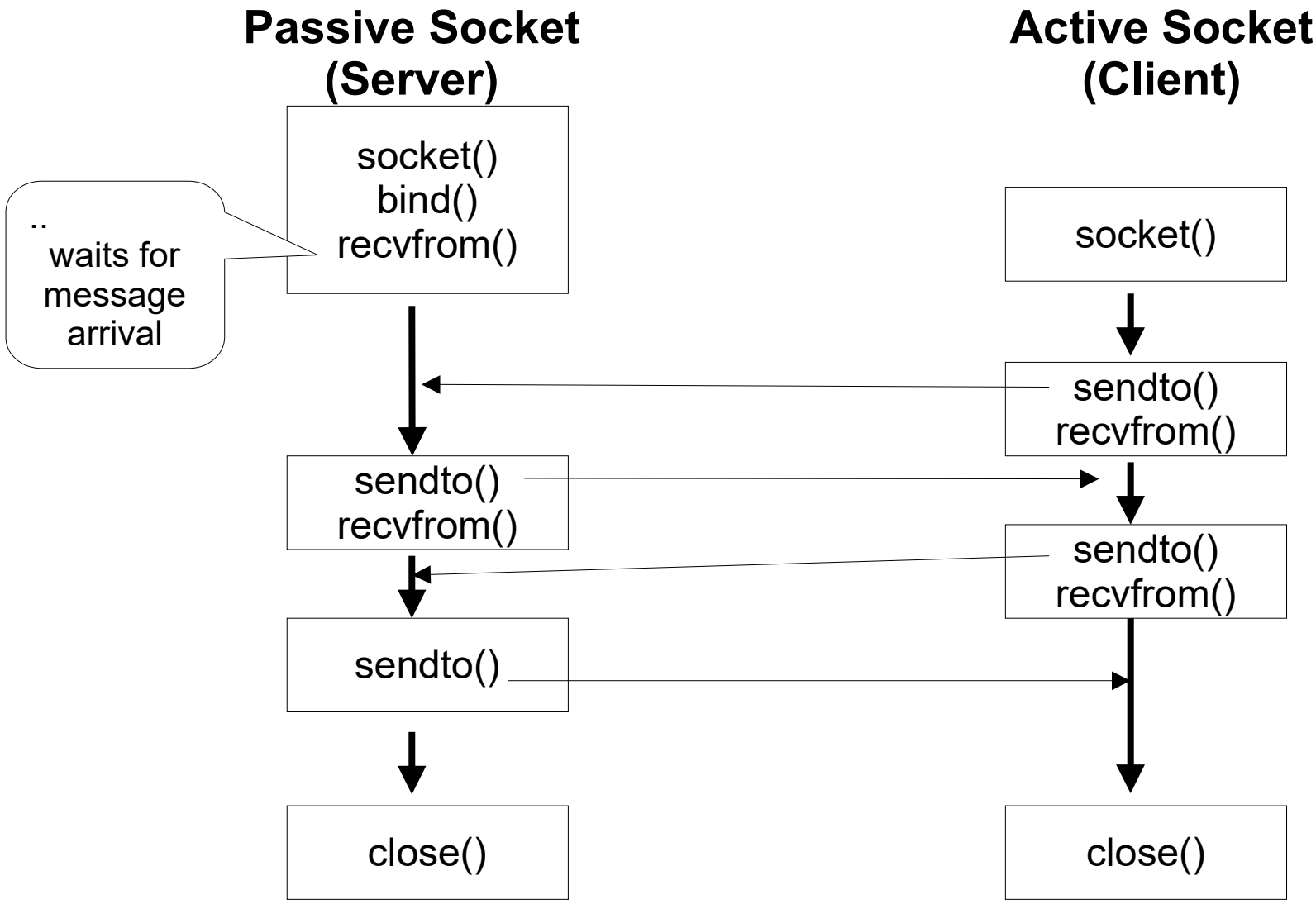
c)

```
socket()
bind()
listen()
accept()
write()
read()
close()
```

d)

```
socket()
bind()
write()
listen()
accept()
read()
close()
```

Datagram Socket Sequence (UDP)



UDP Explanation

- "connectionless" means

  ..
  - It is like an SMS message that is received one-off
  - Each time we receive a message we are told who sent it.
- UDP has no active or passive sockets
  - sendto() needs to specify the receiver's address every time.
  - recvfrom() tells you who sent it.

ABCD UDP Call Sequence

- Which of the following is the most likely sequence of calls for a UDP server?

a)

```
socket()
bind()
sendto()
recvfrom()
close()
```

b)

```
socket()
bind()
listen()
sendto()
close()
```

c)

```
socket()
bind()
read()
write()
close()
```

d)

```
socket()
bind()
recvfrom()
sendto()
close()
```

ABCD: Who’s call is it?

- Which of the options on the right is most likely to use all of the following calls (*not in order*):

```
connect()
close()
read()
socket()
write()
```

```
a) UDP Client
b) UDP Server
c) TCP Client
d) TCP Server
```

ABCD: Who’s call is it?

- Which of the options on the right is most likely to use all of the following calls (*not in order*):

```
bind()
close()
recvfrom()
sendto()
socket()
```

a) UDP Client
b) UDP Server
c) TCP Client
d) TCP Server

ABCD: Who’s call is it?

- Which of the options on the right is most likely to use all of the following calls (*not in order*):

```
accept()
bind()
close()
listen()
read()
socket()
write()
```

a) UDP Client
b) UDP Server
c) TCP Client
d) TCP Server

TCP Activity

- Create two TCP programs: server and client.
  - Implement the socket sequence using AF_UNIX. (Local machine)
  - The client should be able to send messages typed on the terminal to the server.
  - The server should be able to print out the messages.
  - man unix for detailed info for AF_UNIX.
  - An AF_UNIX address uses struct sockaddr_un:

```
struct sockaddr_un {
    sa_family_t sun_family;         /* AF_UNIX */
    char        sun_path[108];      /* Pathname = “tmp” */
};
```

UDP Activity

- Create two UDP programs: server and client.
  - Implement the socket sequence using AF_UNIX. (Local machine)
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```

Summary

- Network Stack has layers (bottom-up)
  - phy, link, IP, transport, application
- Socket: Connect to communicate across network.
- TCP:
  - Connection-oriented; in-order delivery.
  - Server:
    socket(), bind(), listen(), accept(), read(), write()... close()
  - Client: socket(), connect(), write(), read(), ... close()
- UDP:
  - Connectionless
  - Server: socket(), bind(), recvfrom(), sendto(), ... close()
  - Client: socket(), sendto(), recvfrom(), close()