Computer System Principles

Network Programming

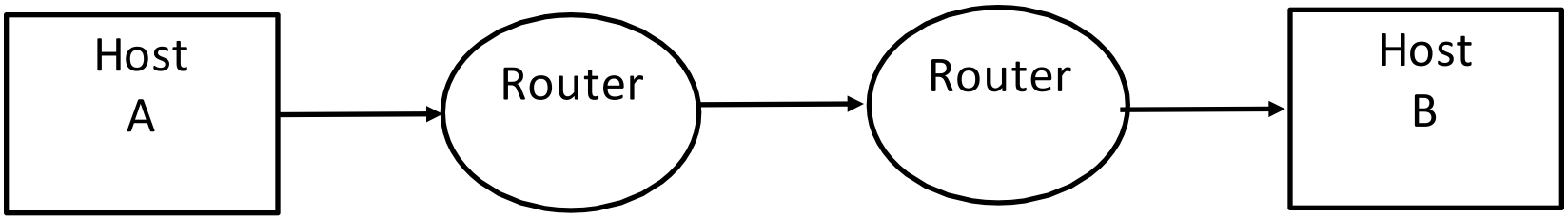
UMASSCS
SCHOOL OF COMPUTER SCIENCE

Announcement

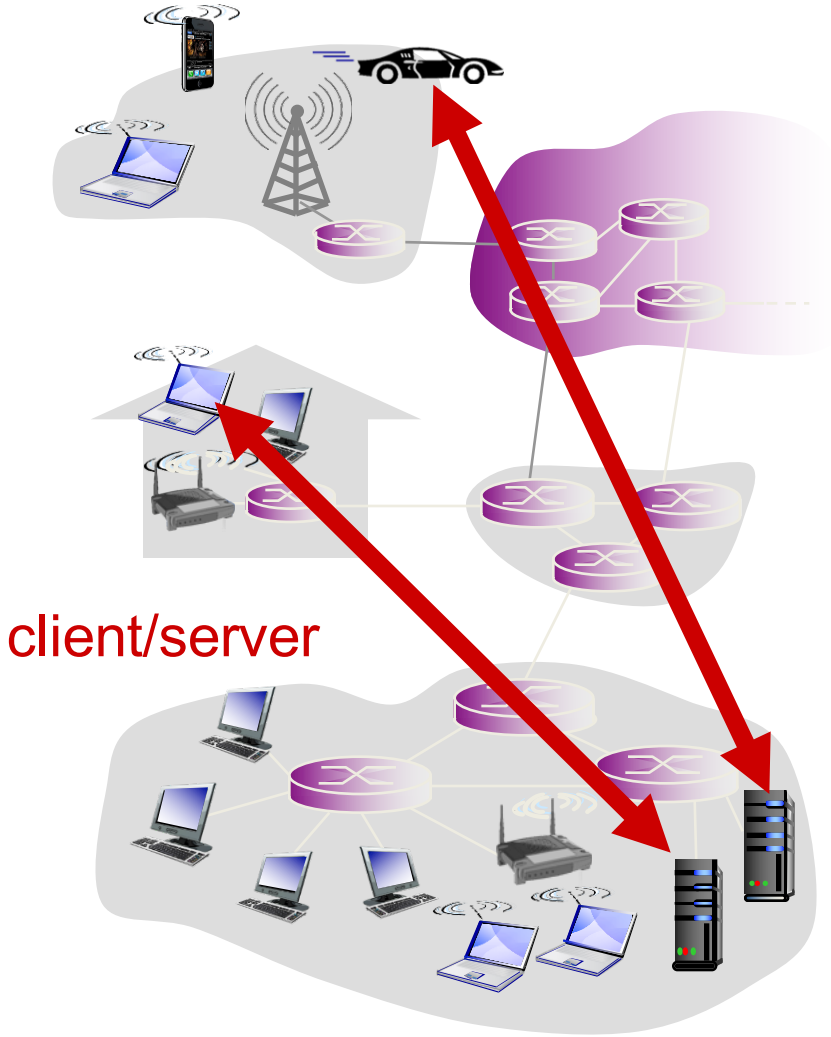
- We will drop the lowest assignment grade, except that we won't drop the grade for the last assignment if that grade is not a passing grade (70%).

NETWORK TOPOLOGY

Network Topology



Client-server architecture



server:

- Generally an “always-on” host
- (e.g. Amazon, telephone)
- Generally at a *permanent* IP address
  - data centers for scaling

clients:

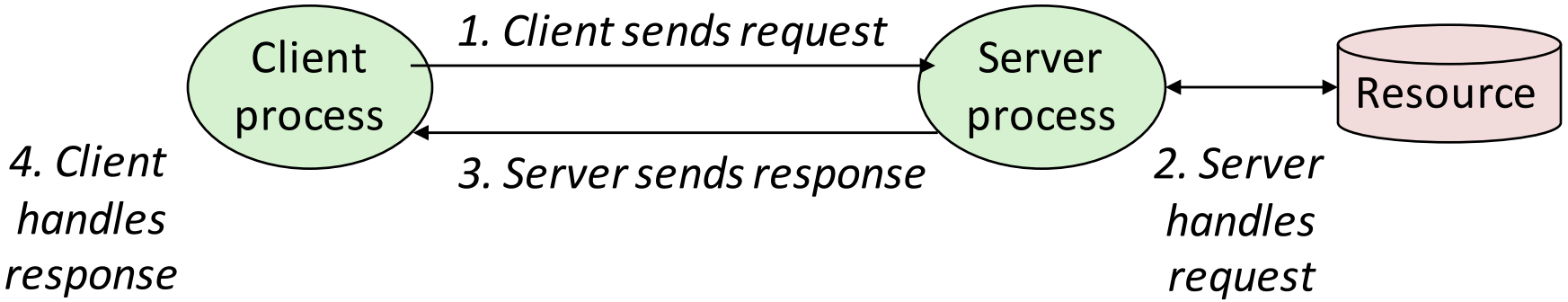
- communicate with server
- may be intermittently connected
- may have dynamic IP addresses
- do not typically communicate directly with each other

Client-Server Model

- An application process is assigned a process identifier number (process ID) - likely to be different each time that process is started.
- Process IDs differ between OS platforms - they are not uniform.
- A server process can have multiple connections to multiple clients at a time - simple connection identifiers at one end are not unique.

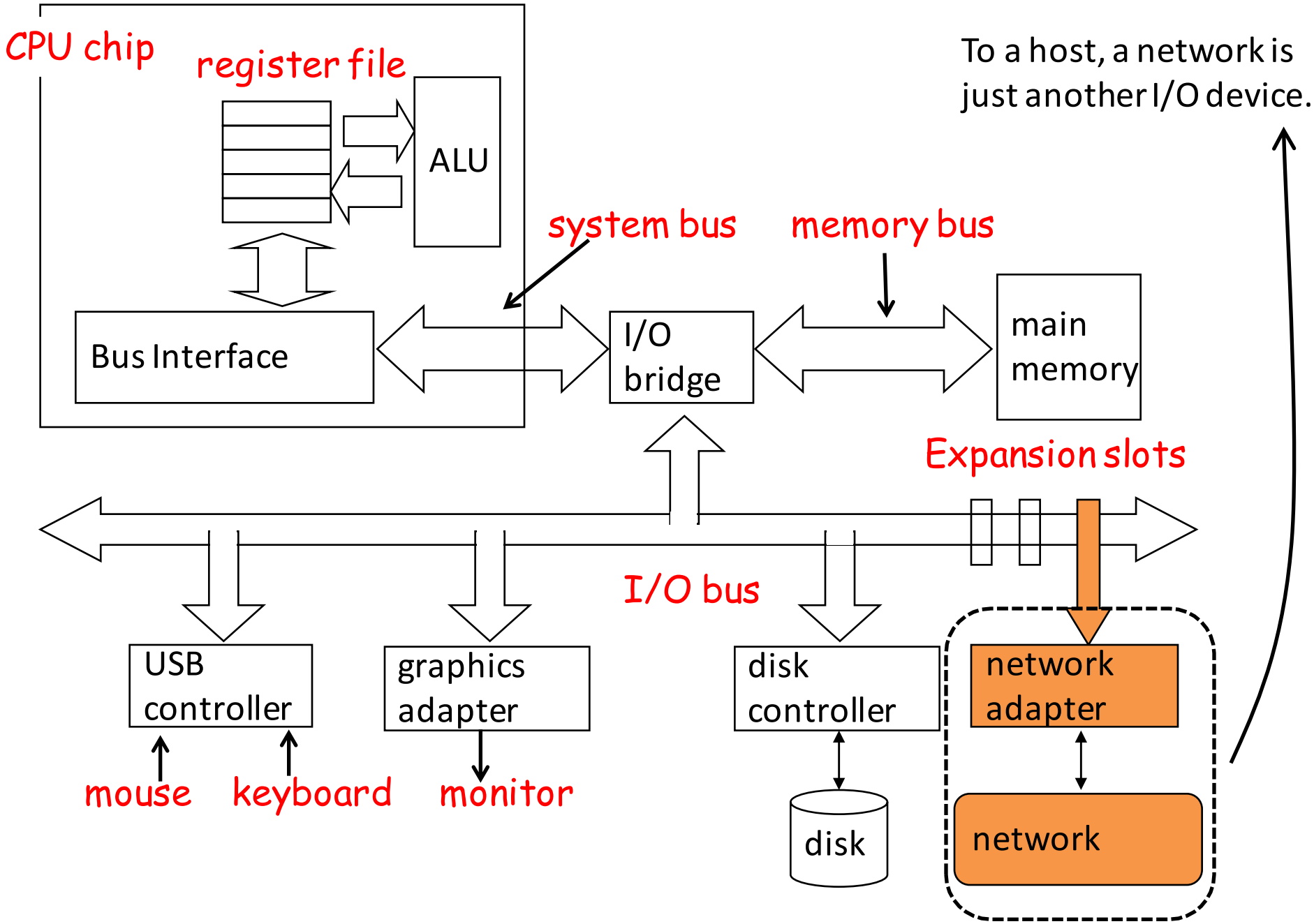
A Client-Server Transaction

- Most network applications are based on the client-server model:
  - A ***server*** process and one or more ***client*** processes
  - Server manages some ***resource***
  - Server provides ***service*** by manipulating resource for clients
  - Server activated by request from client (vending machine analogy)



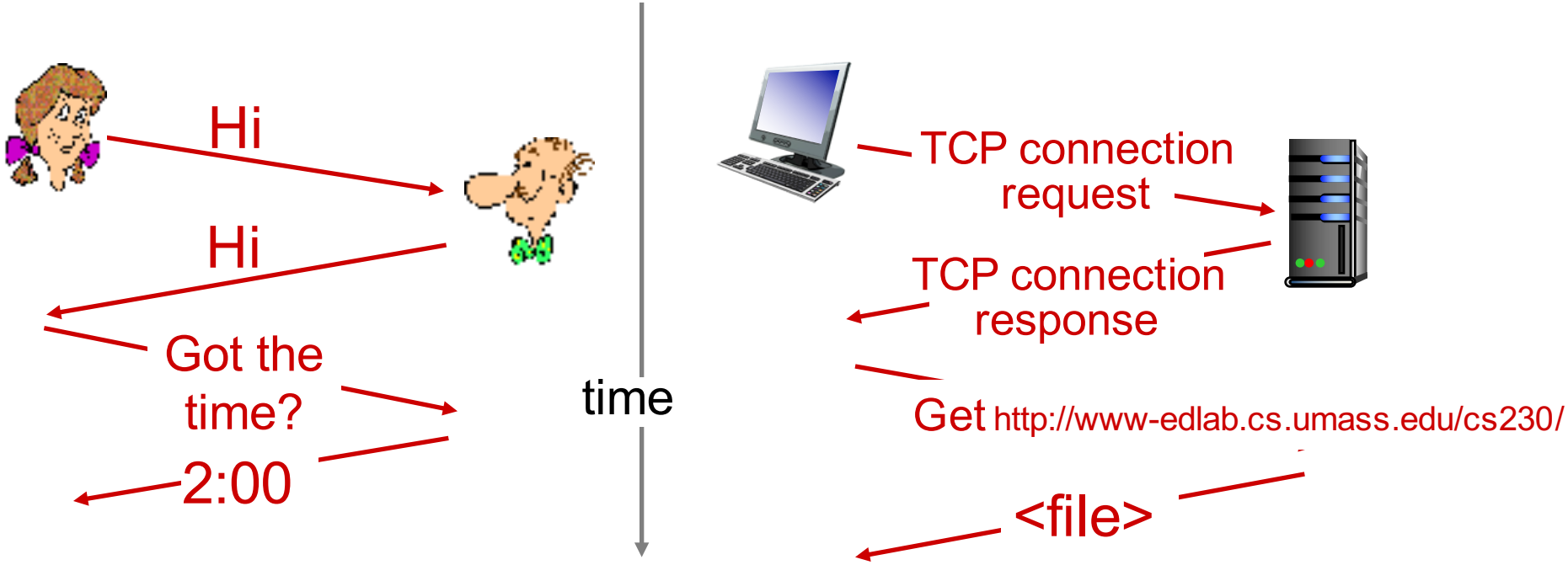
Note: clients and servers are processes running on hosts (can be the same or different hosts)

Network Hardware



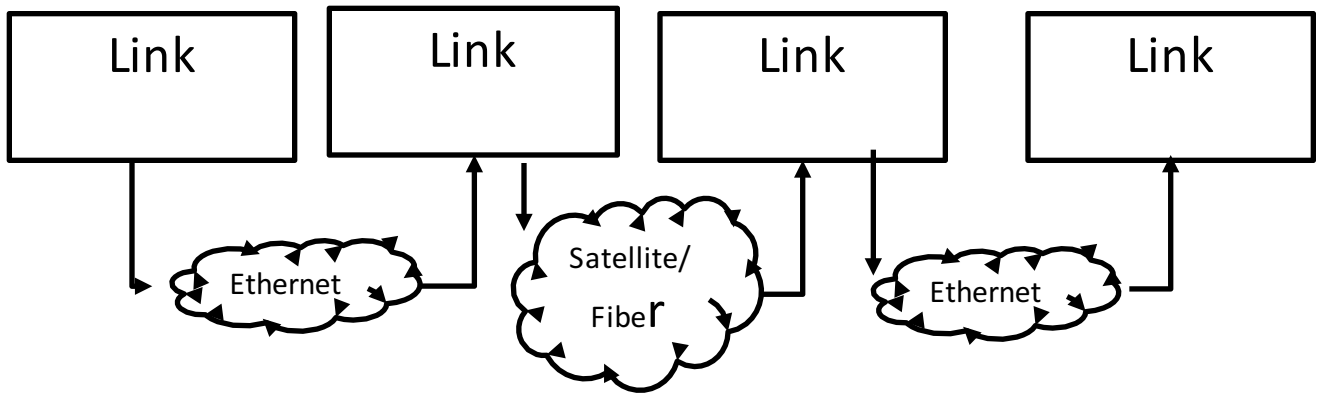
Protocols

a human protocol and a computer network protocol:

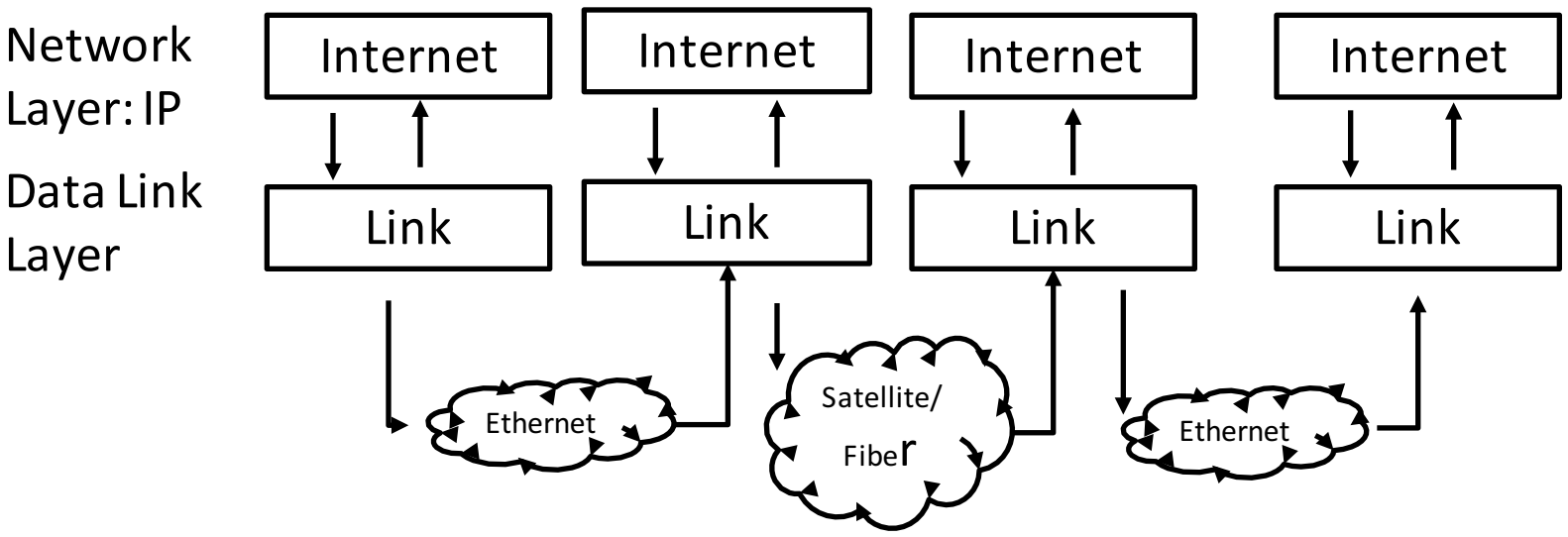


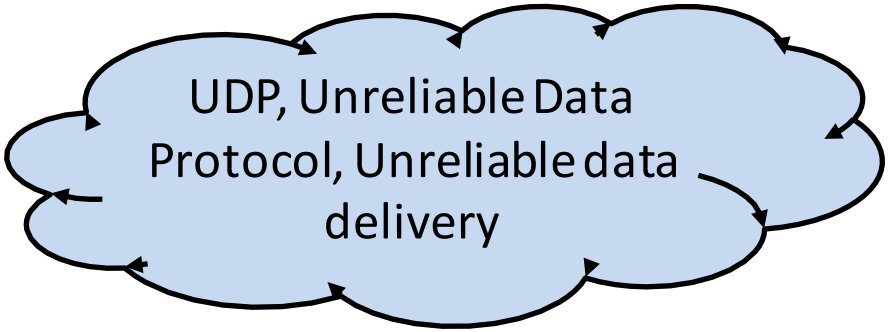
protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

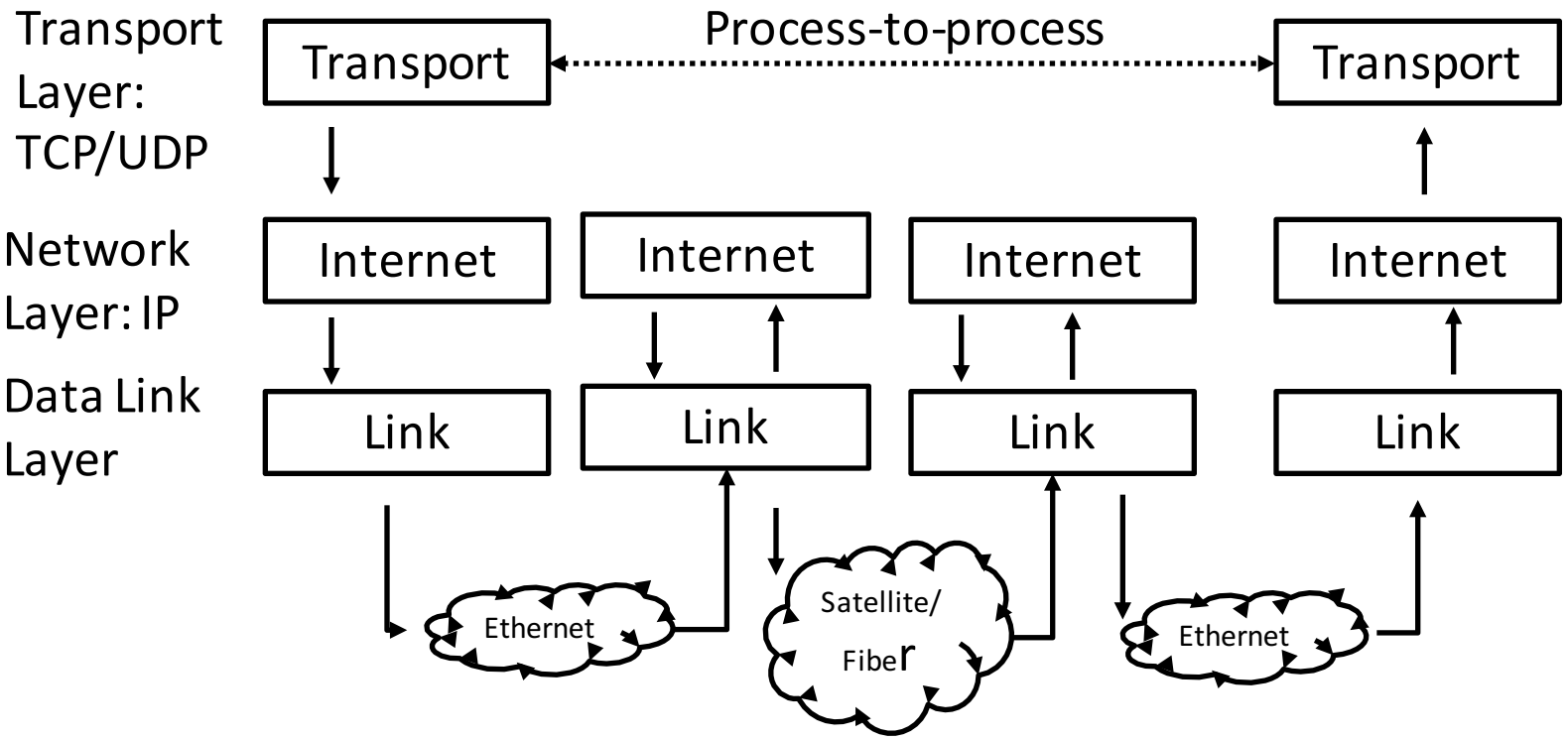
Data Link Layer

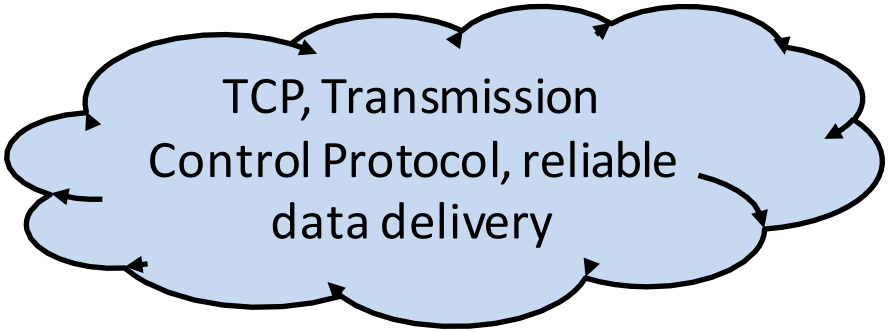


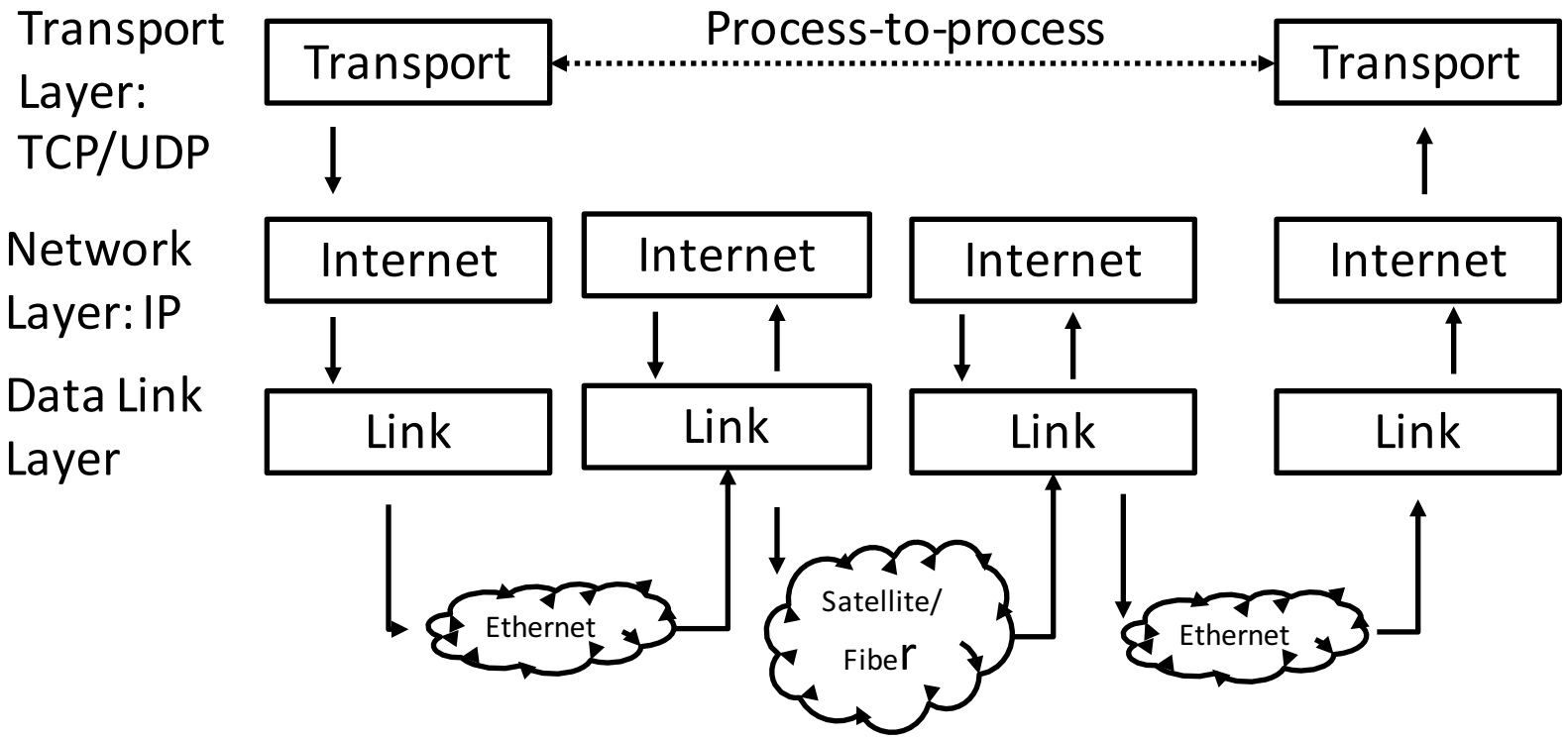
IP: Internet Protocol, provides unreliable delivery of packets




UDP, Unreliable Data Protocol, Unreliable data delivery


Transport Layer: TCP/UDP
Process-to-process
Transport
Transport
Network Layer: IP
Internet
Internet
Internet
Internet
Data Link Layer
Link
Link
Link
Link
Ethernet
Satellite/ Fiber
Ethernet


TCP, Transmission
Control Protocol, reliable
data delivery


Transport
Layer:
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Network
Layer: IP
Data Link
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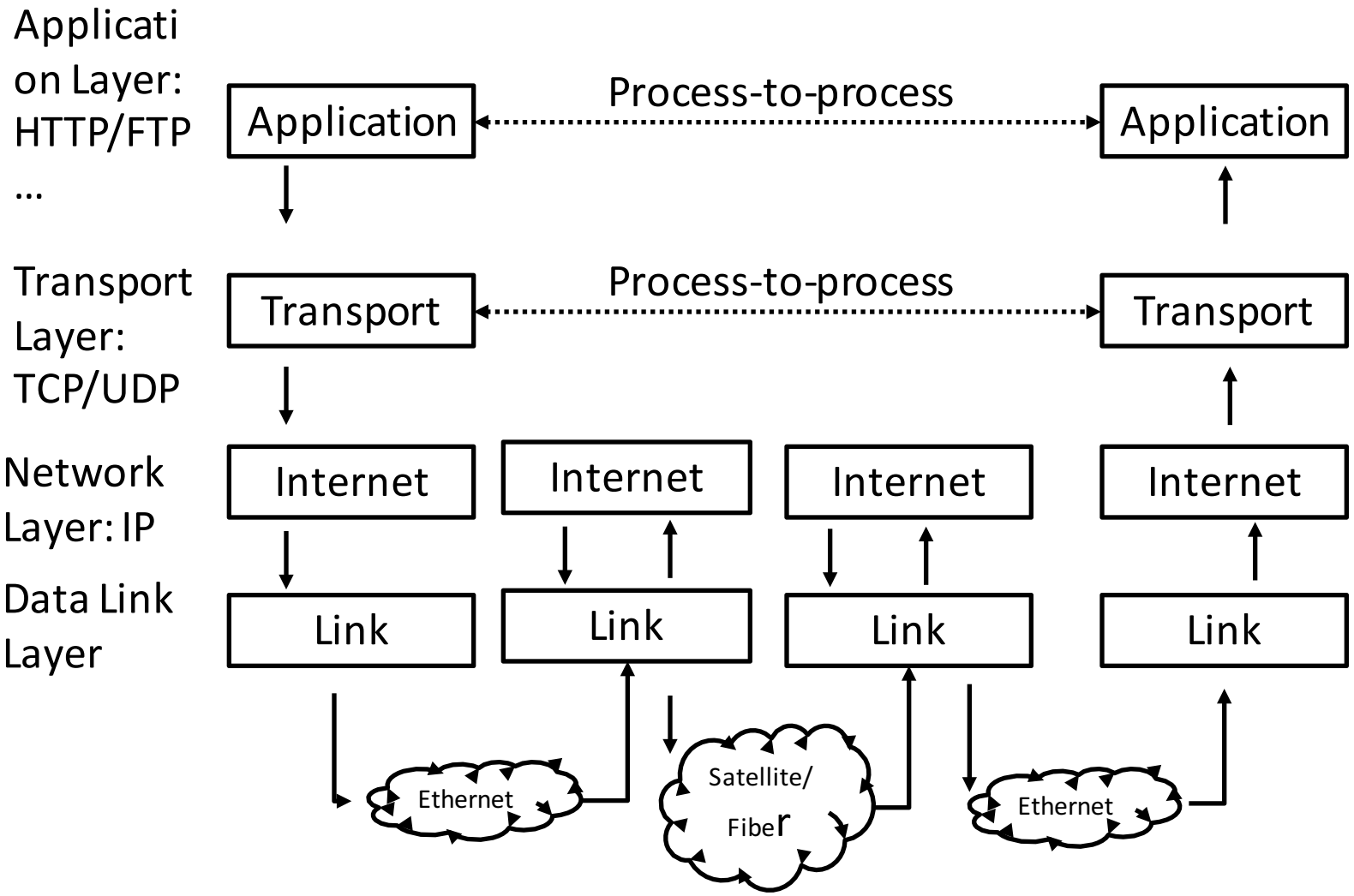
Applicati
on Layer:
HTTP/FTP
…
Application
Process-to-process
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Transport
Layer:
TCP/UDP
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Transport
Network
Layer: IP
Internet
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Internet
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Data Link
Layer
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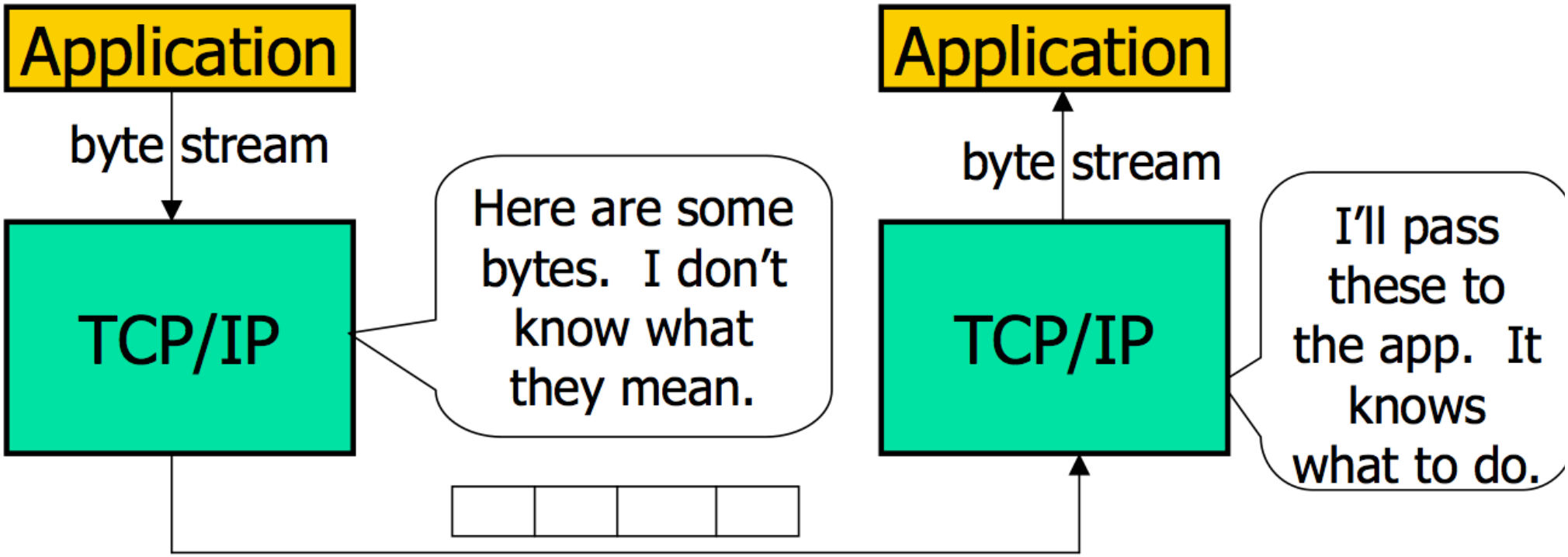
TCP OVERVIEW

TCP

The TCP data unit - segment

- does not recognize messages,
- sends a block of bytes from the byte stream between sender and receiver.



TCP

- The primary purpose of TCP is to provide a reliable logical circuit or connection service between pairs of processes.
  - does not assume reliability from the lower-level protocols (such as IP), so TCP must guarantee this itself
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  - When a packet is successfully delivered to its destination, the destination should send an acknowledgement
  - otherwise, the source system retransmits the packet
    - the destination never receive the packet
    - the ack is lost

TCP Three-Way Handshake

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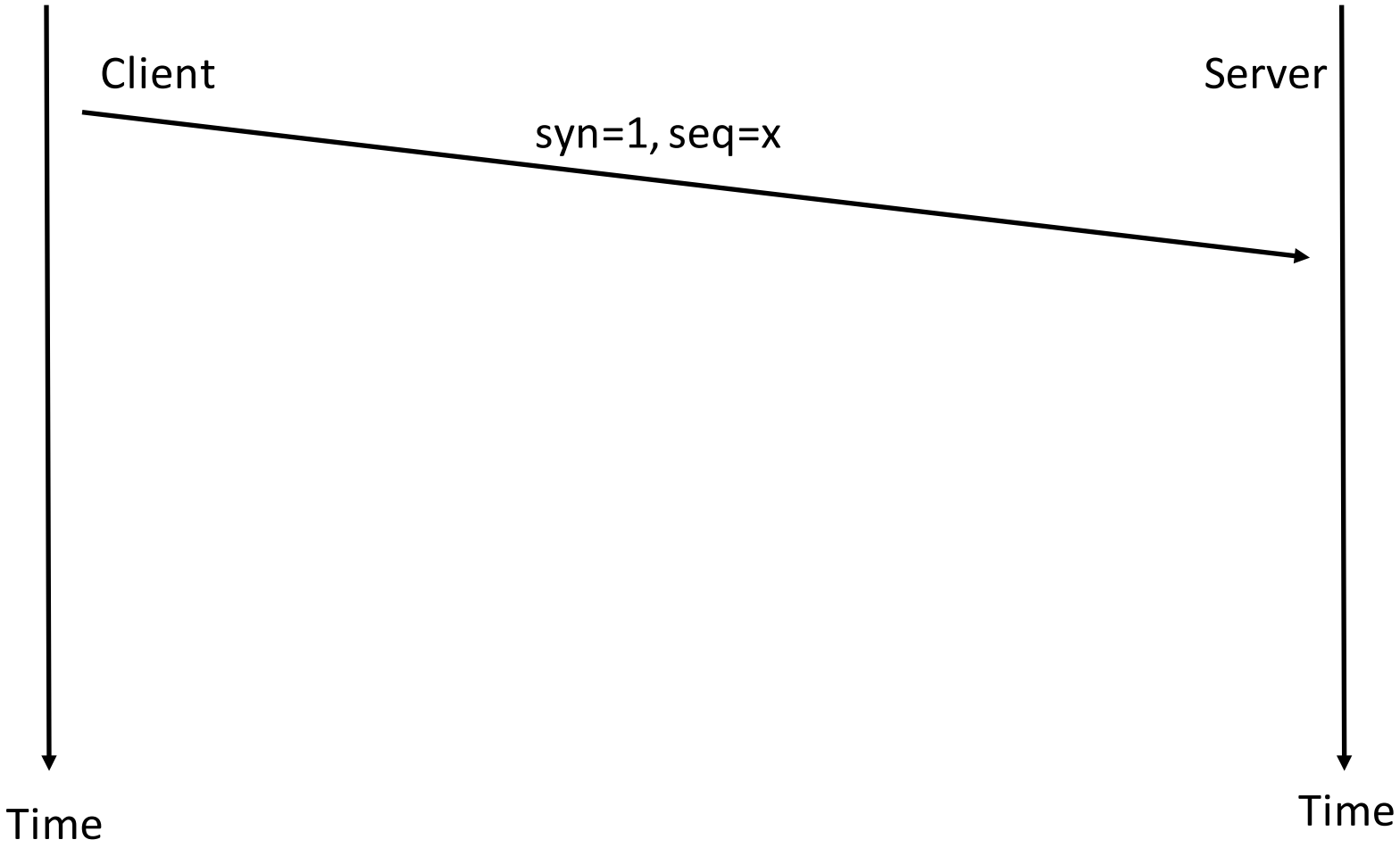

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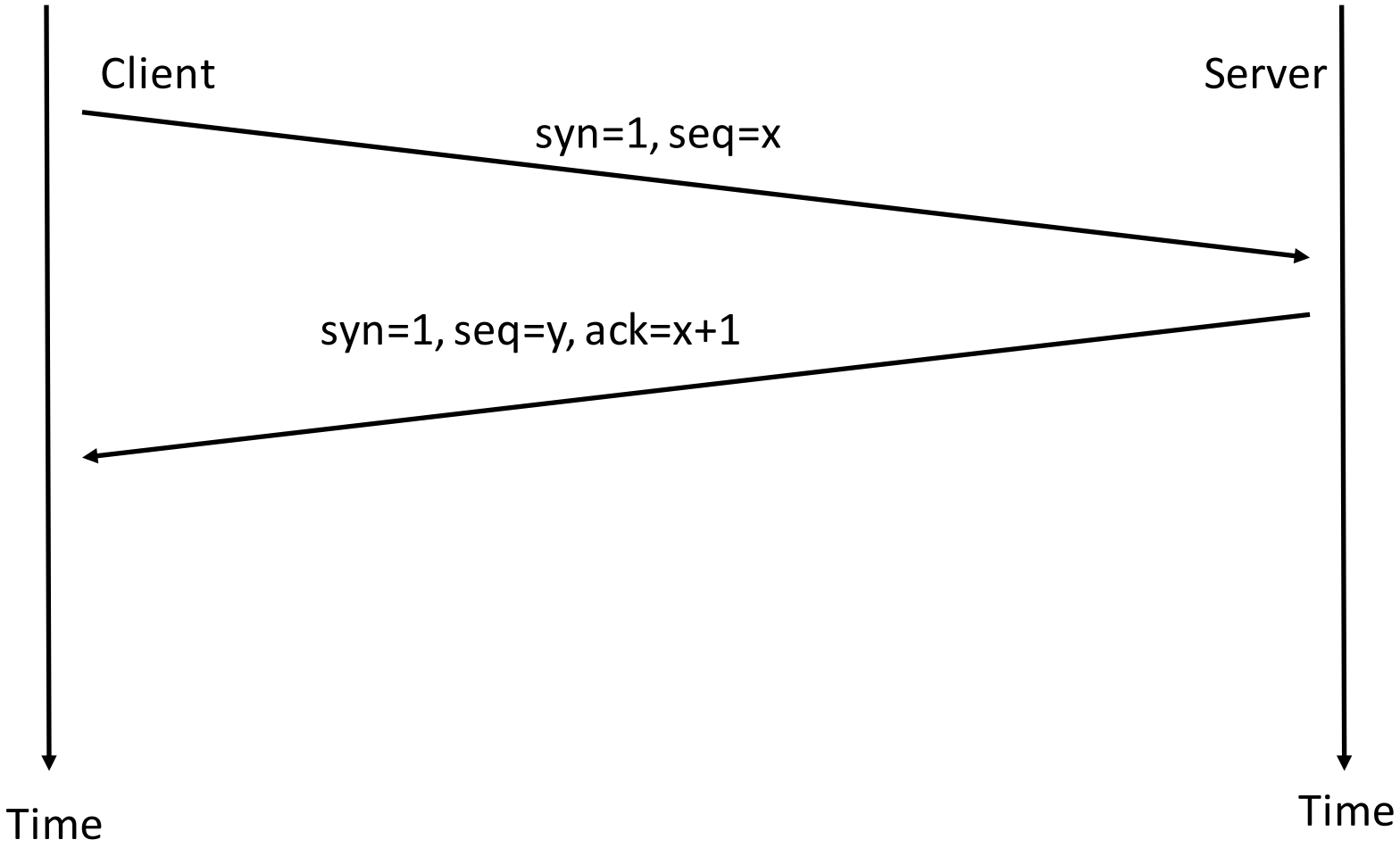

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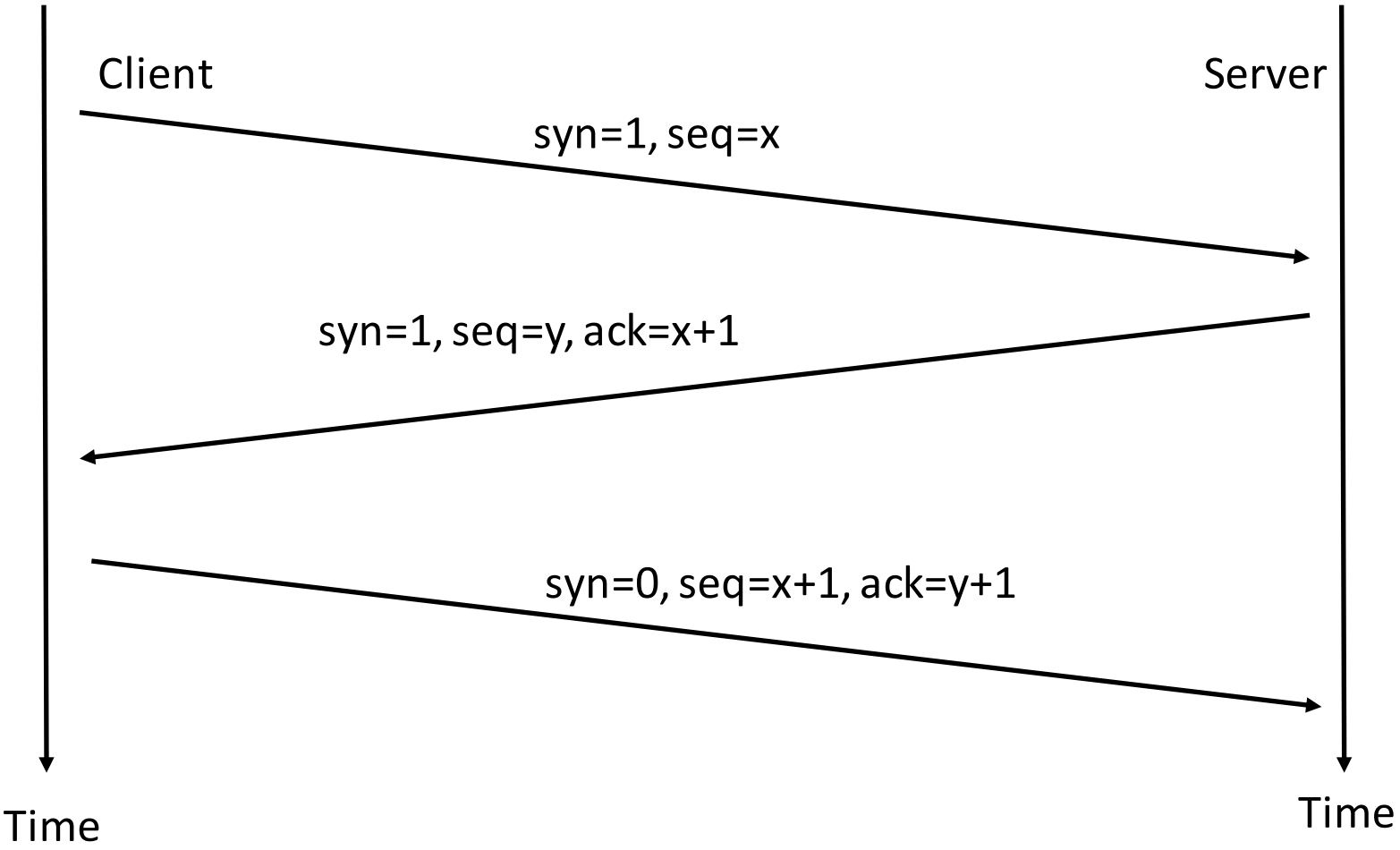

SOCKET

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  - Point-to-point, full-duplex (2-way communication), and reliable.

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- A port is a 16-bit integer that identifies a process:
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  - Well-known port: Associated with some service provided by a server (e.g., port 80 is associated with Web servers)

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- A connection is uniquely identified by the socket addresses of its endpoints (socket pair) (and its protocol, e.g., TCP).
  - (cliaddr:cliport, servaddr:servport)

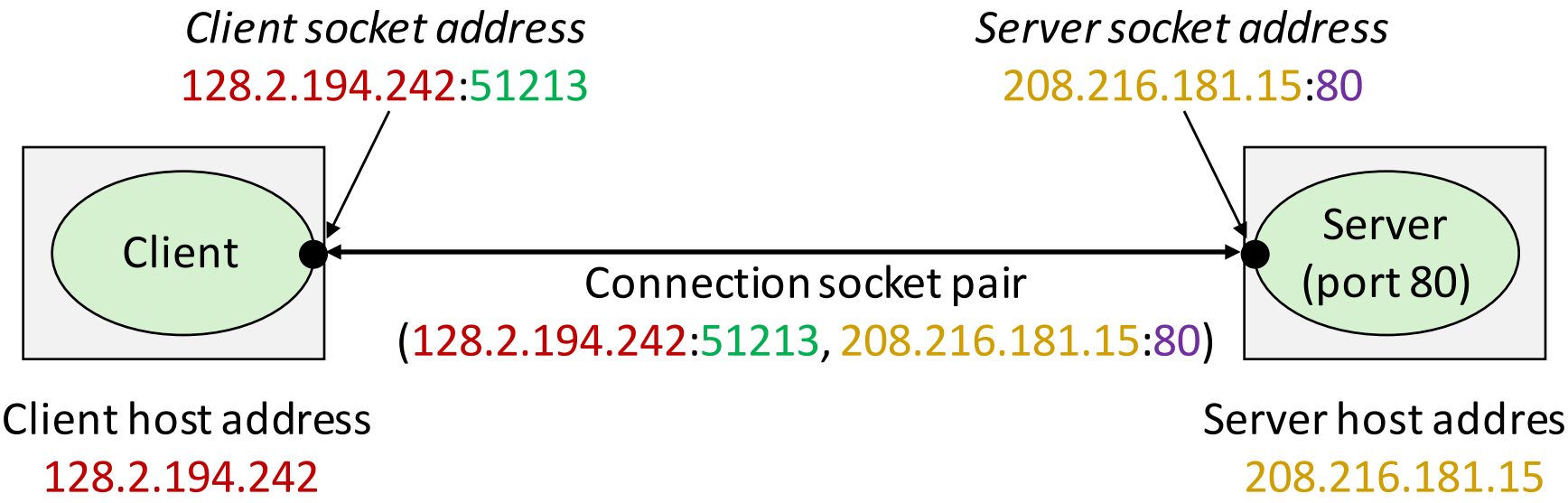
TCP Sockets -Ports

- TCP uses well-known and ephemeral ports
- Well Known Ports: range 0-1023
  - assigned to the server side of an application.
- Registered Ports: range 1024-49151
  - publicly defined; convenience for the Internet community; avoids vendor conflicts
- Dynamic and/or Private Ports: range 49152-65535

  Server
  - can be used freely by any client or server

Anatomy of a Connection

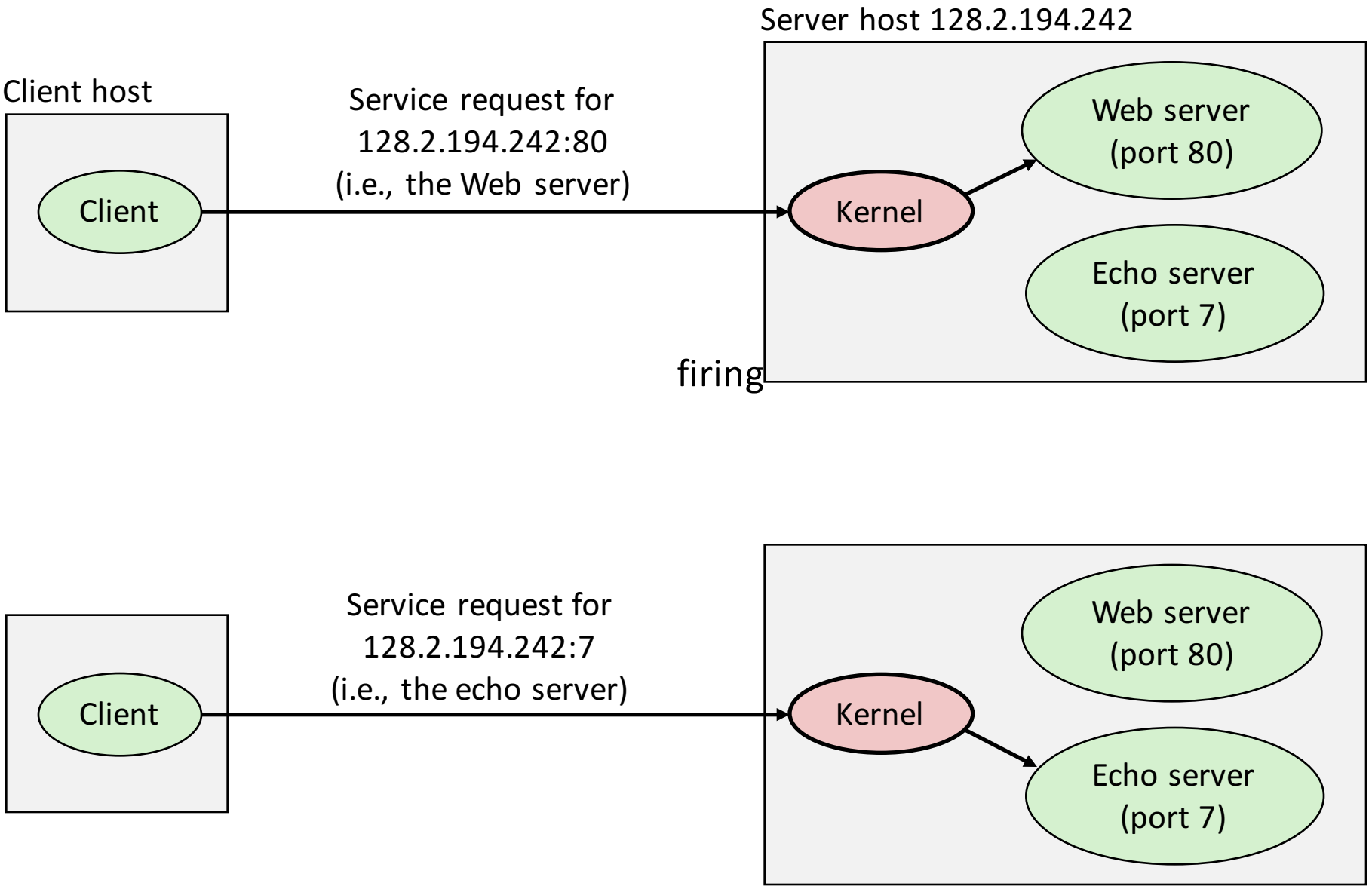
- A connection is uniquely identified by the socket addresses of its endpoints (*socket pair*)
  - **`(cliaddr:cliport, servaddr:servport)`**



51213 is an ephemeral port allocated by the kernel

80 is a well-known port associated with Web servers

Using Ports to Identify Services

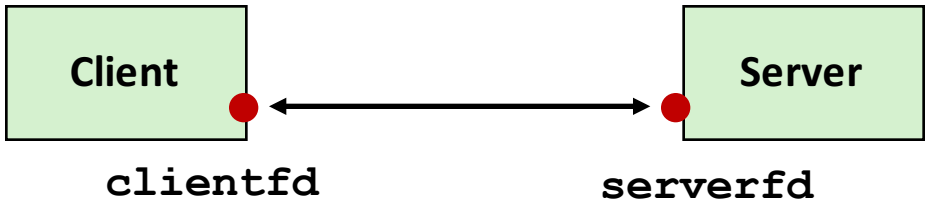


Sockets Interface

- Set of system-level functions used in conjunction with Unix I/O to build network applications.
- Created in the early 80's as part of the original Berkeley distribution of Unix that contained an early version of the Internet protocols.
- Available on all modern systems
  - Unix variants, Windows, OS X, IOS, Android, ARM

Socket is like file I/O

  - To the kernel, a socket is an endpoint of communication
  - To an application, a socket is a file descriptor that lets the application read/write from/to the network
- Remember: All Unix I/O devices, including networks, are modeled as “files”
  - Clients and servers communicate with each other by reading from and writing to socket descriptors

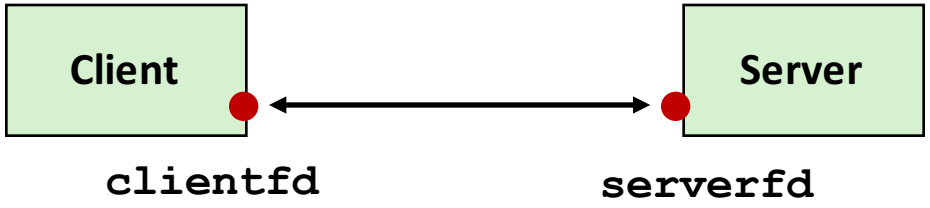


- The main distinction between regular file I/O and socket I/O is how the application “opens” the socket descriptors

Socket v.s. pipe

- Fundamental difference between a socket and a pipe: sockets serve to interconnect two processes that execute on arbitrary machines. (Pipes work only on the same machine.)
  - Two processes can execute on the same host, or
  - on networked hosts across the world from each other.

  The set up and operations on the sockets are the same!



- TCP sockets implement a high level abstraction:
  - It gives the programmer a byte-stream communication channel across networked hosts that is reliable and order-preserving.

iClicker question

Suppose there is a connection from:

192.168.0.17:53268 to 128.119.40.1:80

Which of these statements is true?

A) 192.168.0.17 is the client

B) 53268 is an ephemeral port

C) 128.119.40.1 is the server

D) 80 is a well-known port (for HTTP)

E) All of the above

iClicker question solution

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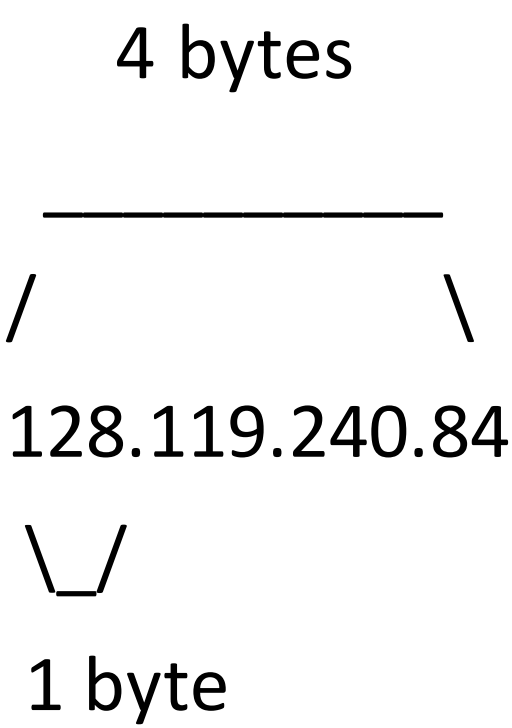
SOCKET ADDRESSING

Ipv4 address: a dotted quad



Storing an IP address in struct in_addr

```
typedef uint32_t in_addr_t;
struct in_addr
{
  in_addr_t s_addr;
};
```

Storing an IP address in struct in_addr

```
int main(){
  struct in_addr addr;
  unsigned char * ip;

  ip = (unsigned char *) &(addr.s_addr);

  ip[0]=128;
  ip[1]=119;
  ip[2]=240;
  ip[3]=84;

  printf("Hello %s\n", inet_ntoa(addr));
}
```

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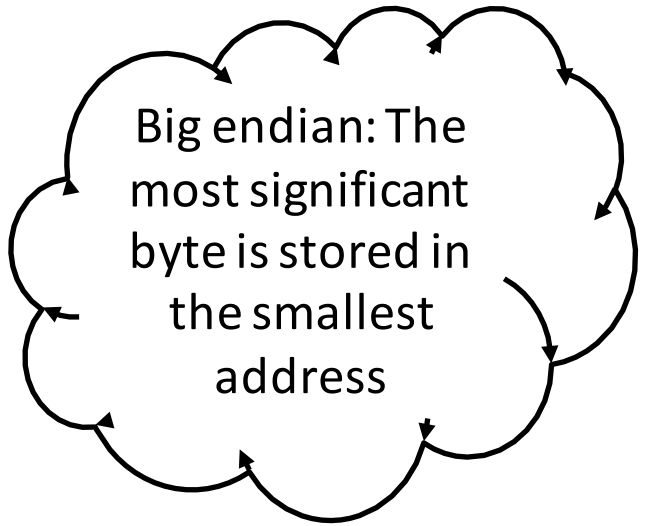
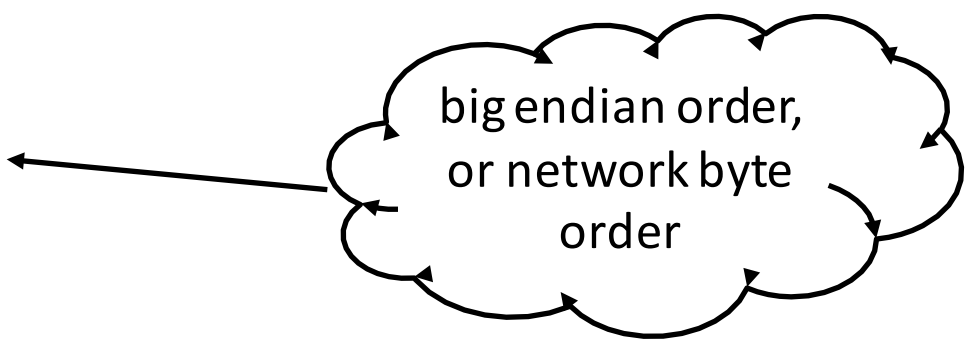


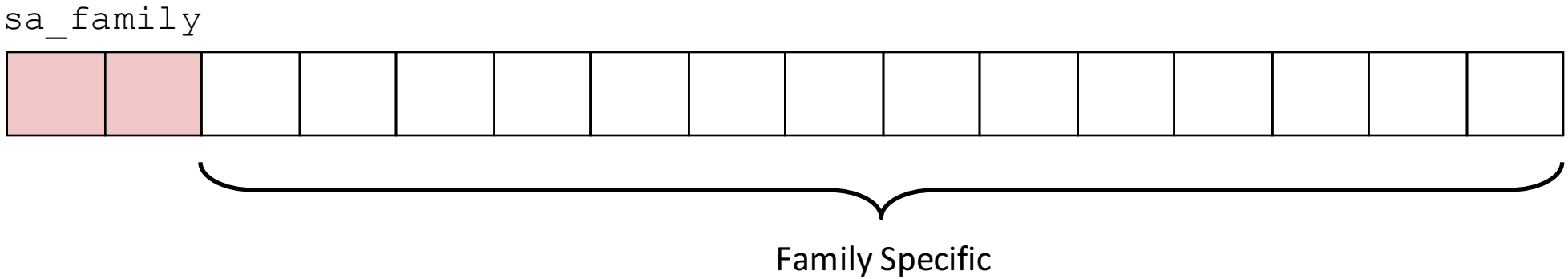


Storing an IP address in struct in_addr

```
int main(){
  struct in_addr addr;
  inet_aton("128.119.240.84",  &(addr));
  printf("Hello %s\n", inet_ntoa(addr));
}
```

Socket Address Structures

```
struct sockaddr {
  uint16_t  sa_family;    /* Protocol family */
  char      sa_data[14];  /* Address data.  */
};
```



Socket Address Structures

- Generic socket address:
  - For address arguments to **`connect`**, **`bind`**, and **`accept`**
  - Necessary only because C did not have generic (**`void *`**) pointers when the sockets interface was designed

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  uint16_t  sa_family;    /* Protocol family */
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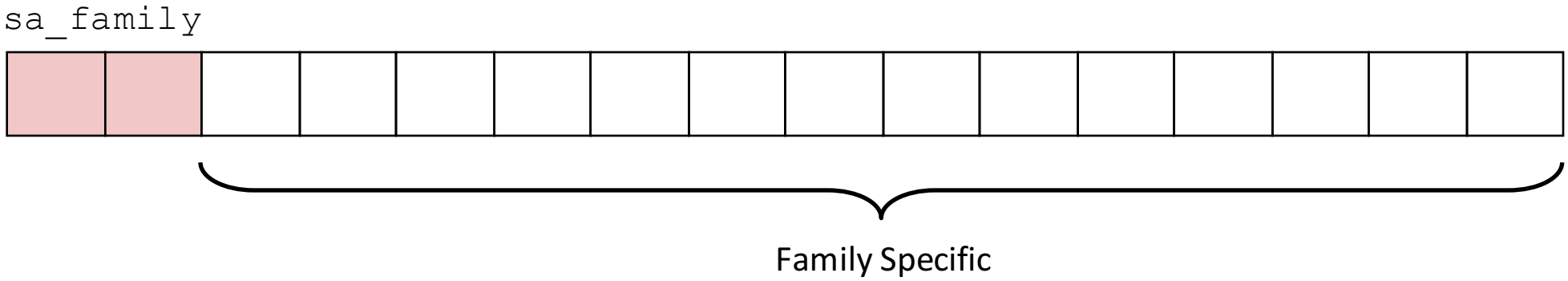
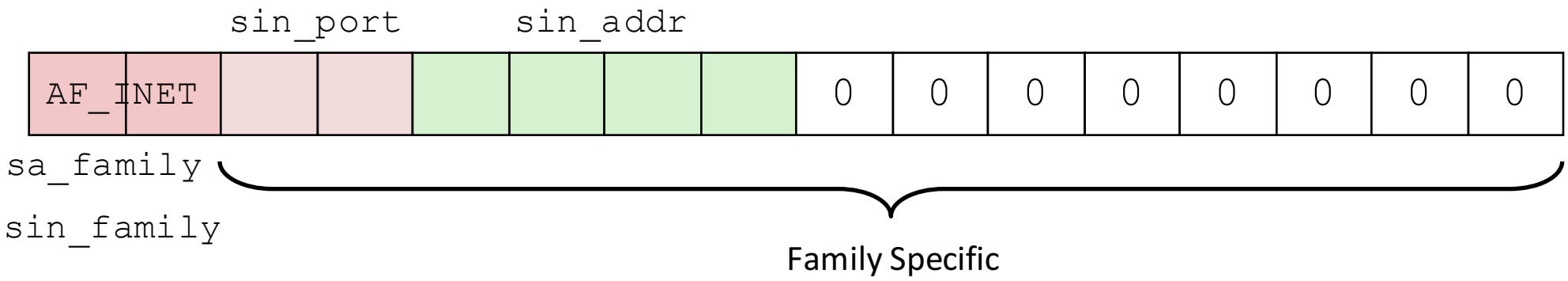
```



Socket Address Structures

- Internet-specific socket address

```
struct sockaddr_in  {
  uint16_t        sin_family;  /* Protocol family (always AF_INET) */
  uint16_t        sin_port;    /* Port num in network byte order */
  struct in_addr  sin_addr;    /* IP addr in network byte order */
  unsigned char   sin_zero[8]; /* Pad to sizeof(struct sockaddr) */
};
```



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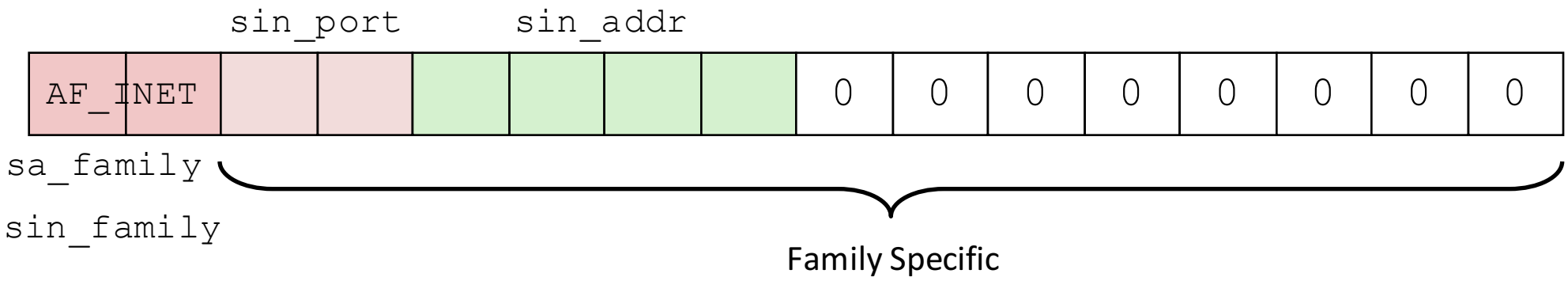

Socket Address Structures

- Internet-specific socket address:
  - sockaddr_in is like a subtype of sockaddr
  - Must cast (`struct sockaddr_in *`) to (`struct sockaddr *`) for functions that take socket address arguments.

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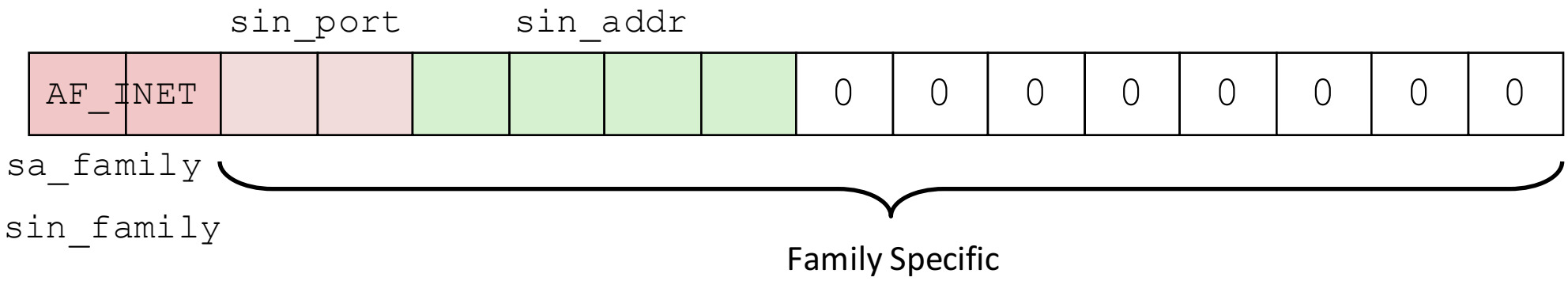

Storing IP Addresses in sockaddr_in

```
int main(){
  struct sockaddr saddr;
  struct sockaddr_in * saddr_in = (struct sockaddr_in *)
&saddr;
  inet_aton("128.119.240.84",  &(saddr_in->sin_addr));
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Is this correct in little endian systems?

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struct sockaddr_in * saddr_in = (struct sockaddr_in *) &saddr;

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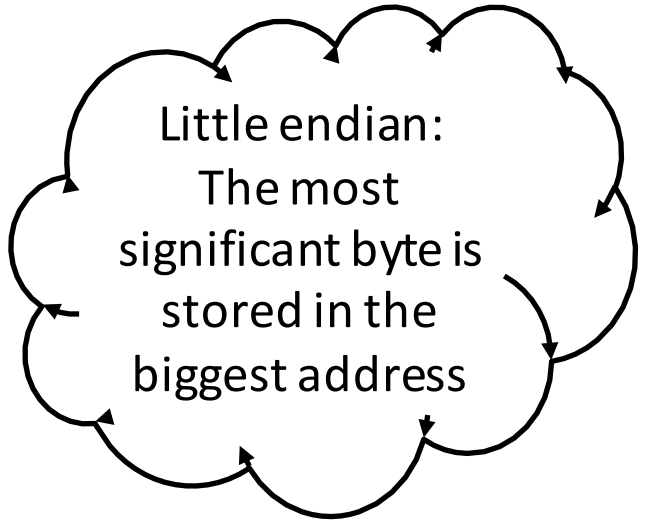

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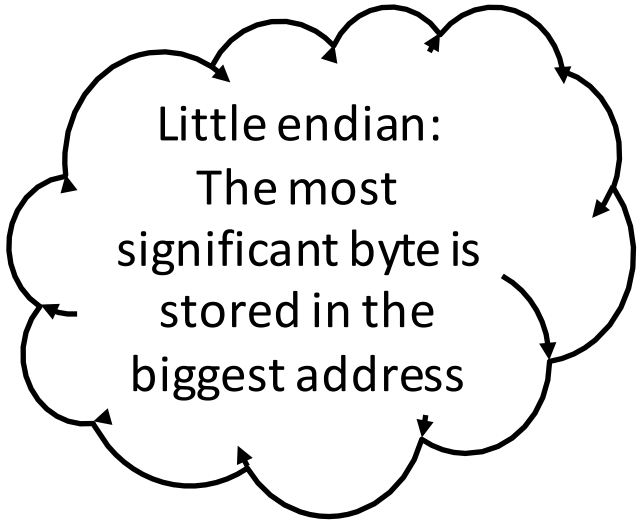
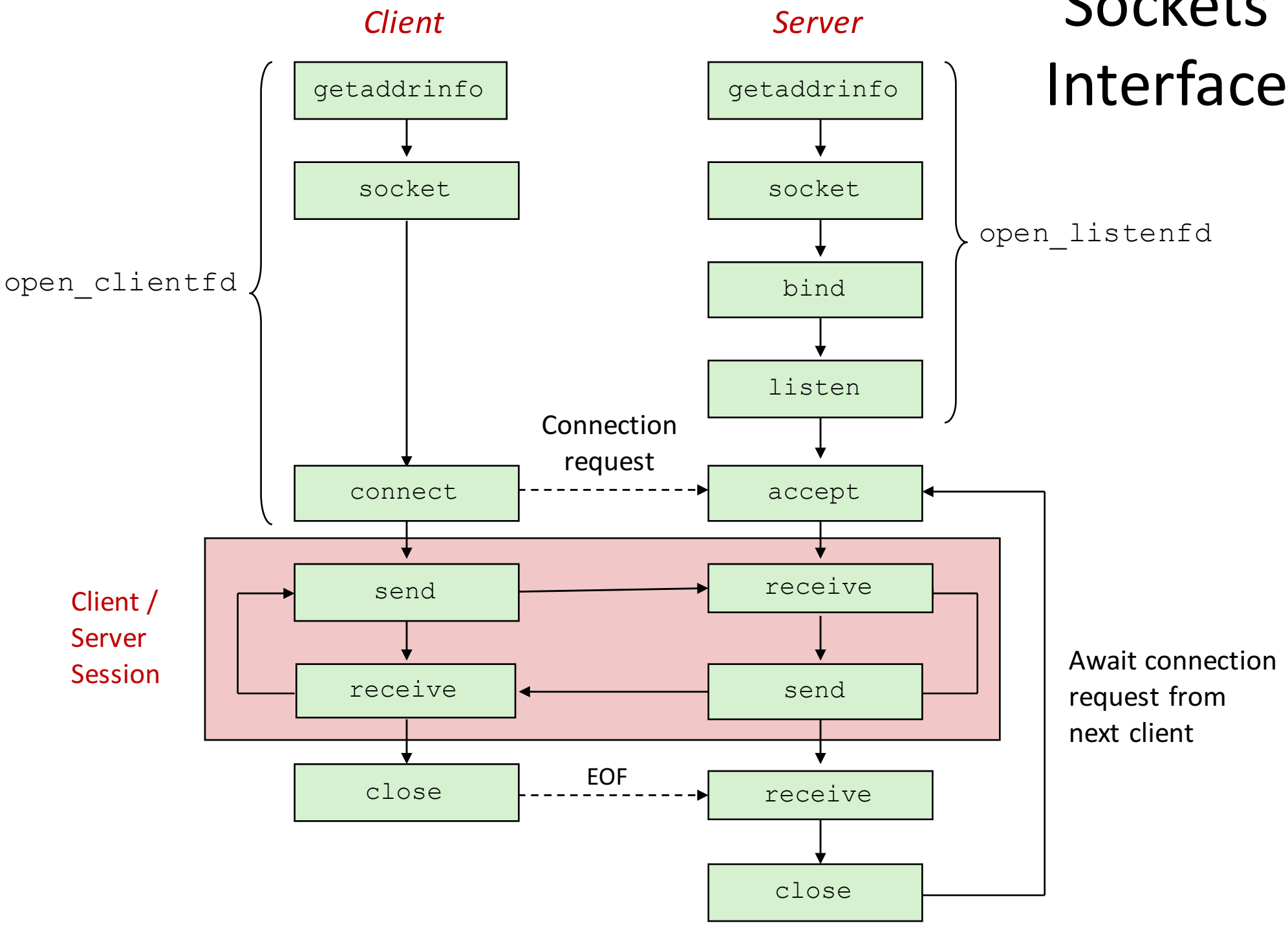


SOCKET API

Sockets Interface



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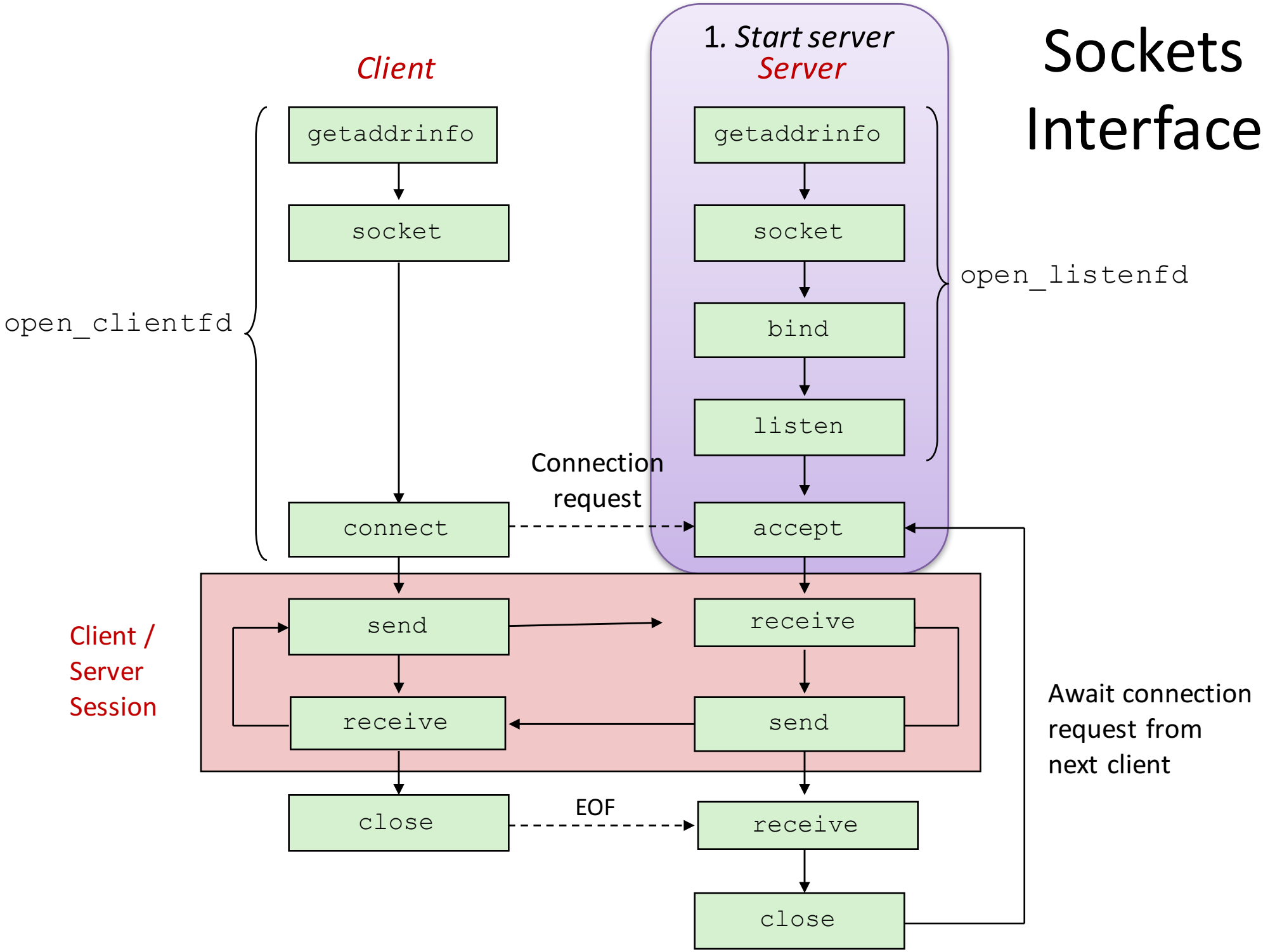
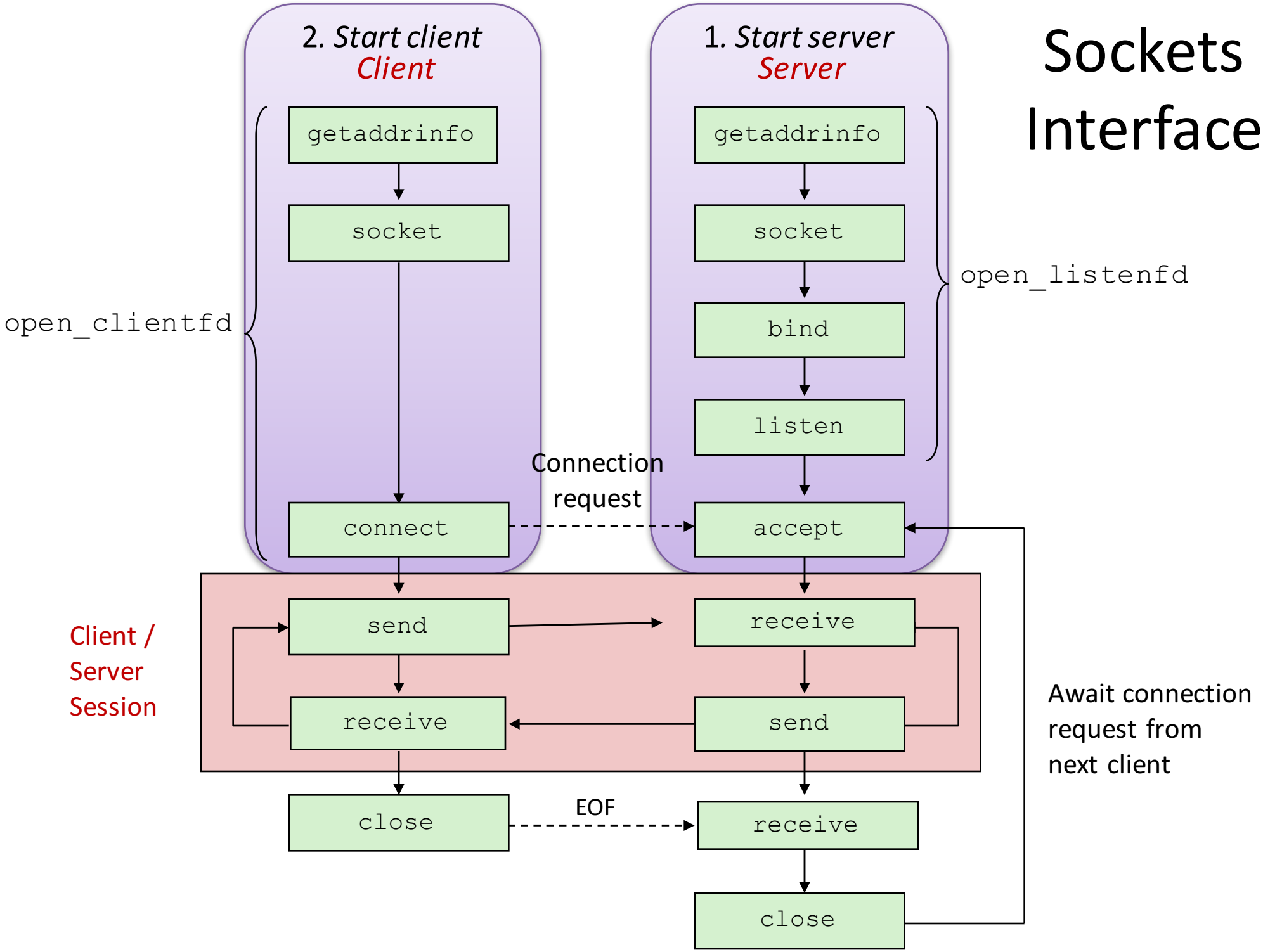
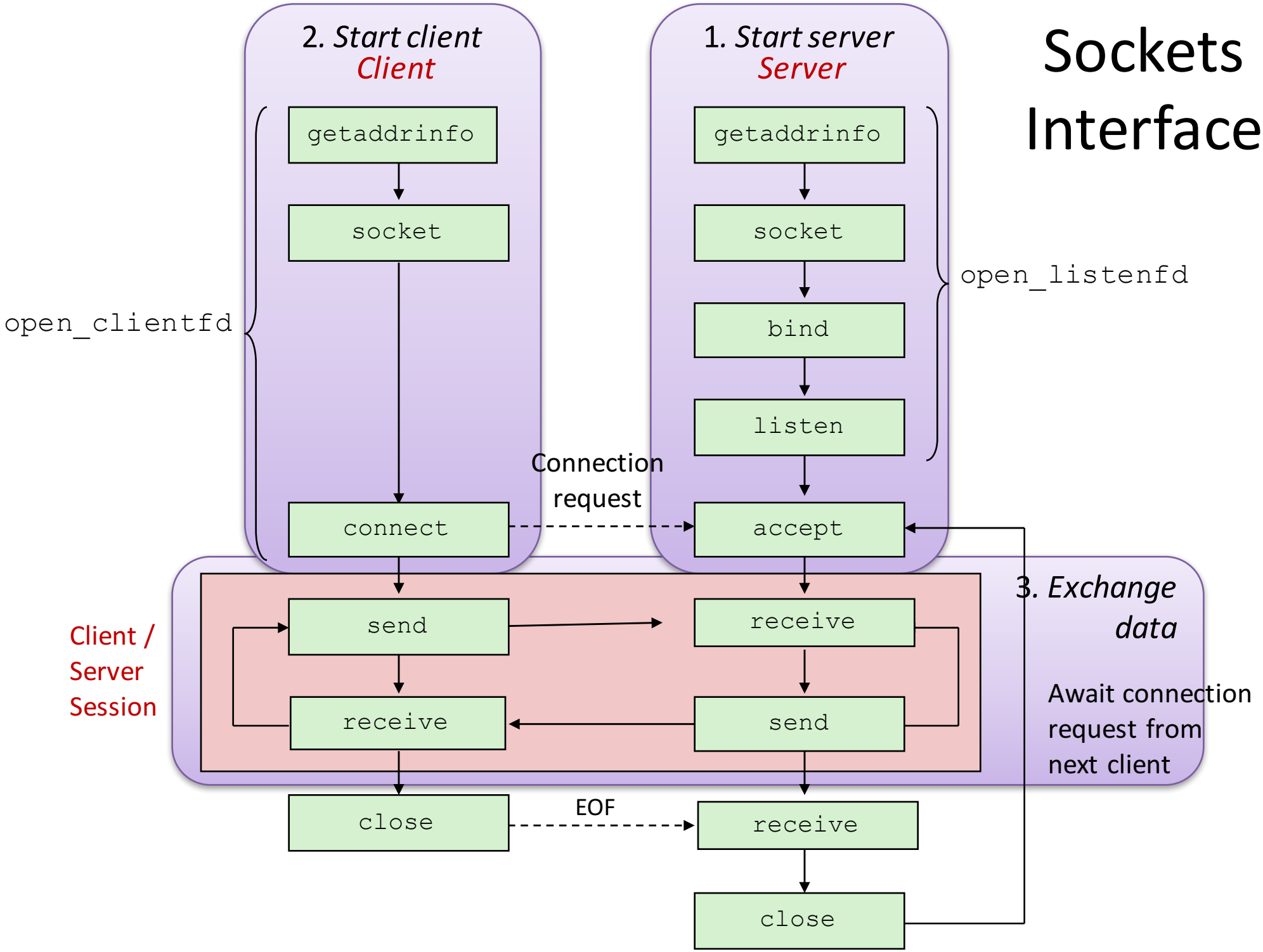


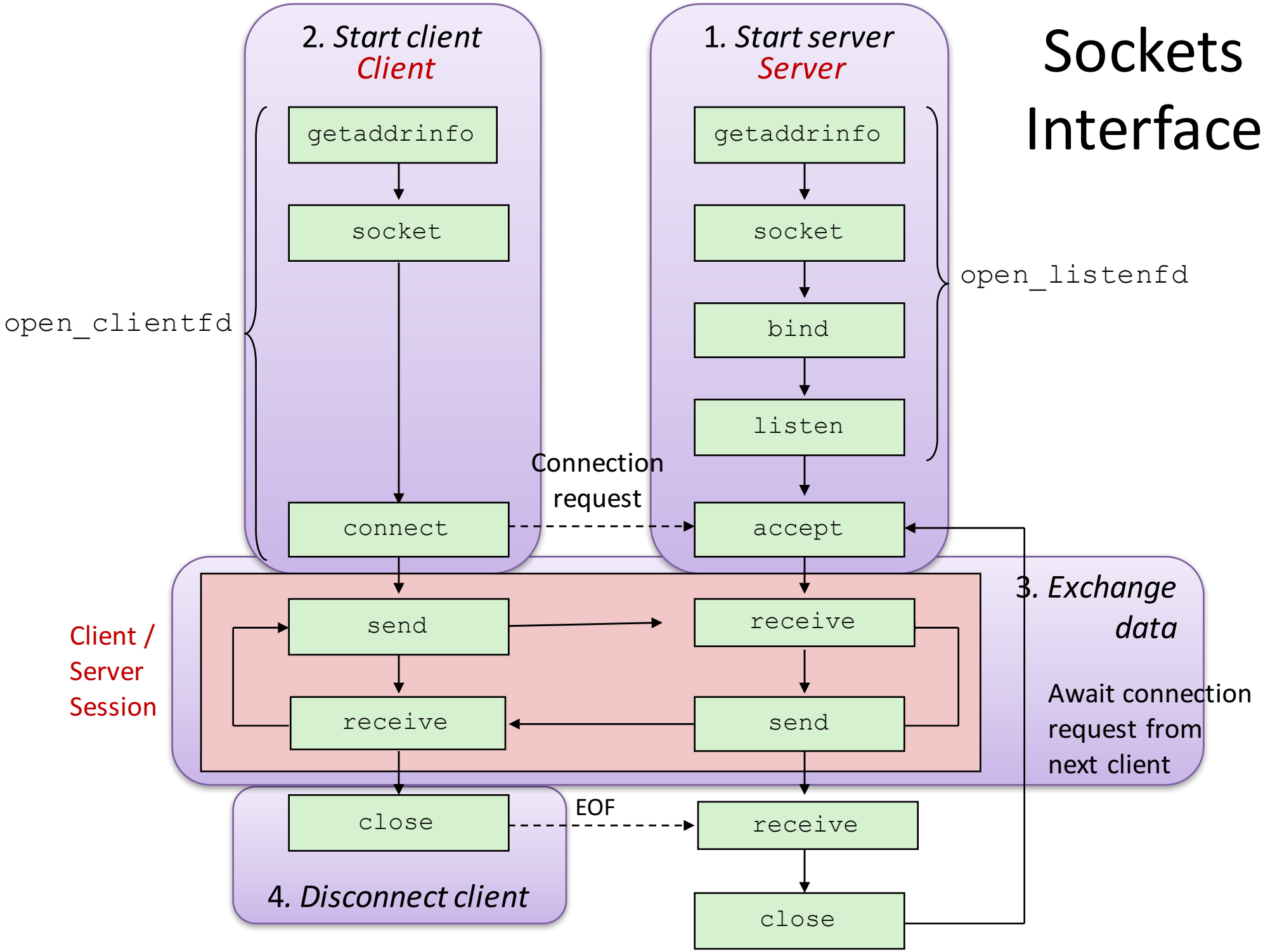
Sockets Interface



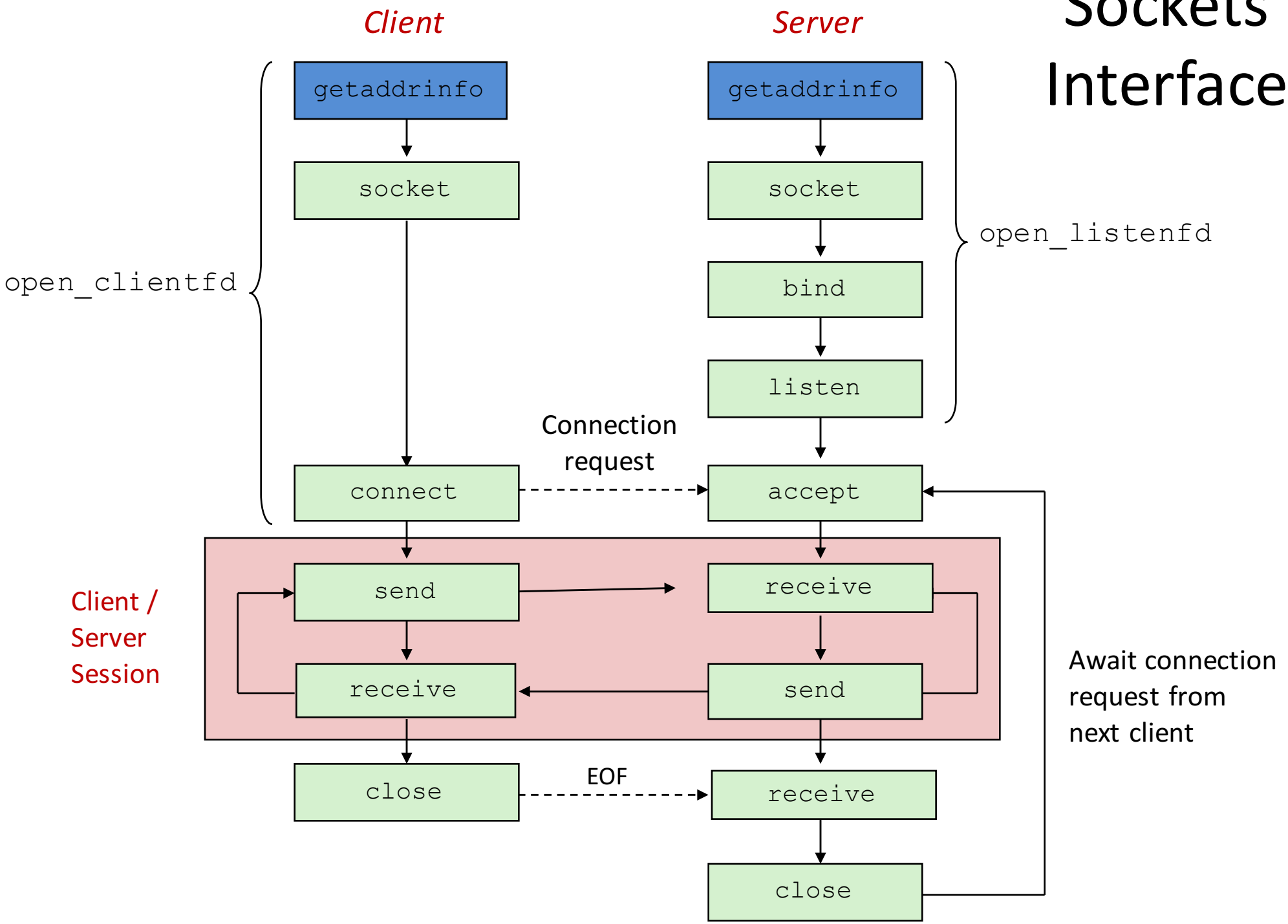
Sockets Interface



Sockets Interface



Sockets Interface



Host and Service Conversion: `getaddrinfo`

```
int getaddrinfo(const char *host,              /* Hostname or address */
                const char *service,           /* Port or service name */
                const struct addrinfo *hints,/* Input parameters */
                struct addrinfo **result);    /* Output linked list */
```

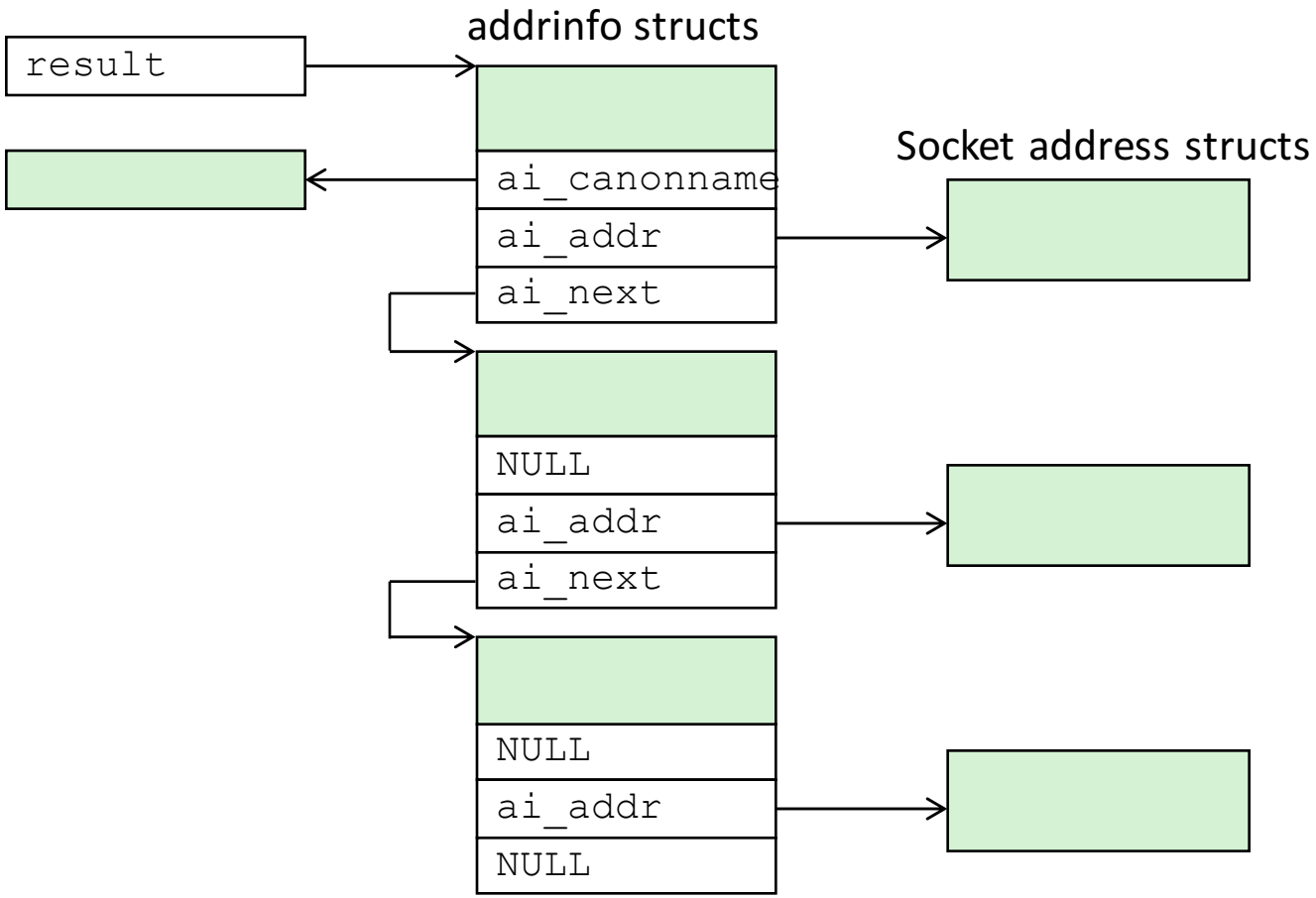
- Given `host` and `service`, `getaddrinfo` returns `result` that points to a linked list of `addrinfo` structs, each of which points to a corresponding socket address struct, and which contains arguments for the sockets interface functions.

Host and Service Conversion: `getaddrinfo`

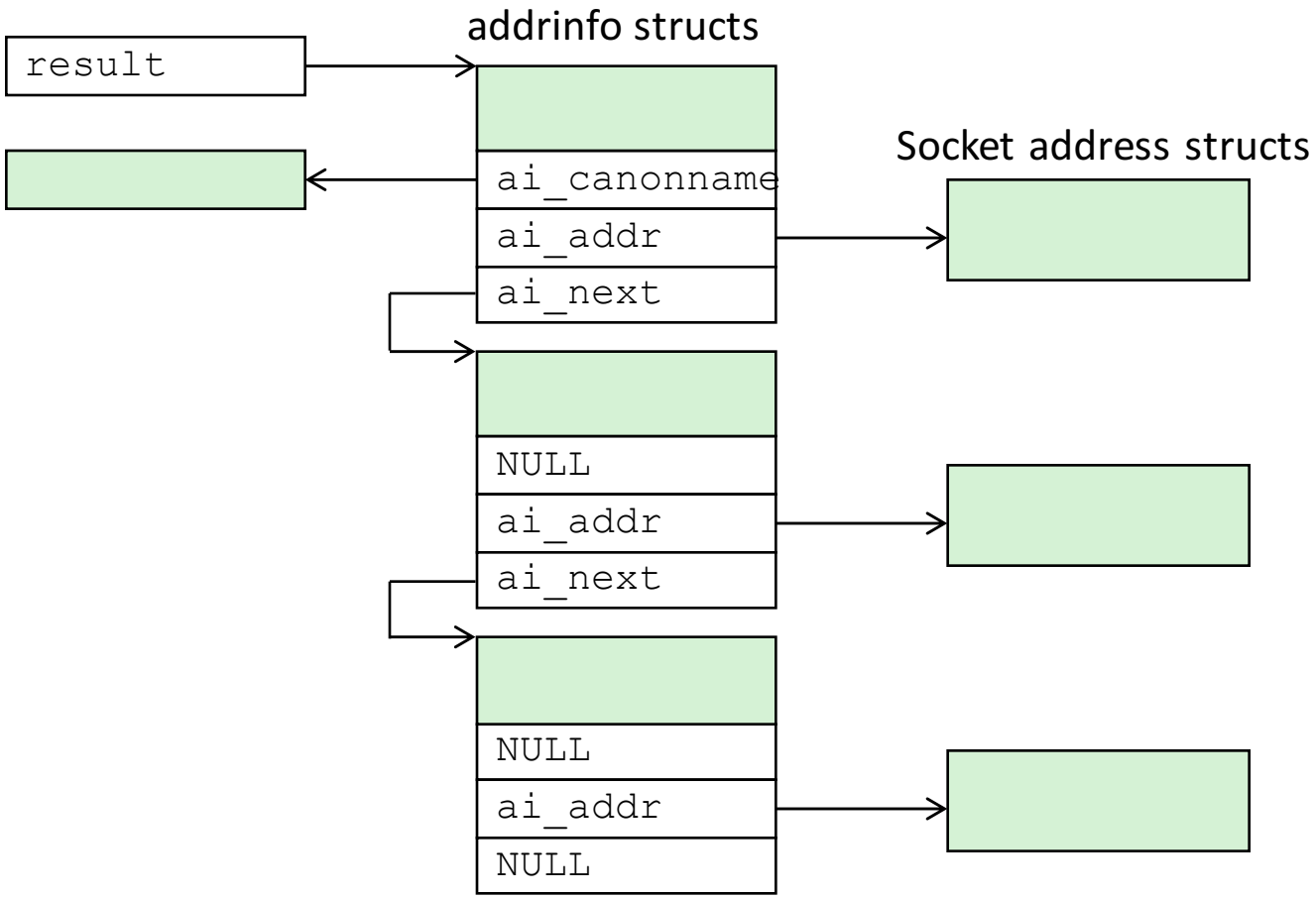
```
int getaddrinfo(const char *host,              /* Hostname or address */
                const char *service,           /* Port or service name */
                const struct addrinfo *hints,/* Input parameters */
                struct addrinfo **result);    /* Output linked list */

void freeaddrinfo(struct addrinfo *result);   /* Free linked list */

const char *gai_strerror(int errcode);        /* Return error msg */
```

- Given `host` and `service`, `getaddrinfo` returns `result` that points to a linked list of `addrinfo` structs, each of which points to a corresponding socket address struct, and which contains arguments for the sockets interface functions.
- Helper functions:
  - `freeadderinfo` frees the entire linked list.
  - `gai_strerror` converts error code to an error message.

Linked List Returned by `getaddrinfo`



Linked List Returned by `getaddrinfo`



- Clients: walk this list, trying each socket address in turn, until the calls to `socket` and `connect` succeed.
- Servers: walk the list until calls to `socket` and `bind` succeed.

`addrinfo` Struct

```
struct addrinfo {
    int              ai_flags;     /* Hints argument flags */
    int              ai_family;    /* First arg to socket function */
    int              ai_socktype;  /* Second arg to socket function */
    int              ai_protocol;  /* Third arg to socket function  */
    char            *ai_canonname; /* Canonical host name */
    size_t           ai_addrlen;   /* Size of ai_addr struct */
    struct sockaddr *ai_addr;      /* Ptr to socket address structure */
    struct addrinfo *ai_next;      /* Ptr to next item in linked list */
};
```

- Each addrinfo struct returned by getaddrinfo contains arguments that can be passed directly to `socket` function.
- Also points to a socket address struct that can be passed directly to `connect` and `bind` functions.

Host and Service Conversion: `getnameinfo`

- `getnameinfo` is the inverse of getaddrinfo, converting a socket address to the corresponding host and service.
  - Replaces obsolete `gethostbyaddr` and `getservbyport` funcs.
  - Reentrant and protocol independent.

```
int getnameinfo(const SA *sa, socklen_t salen, /* In: socket addr */
                char *host, size_t hostlen,    /* Out: host */
                char *serv, size_t servlen,    /* Out: service */
                int flags);                    /* optional flags */
```

Conversion Example

```
#include "csapp.h"

int main(int argc, char **argv)
{
    struct addrinfo *p, *listp, hints;
    char buf[MAXLINE];
    int rc, flags;

    /* Get a list of addrinfo records */
    memset(&hints, 0, sizeof(struct addrinfo));
    hints.ai_family = AF_INET;        /* IPv4 only */
    hints.ai_socktype = SOCK_STREAM;  /* Connections only */
    if ((rc = getaddrinfo(argv[1], NULL, &hints, &listp)) != 0) {
        fprintf(stderr, "getaddrinfo error: %s\n", gai_strerror(rc));
        exit(1);
    }
```

hostinfo.c

Conversion Example (cont)

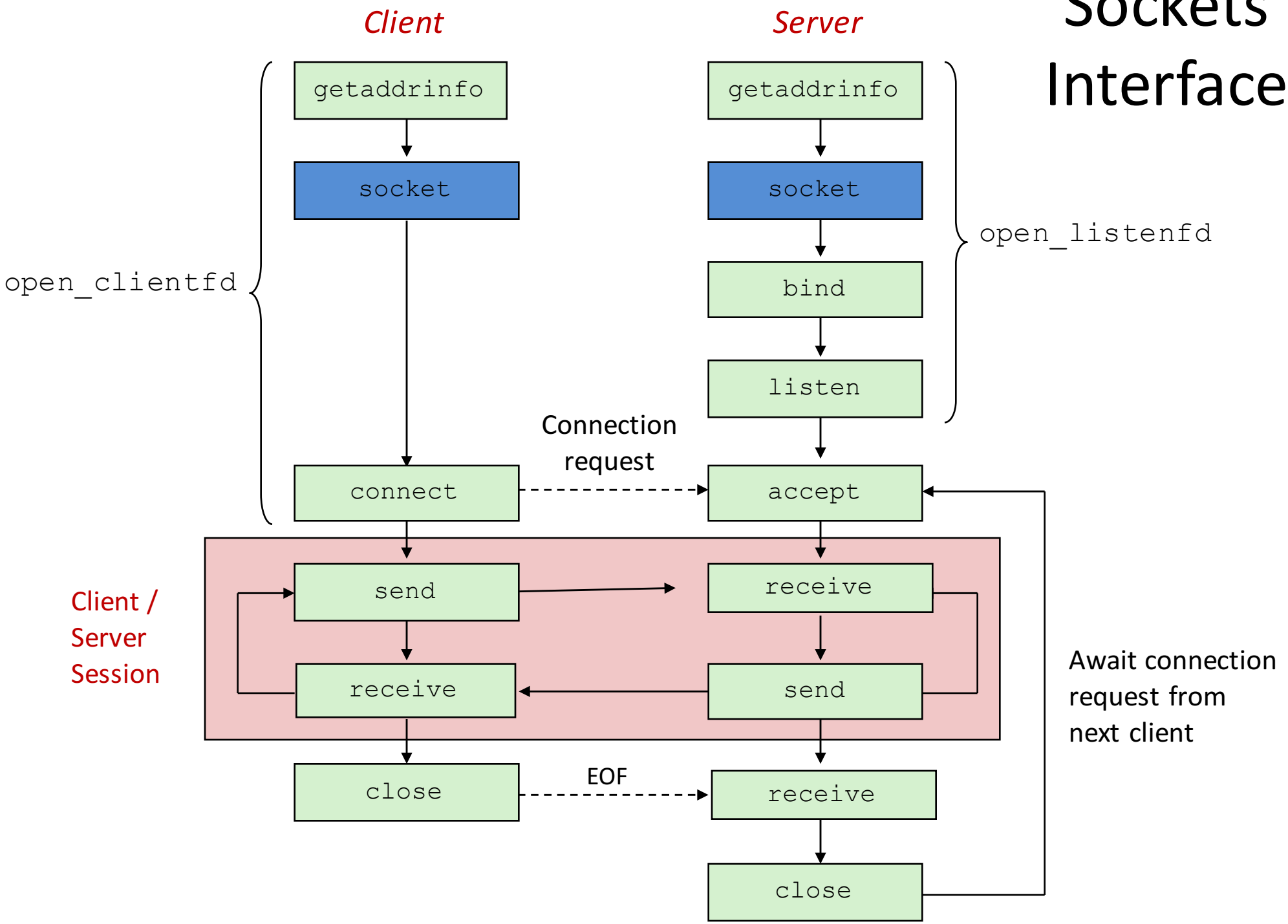
```
    /* Walk the list and display each IP address */
    flags = NI_NUMERICHOST; /* Display address instead of name */
    for (p = listp; p; p = p->ai_next) {
        Getnameinfo(p->ai_addr, p->ai_addrlen,
                    buf, MAXLINE, NULL, 0, flags);
        printf("%s\n", buf);
    }

    /* Clean up */
    Freeaddrinfo(listp);

    exit(0);
}
```

hostinfo.c

Running hostinfo

```
student@osboxes:~/Code/lec24$ ./hostinfo amazon.com
54.239.25.192
54.239.25.208
54.239.25.200
54.239.17.6
54.239.26.128
54.239.17.7

student@osboxes:~/Code/lec24$ ./hostinfo google.com
216.58.219.206

student@osboxes:~/Code/lec24$ ./hostinfo localhost
127.0.0.1

student@osboxes:~/Code/lec24$ ./hostinfo umass.edu
128.119.103.148
```

Sockets Interface



Sockets Interface: `socket`

- Clients and servers use the `socket` function to create a *socket descriptor*:
- Example:

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

Indicate protocol number, normally 0

```
int clientfd = Socket(AF_INET, SOCK_STREAM, 0);
```

Indicates that we are using 32-bit IPV4 addresses

Indicates socket type

Sockets Interface: `socket`

- Clients and servers use the `socket` function to create a *socket descriptor*.
- Example:

Protocol specific! Best practice is to use `getaddrinfo` to generate the parameters automatically, so that code is protocol independent.

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

Indicate protocol number, normally 0

```
int clientfd = Socket(AF_INET, SOCK_STREAM, 0);
```

Indicates that we are using 32-bit IPV4 addresses

Indicates socket type

`addrinfo` Struct

```
struct addrinfo {
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    int              ai_family;    /* First arg to socket function */
    int              ai_socktype;  /* Second arg to socket function */
    int              ai_protocol;  /* Third arg to socket function  */
    char            *ai_canonname; /* Canonical host name */
    size_t           ai_addrlen;   /* Size of ai_addr struct */
    struct sockaddr *ai_addr;      /* Ptr to socket address structure */
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};
```

- Each addrinfo struct returned by getaddrinfo contains arguments that can be passed directly to `socket` function.
- Also points to a socket address struct that can be passed directly to `connect` and `bind` functions.

Sockets Interface: `socket`

- Clients and servers use the `socket` function to create a *socket descriptor*.
- Example:

Protocol specific! Best practice is to use `getaddrinfo` to generate the parameters automatically, so that code is protocol independent.

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

Indicate protocol number, normally 0

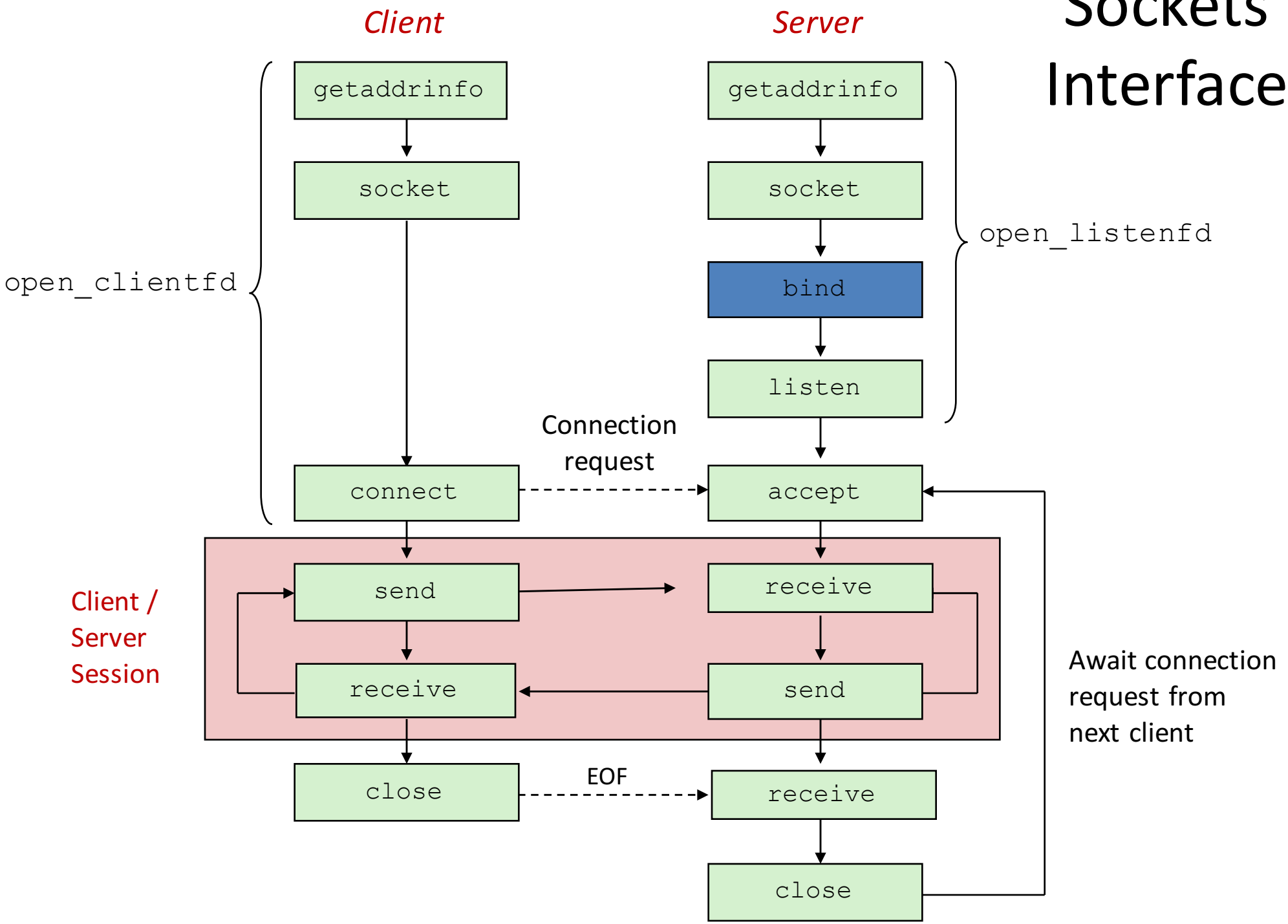
```
int clientfd = Socket(AF_INET, SOCK_STREAM, 0);
```

A socket descriptor

Indicates that we are using 32-bit IPV4 addresses

Indicates socket type

Sockets Interface



Sockets Interface: `bind`

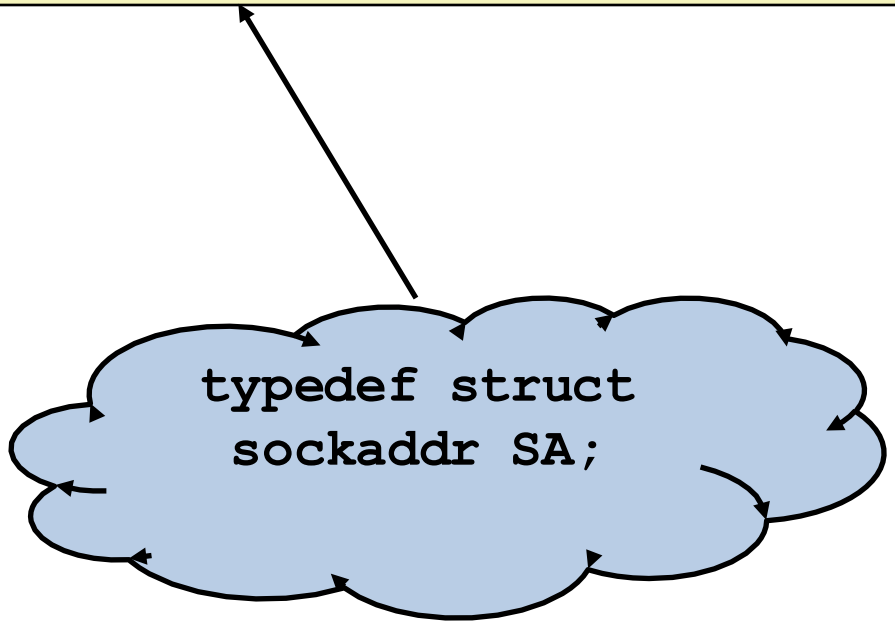
- A server uses `bind` to ask the kernel to associate the server's socket address with a socket descriptor:

- The process can read bytes that arrive on the connection whose endpoint is `addr` by reading from descriptor `sockfd`.
- Similarly, writes to `sockfd` are transferred along connection whose endpoint is `addr`.

Sockets Interface: `bind`

- A server uses `bind` to ask the kernel to associate the server's socket address with a socket descriptor:

```
int bind(int sockfd, SA *addr, socklen_t addrlen);
```

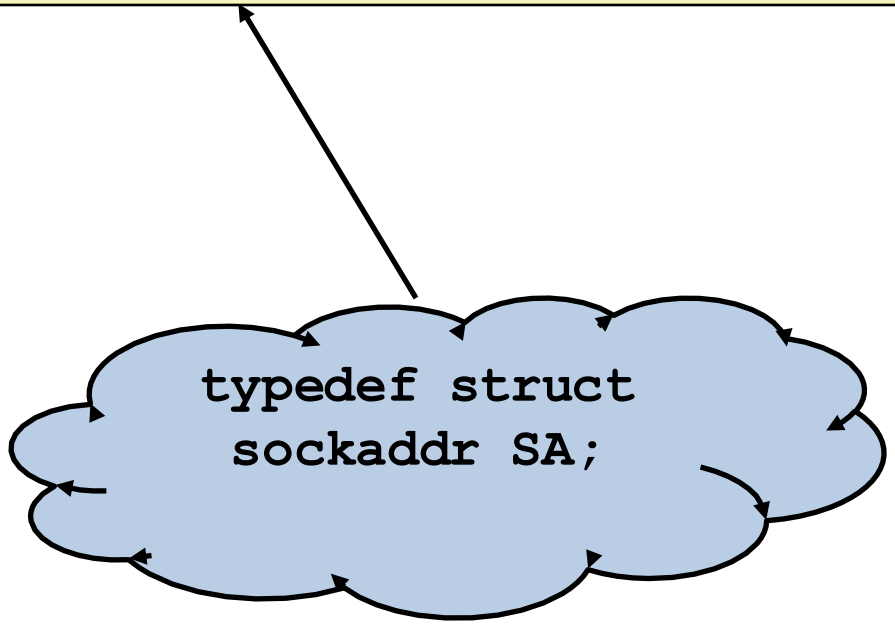


Sockets Interface: `bind`

- A server uses `bind` to ask the kernel to associate the server's socket address with a socket descriptor:

Best practice is to use `getaddrinfo` to supply the arguments `addr` and `addrlen`.

```
int bind(int sockfd, SA *addr, socklen_t addrlen);
```

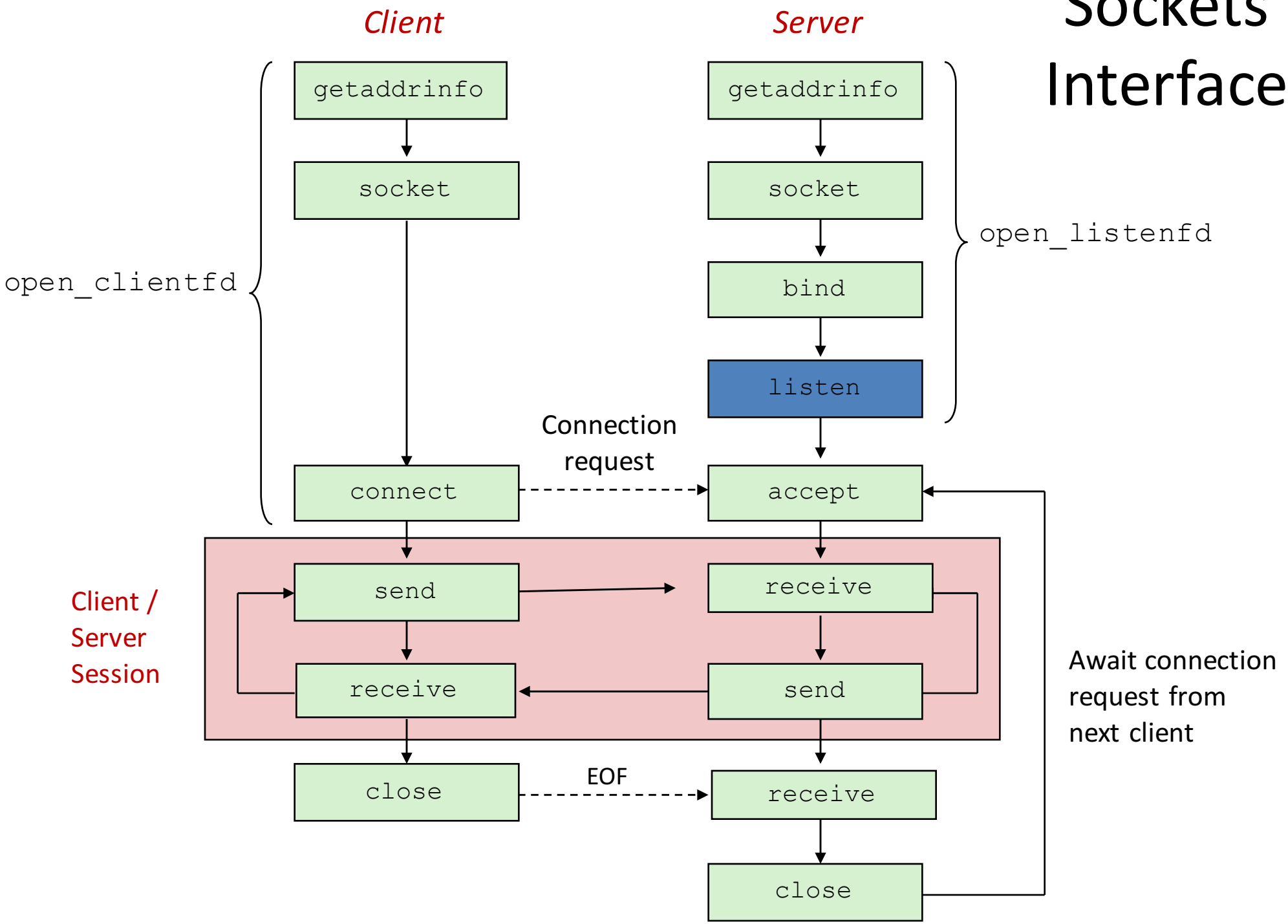


`addrinfo` Struct

```
struct addrinfo {
    int              ai_flags;     /* Hints argument flags */
    int              ai_family;    /* First arg to socket function */
    int              ai_socktype;  /* Second arg to socket function */
    int              ai_protocol;  /* Third arg to socket function  */
    char            *ai_canonname; /* Canonical host name */
    size_t           ai_addrlen;   /* Size of ai_addr struct */
    struct sockaddr *ai_addr;      /* Ptr to socket address structure */
    struct addrinfo *ai_next;      /* Ptr to next item in linked list */
};
```

- Each addrinfo struct returned by getaddrinfo contains arguments that can be passed directly to `socket` function.
- Also points to a socket address struct that can be passed directly to `connect` and `bind` functions.

Sockets Interface



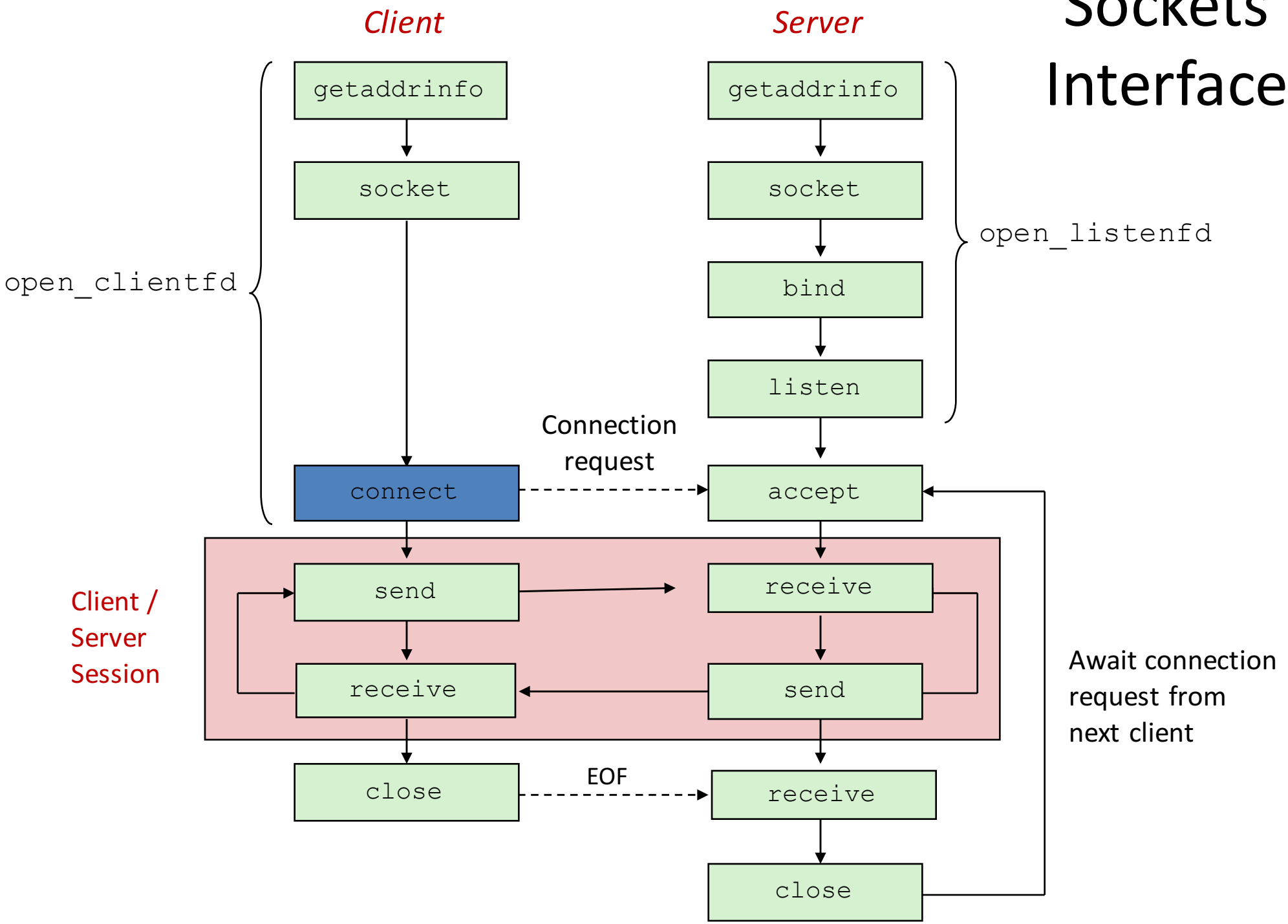
Sockets Interface: `listen`

- By default, kernel assumes that descriptor from socket function is an *active socket* that will be on the client end of a connection.
- A server calls the listen function to tell the kernel that a descriptor will be used by a server rather than a client:

```
int listen(int sockfd, int backlog);
```

- Converts `sockfd` from an active socket to a *listening socket* that can accept connection requests from clients.
- `backlog` is a hint about the number of outstanding connection requests that the kernel should queue up before starting to refuse requests.

Sockets Interface



Sockets Interface: `connect`

- A client establishes a connection with a server by calling connect:
- Attempts to establish a connection with server at socket address `addr`
  - If successful, then `clientfd` is now ready for reading and writing.
  - Resulting connection is characterized by socket pair
    `(x:y, addr.sin_addr:addr.sin_port)`
    - `x` is client address
    - `y` is ephemeral port that uniquely identifies client process on client host

Best practice is to use `getaddrinfo` to supply the arguments `addr` and `addrlen`.

```
int connect(int clientfd, SA *addr, socklen_t addrlen);
```

`addrinfo` Struct

```
struct addrinfo {
    int              ai_flags;     /* Hints argument flags */
    int              ai_family;    /* First arg to socket function */
    int              ai_socktype;  /* Second arg to socket function */
    int              ai_protocol;  /* Third arg to socket function  */
    char            *ai_canonname; /* Canonical host name */
    size_t           ai_addrlen;   /* Size of ai_addr struct */
    struct sockaddr *ai_addr;      /* Ptr to socket address structure */
    struct addrinfo *ai_next;      /* Ptr to next item in linked list */
};
```

- Each addrinfo struct returned by getaddrinfo contains arguments that can be passed directly to `socket` function.
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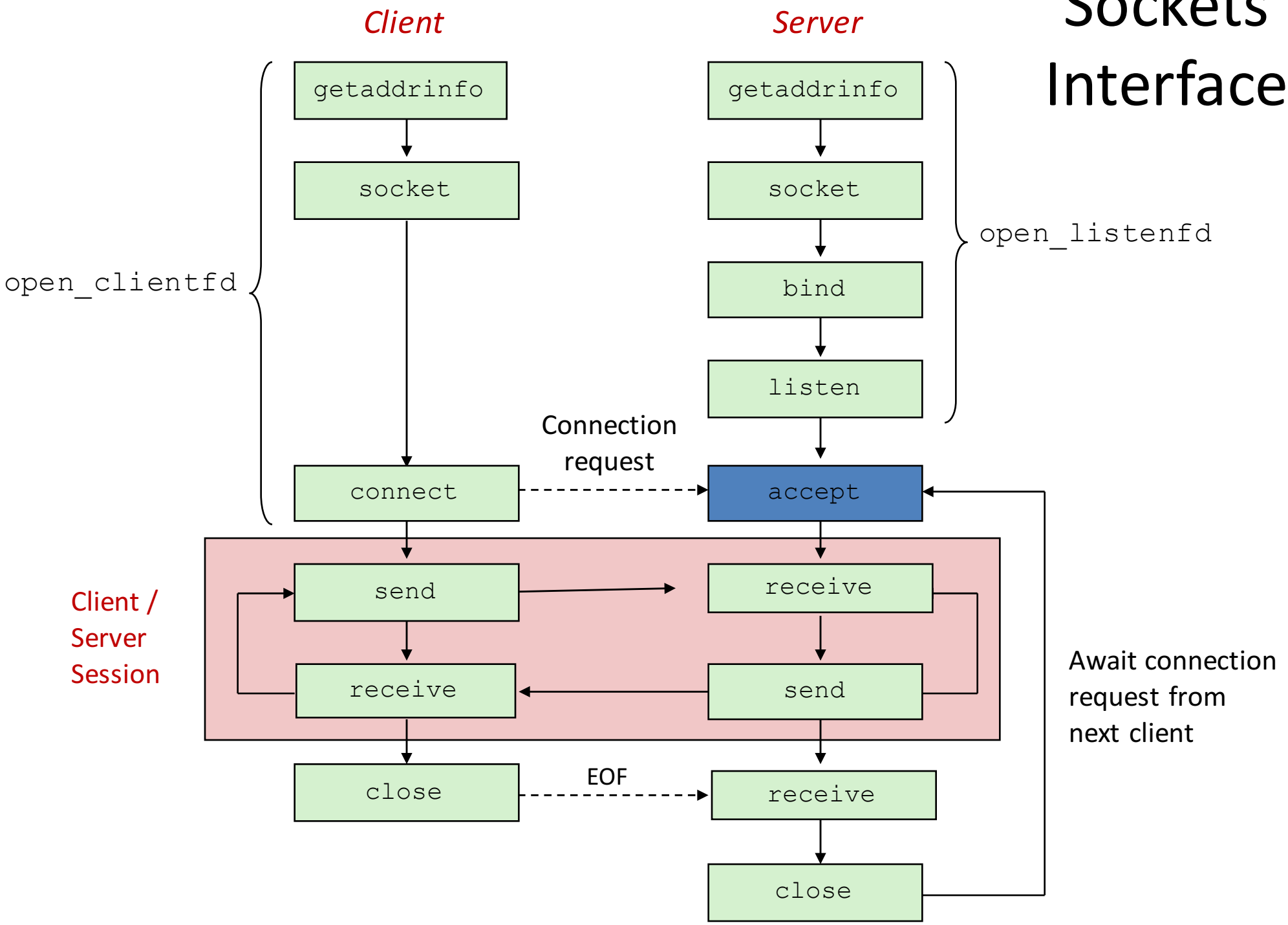
Sockets Interface



Sockets Interface: `accept`

- Servers wait for connection requests from clients by calling `accept`:

```
int accept(int listenfd, SA *addr, int *addrlen);
```

- Waits for connection request to arrive on the connection bound to `listenfd`, then fills in client's socket address in `addr` and size of the socket address in `addrlen`.
- Returns a *connected descriptor* that can be used to communicate with the client via Unix I/O routines.

`accept` Illustrated

1. Server blocks in `accept`, waiting for connection request on listening descriptor `listenfd`

`accept` Illustrated

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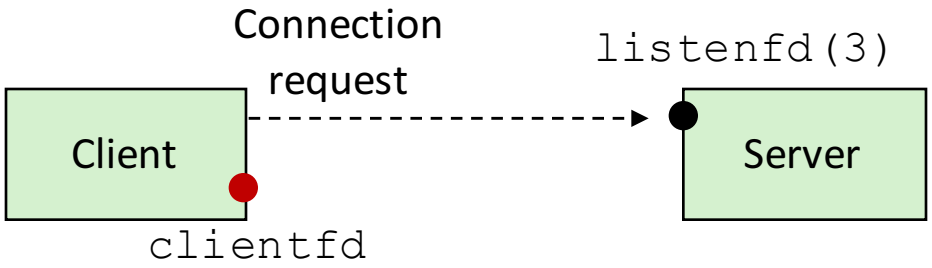
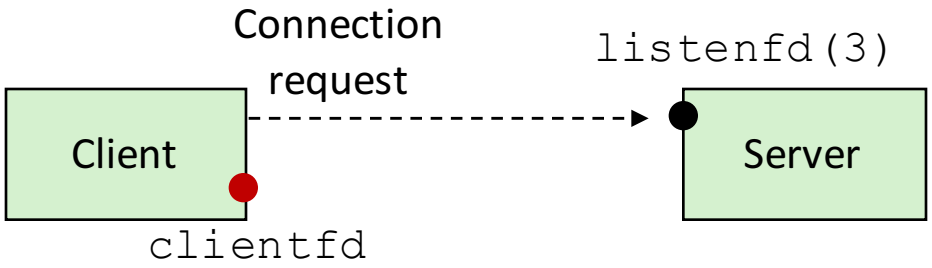


2. Client makes connection request by calling and blocking in `connect`

`accept` Illustrated

1. Server blocks in `accept`, waiting for connection request on listening descriptor `listenfd`



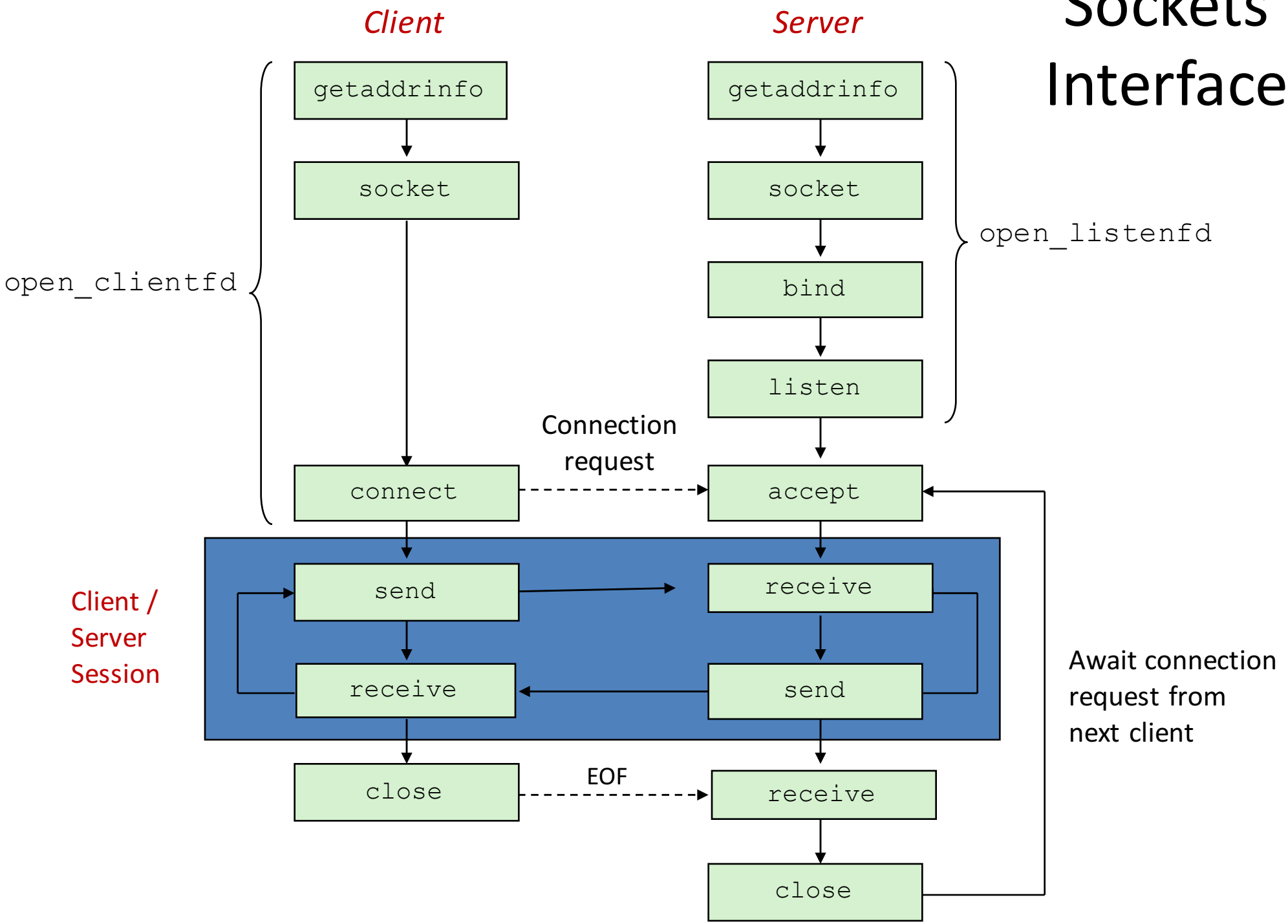
2. Client makes connection request by calling and blocking in `connect`

3. Server returns `connfd` from `accept`. Client returns from `connect`. Connection is now established between `clientfd` and `connfd`

Connected vs. Listening Descriptors

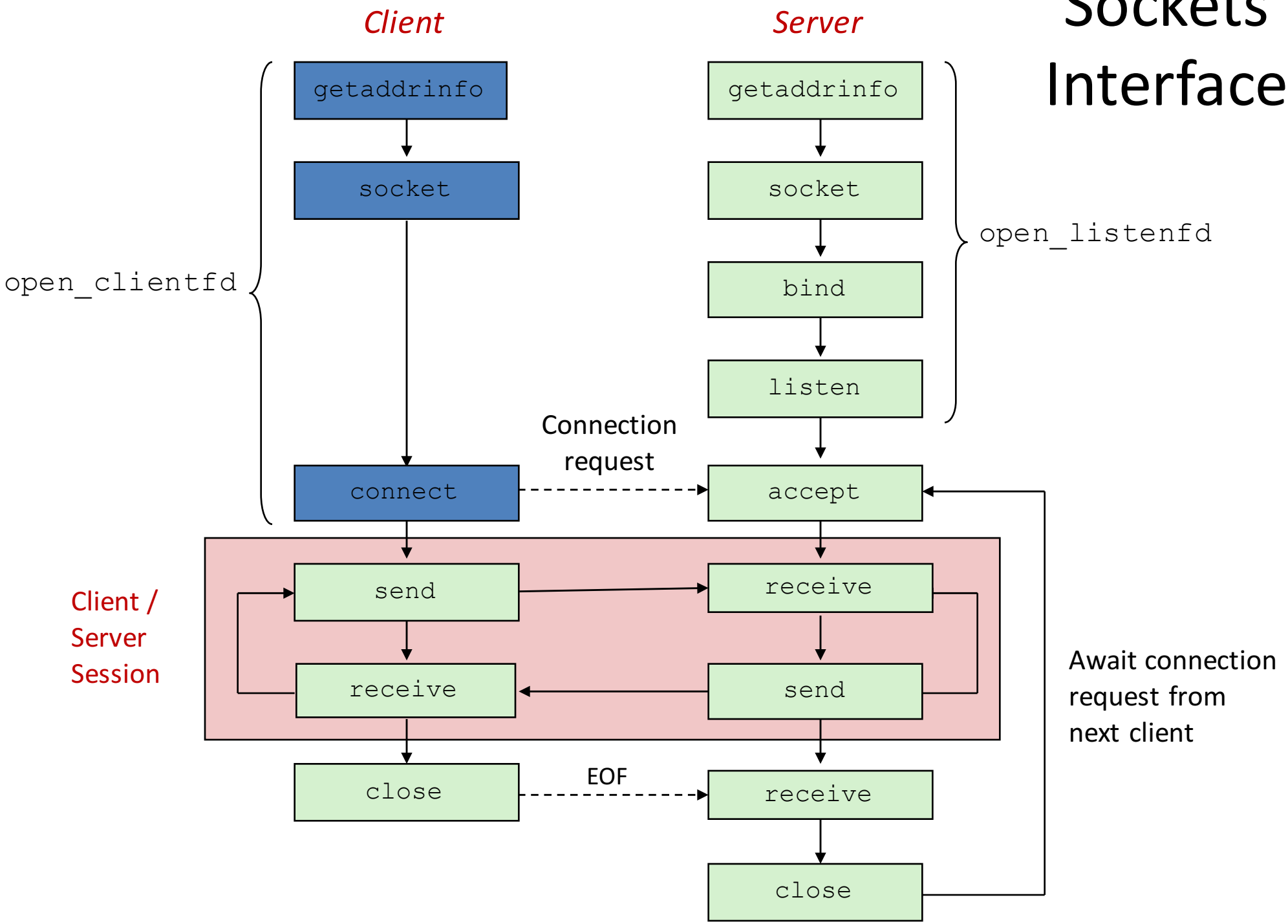
- Listening descriptor
  - End point for client connection requests
  - Created once and exists for lifetime of the server
- Connected descriptor
  - End point of the connection between client and server
  - A new descriptor is created each time the server accepts a connection request from a client
  - Exists only as long as it takes to service client
- Why the distinction?
  - Allows for concurrent servers that can communicate over many client connections simultaneously
    - E.g., Each time we receive a new request, we fork a child to handle the request

Sockets Interface



ECHO SERVER

Sockets Interface



Sockets Helper: `open_clientfd`

- Establish a connection with a server

```
int open_clientfd(char *hostname, char *port) {
  …
```

Sockets Helper: `open_clientfd`

- Establish a connection with a server

```
int open_clientfd(char *hostname, char *port) {
  int clientfd;
  struct addrinfo hints, *listp, *p;

  /* Get a list of potential server addresses */
  memset(&hints, 0, sizeof(struct addrinfo));
  hints.ai_socktype = SOCK_STREAM;  /* Open a connection */
  hints.ai_flags = AI_NUMERICSERV;  /* …using numeric port arg. */
  hints.ai_flags |= AI_ADDRCONFIG;  /* Recommended for connections */
  Getaddrinfo(hostname, port, &hints, &listp);
```

csapp.c

Sockets Helper: `open_clientfd` (cont)

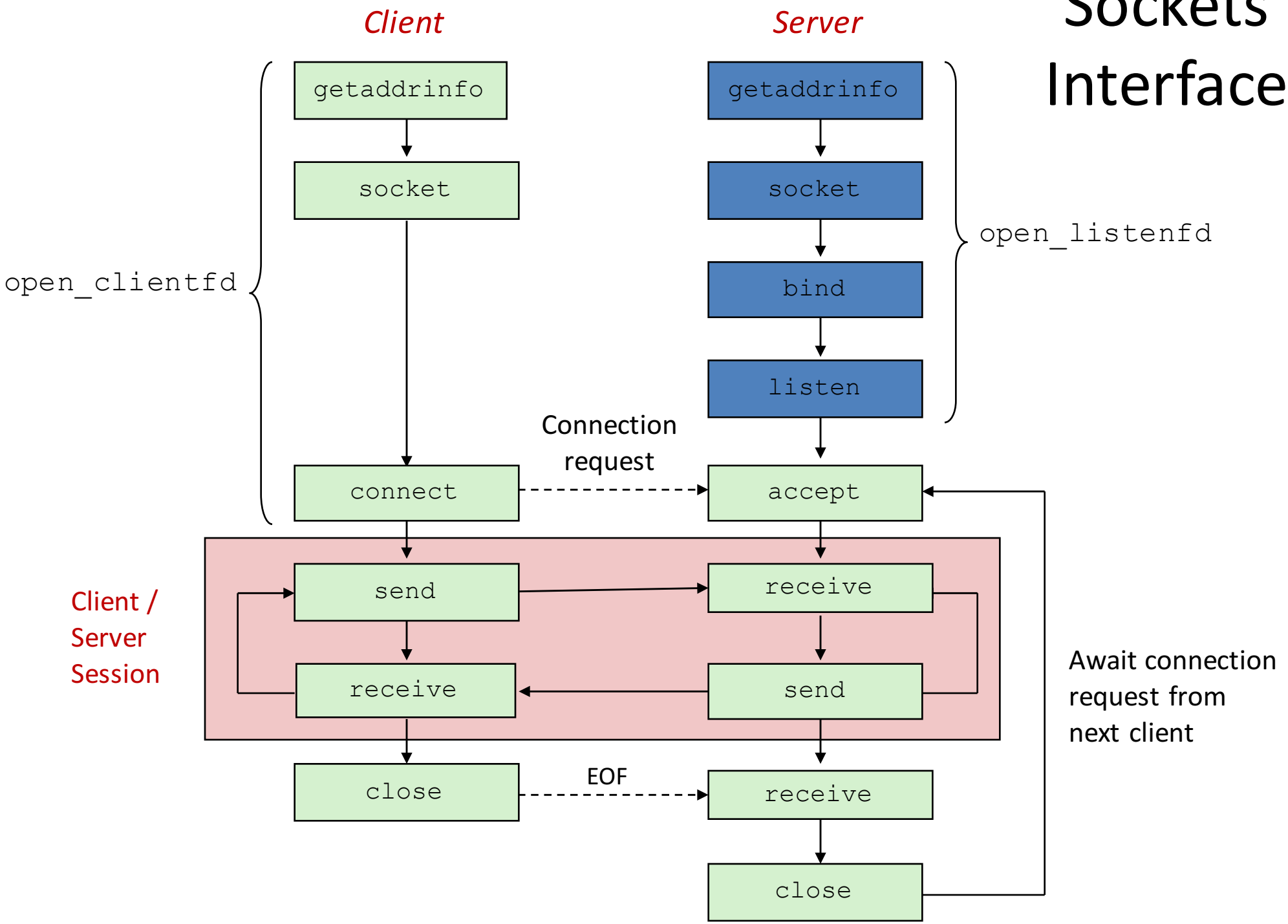
```
    /* Walk the list for one that we can successfully connect to */
    for (p = listp; p; p = p->ai_next) {
        /* Create a socket descriptor */
        if ((clientfd = socket(p->ai_family, p->ai_socktype,
                               p->ai_protocol)) < 0)
            continue; /* Socket failed, try the next */

        /* Connect to the server */
        if (connect(clientfd, p->ai_addr, p->ai_addrlen) != -1)
            break; /* Success */
        Close(clientfd); /* Connect failed, try another */
    }

    /* Clean up */
    Freeaddrinfo(listp);
    if (!p) /* All connects failed */
        return -1;
    else    /* The last connect succeeded */
        return clientfd;
}
```

csapp.c

Sockets Interface



Sockets Helper: `open_listenfd`

- Create a listening descriptor that can be used to accept connection requests from clients.

```
 int open_listenfd(char *port)
{
    struct addrinfo hints, *listp, *p;
    int listenfd, optval=1;

    /* Get a list of potential server addresses */
    memset(&hints, 0, sizeof(struct addrinfo));
    hints.ai_socktype = SOCK_STREAM;              /* Accept connect. */
    hints.ai_flags = AI_PASSIVE | AI_ADDRCONFIG;  /* …on any IP addr */
    hints.ai_flags |= AI_NUMERICSERV;             /* …using port no. */
    Getaddrinfo(NULL, port, &hints, &listp);
```

csapp.c

Sockets Helper: `open_listenfd` (cont)

```
    /* Walk the list for one that we can bind to */
    for (p = listp; p; p = p->ai_next) {
        /* Create a socket descriptor */
        if ((listenfd = socket(p->ai_family, p->ai_socktype,
                               p->ai_protocol)) < 0)
            continue;  /* Socket failed, try the next */

        Setsockopt(listenfd, SOL_SOCKET, SO_REUSEADDR,
                   (const void *)&optval , sizeof(int));

        /* Bind the descriptor to the address */
        if (bind(listenfd, p->ai_addr, p->ai_addrlen) == 0)
            break; /* Success */
        Close(listenfd); /* Bind failed, try the next */
    }
```

csapp.c

Sockets Helper: `open_listenfd` (cont)

```
    /* Clean up */
    Freeaddrinfo(listp);
    if (!p) /* No address worked */
        return -1;

    /* Make it a listening socket ready to accept conn. requests */
    if (listen(listenfd, LISTENQ) < 0) {
        Close(listenfd);
        return -1;
    }
    return listenfd;
}
```

csapp.c

- **Key point: `open_clientfd` and `open_listenfd` are both independent of any particular version of IP.**

Echo Client: Main Routine

```
#include "csapp.h"

int main(int argc, char **argv)
{
  …
  clientfd = open_clientfd(host, port);

  printf("type: ");
  fflush(stdout);

  while (fgets(buf, MAXLINE, stdin) != NULL) {
    send(clientfd, buf, strlen(buf), 0);
    recv(clientfd, buf, MAXLINE, 0);

    // Display and read again:
    printf("echo: ");
    fputs(buf, stdout);
    printf("type: ");
    fflush(stdout);
  }
  …
```

echoclient.c

Iterative Echo Server: Main Routine

```
#include "csapp.h"
void echo(int connfd);

int main(int argc, char **argv)
{
    …
    port = atoi(argv[1]);

    listenfd = open_listenfd(port);
    while (1) {
        clientlen = sizeof(clientaddr);
        connfd = accept(listenfd, (SA *)(&clientaddr), &clientlen);

        /* determine the domain name and IP address of the client */
        hp = gethostbyaddr((const char *)(&clientaddr.sin_addr.s_addr),
                           sizeof(clientaddr.sin_addr.s_addr), AF_INET);
        haddrp = inet_ntoa(clientaddr.sin_addr);
        client_port = ntohs(clientaddr.sin_port);
        printf("server connected to %s (%s), port %u\n",
               hp->h_name, haddrp, client_port);
        echo(connfd);
        printf("Connection closed\n");
        close(connfd);
    }
```

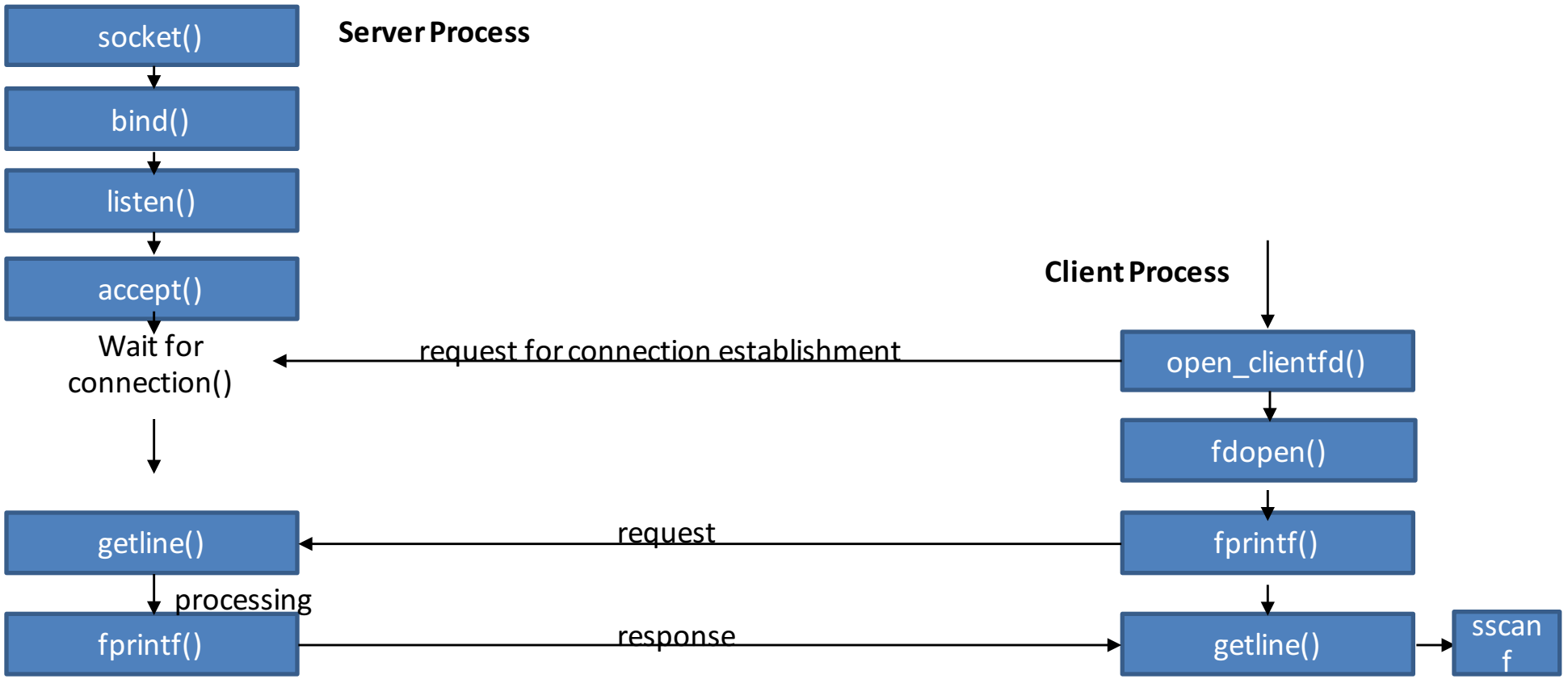
echoserveri.c

Echo Server: `echo` function

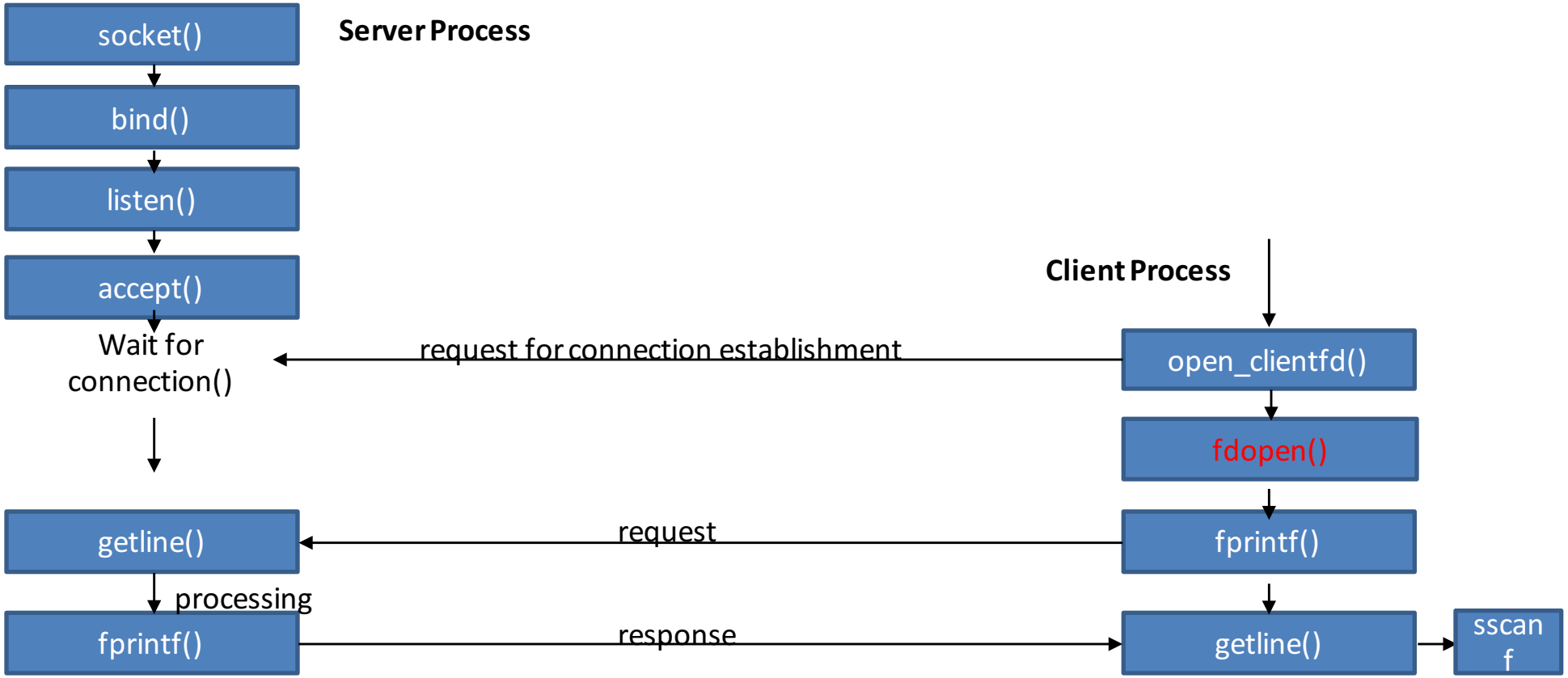
```
void echo (int connfd) {
  // Local variable declarations:
  size_t n;
  char buf[MAXLINE];

  // Keep reading lines until client closes connection:
  while((n = recv(connfd, buf, MAXLINE, 0)) != 0) {
    printf("server received %d bytes\n", (int) n);
    upper_case(buf);
    send(connfd, buf, n, 0);
  }
}
```

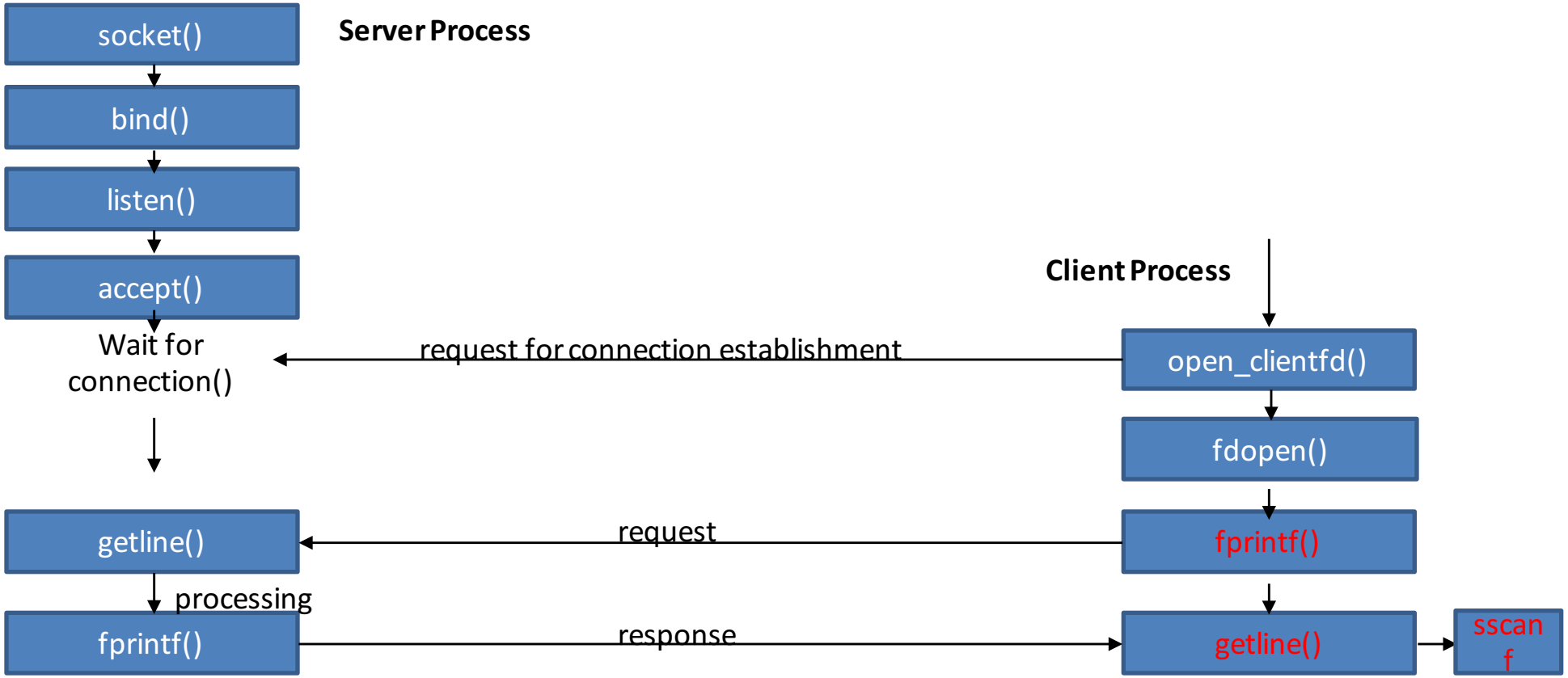
HW9


socket()
Server Process
bind()
listen()
accept()
Wait for connection()
Client Process
request for connection establishment
open_clientfd()
fdopen()
getline()
request
fprintf()
processing
fprintf()
response
getline()
sscanf

TCP connection



TCP connection



i-clicker question

Which of the following option is wrong?

A. If open_clientfd() returns -1, it may indicate that your internet is not working.
B. client can send request to the server using getline() and read response from the server using fprintf()
C. We use getline to get the whole line, and sscanf to break the input into its pieces
D. The *fdopen*() function shall associate a stream with the socket descriptor.

i-clicker question

Which of the following option is wrong?

A. If open_clientfd() returns -1, it may indicate that your internet is not working.

B. client can send request to the server using getline() and read response from the server using fprintf()

C. We use getline to get the whole line, and sscanf to break the input into its pieces

D. The *fdopen*() function shall associate a stream with the socket descriptor.