

# Network Programming: Part II

CSE4100: System Programming

Youngjae Kim (PhD)

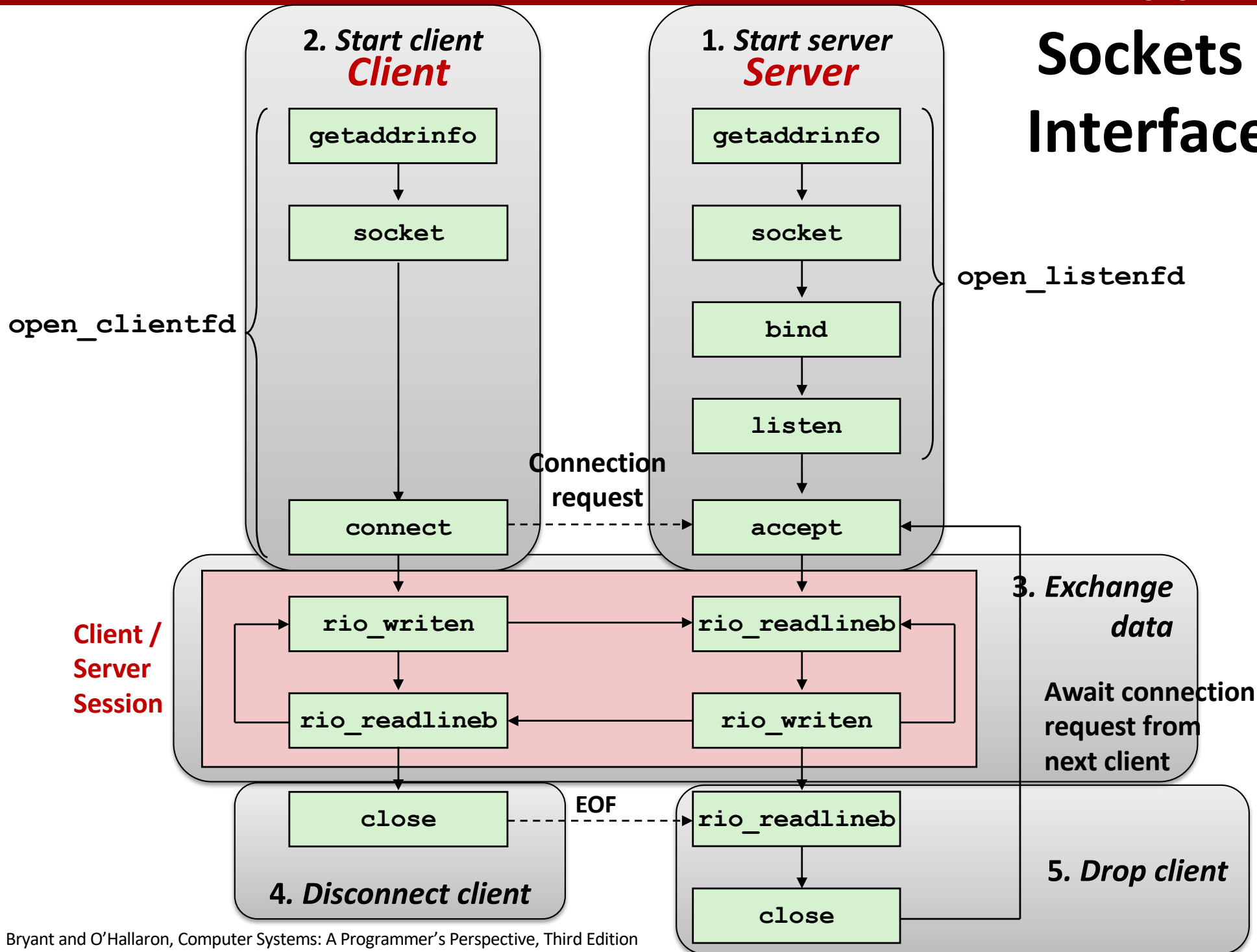
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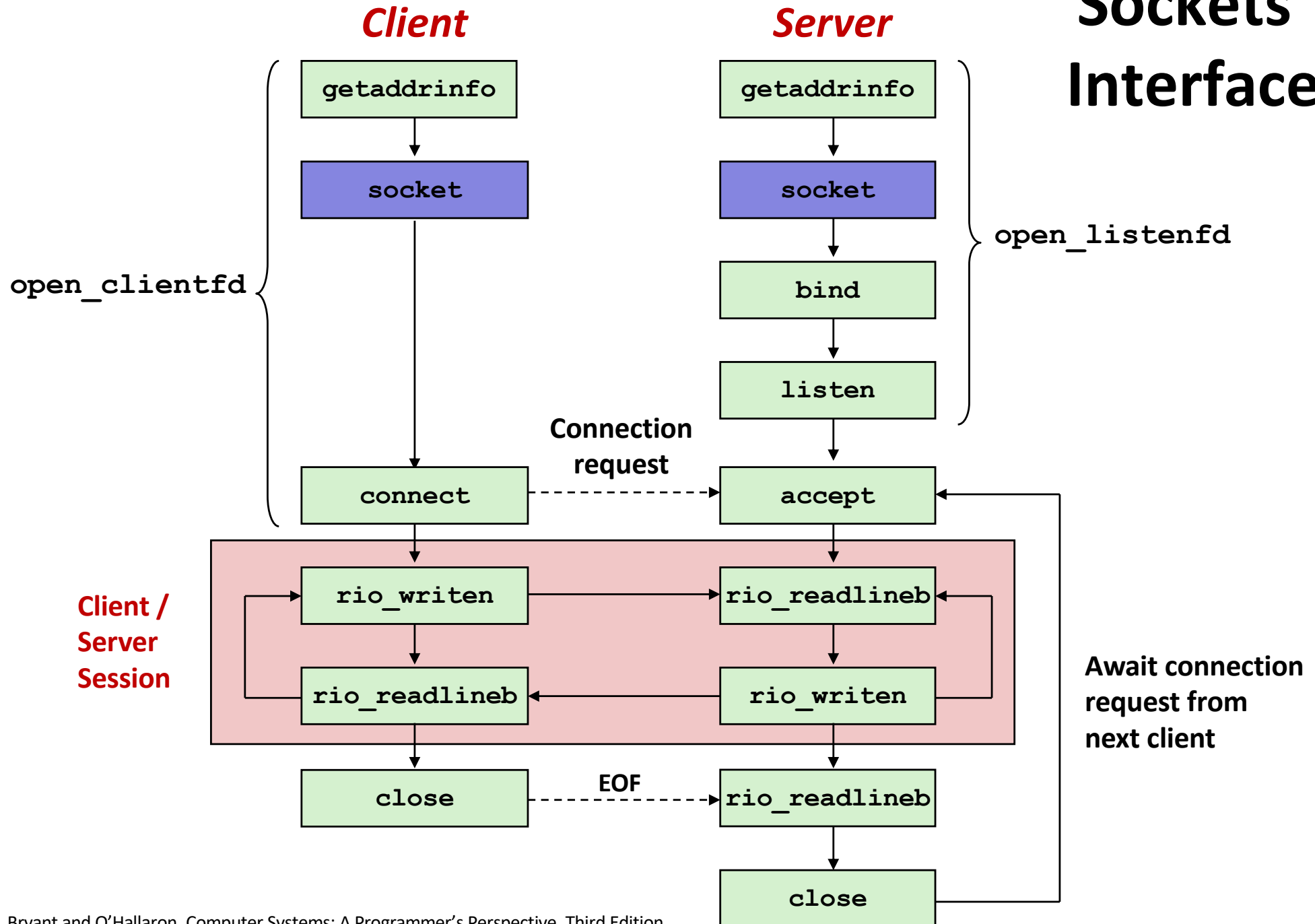
<https://discos.sogang.ac.kr>

Office: R911, E-mail: [youkim@sogang.ac.kr](mailto:youkim@sogang.ac.kr)

# Sockets Interface



# Sockets Interface



# Sockets Interface: `socket`

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

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

- Example:

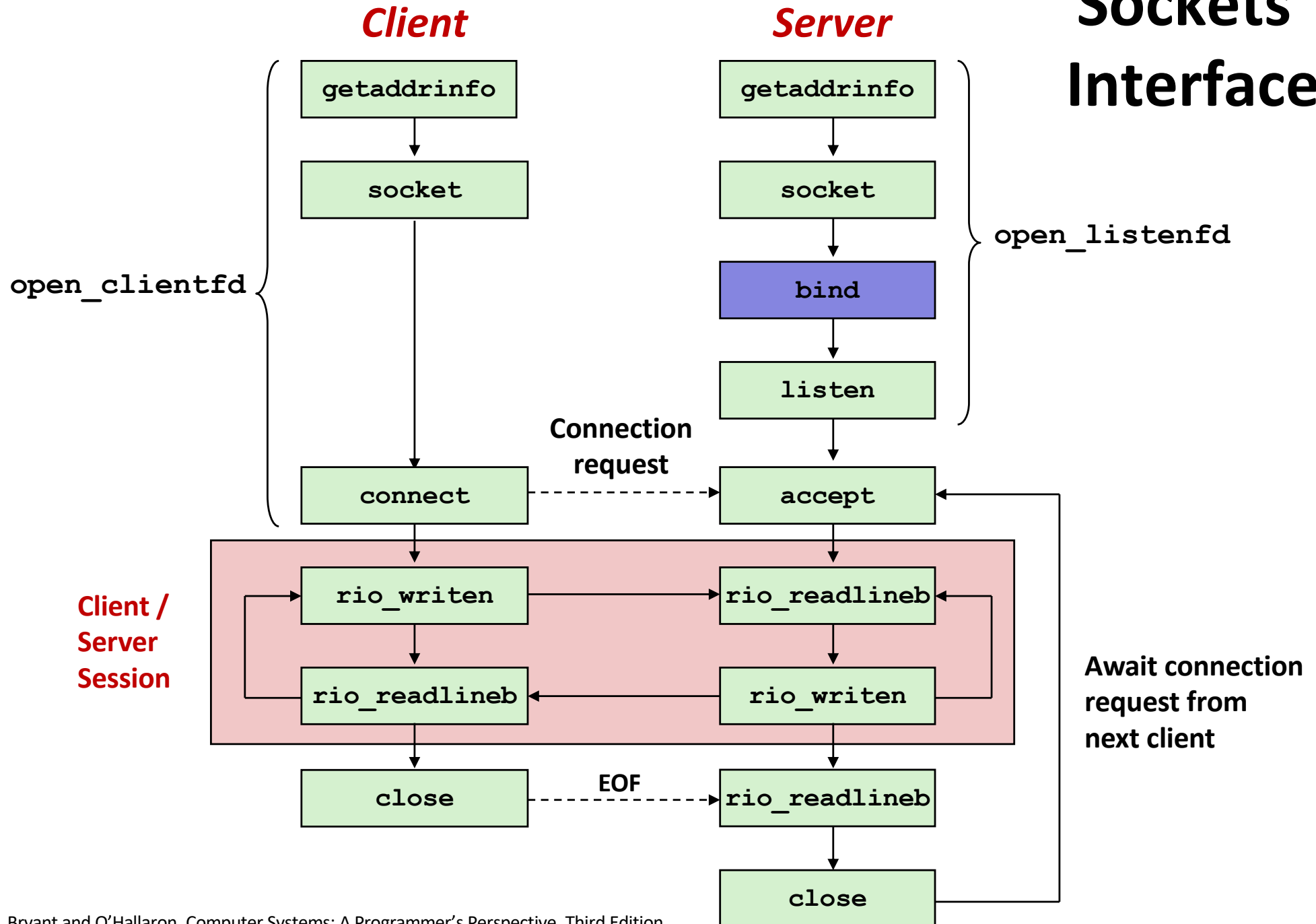
```
int clientfd = Socket(AF_INET, SOCK_STREAM, 0);
```

Indicates that we are using  
32-bit IPV4 addresses

Indicates that the socket  
will be the end point of a  
connection

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

# Sockets Interface



# Sockets Interface: `bind`

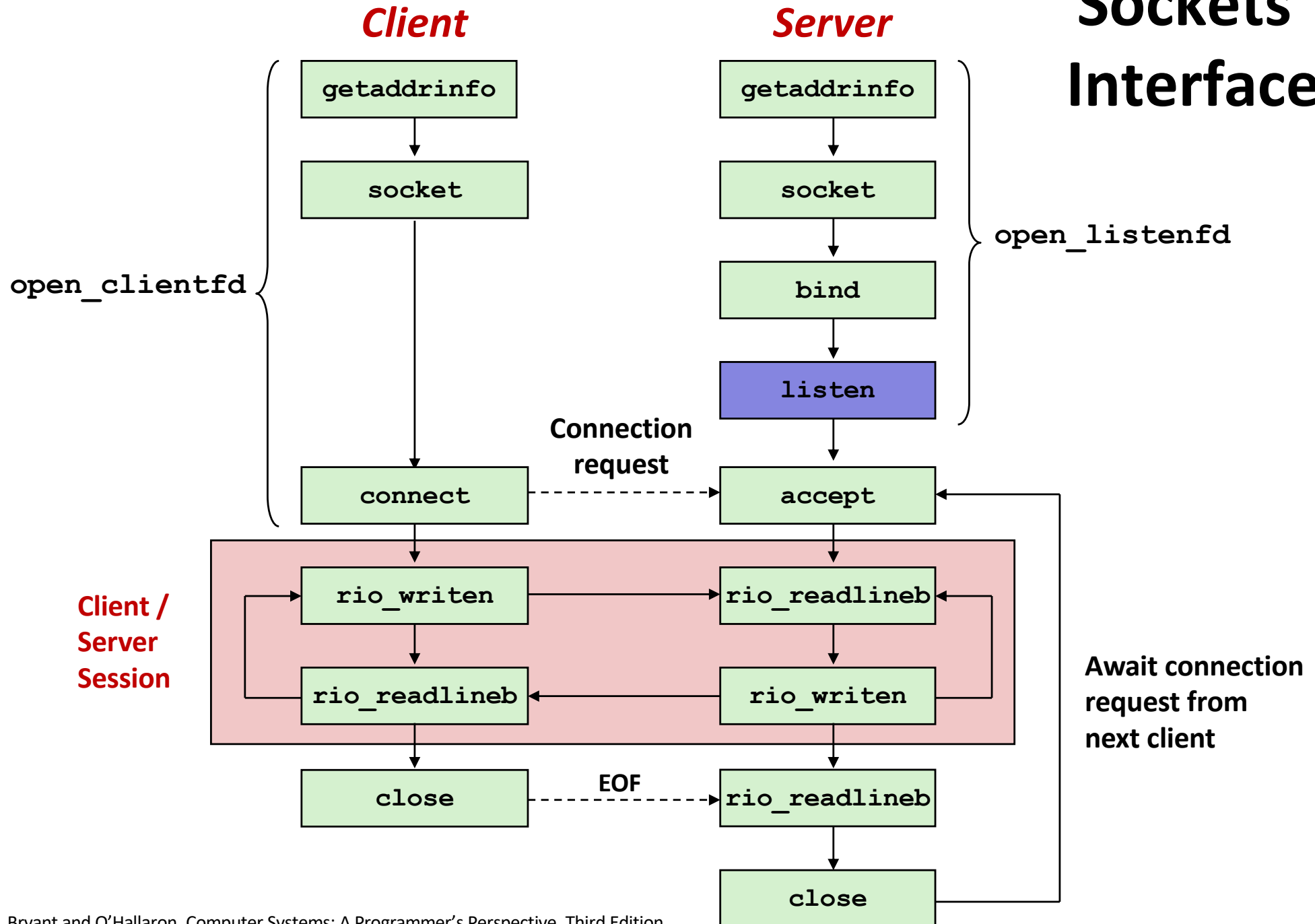
- A server uses `bind` to ask the kernel to associate the server's socket address with a socket descriptor:

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

- 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`.

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

# Sockets Interface



# Sockets Interface: `listen`

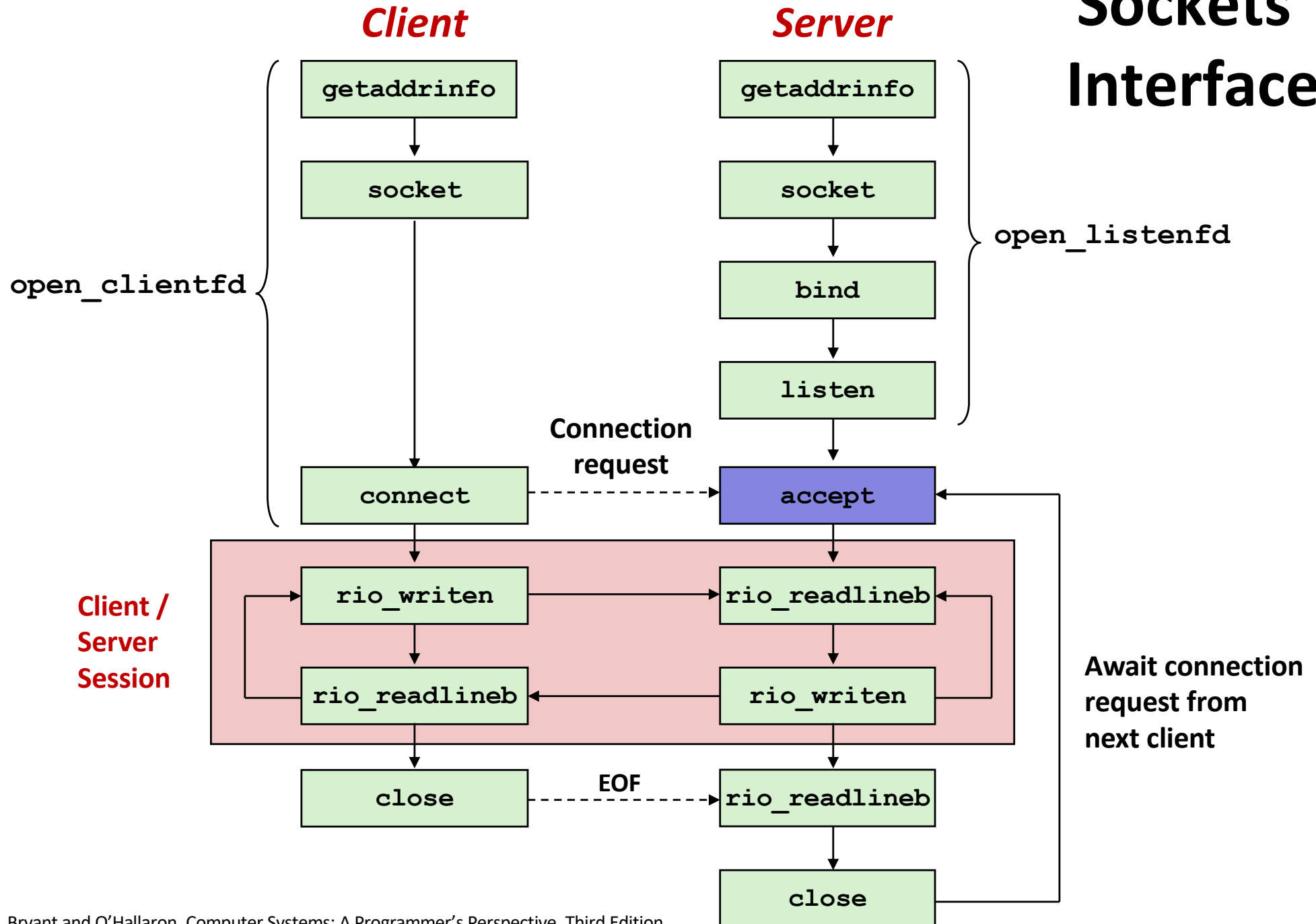
- By default, kernel assumes that descriptor from `socket` function is an *active socket* that will be on the client end of a connection.
- A server calls the `listen` function to tell the kernel that a descriptor will be used by a server rather than a client:

```
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



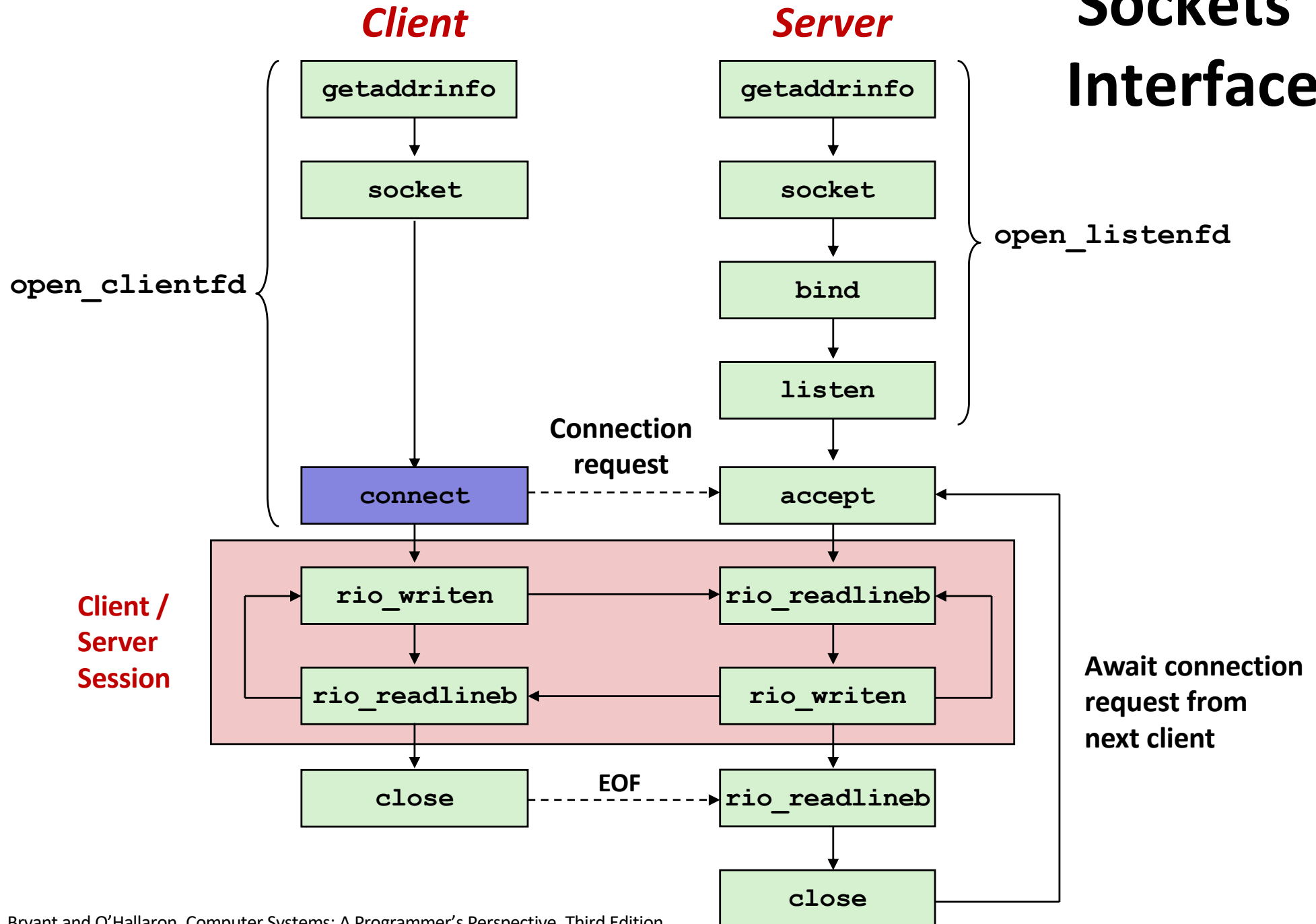
# Sockets Interface: `accept`

- 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.

# Sockets Interface



# Sockets Interface: connect

- A client establishes a connection with a server by calling **connect**:

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

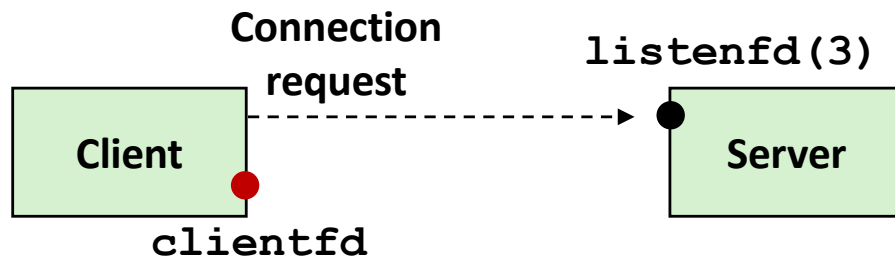
- Attempts to establish a connection with server at socket address **addr**
  - If successful, then `clientfd` is now ready for reading and writing.
  - Resulting connection is characterized by socket pair  
(`x:y`, `addr.sin_addr:addr.sin_port`)
    - `x` is client address
    - `y` is ephemeral port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

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

# 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

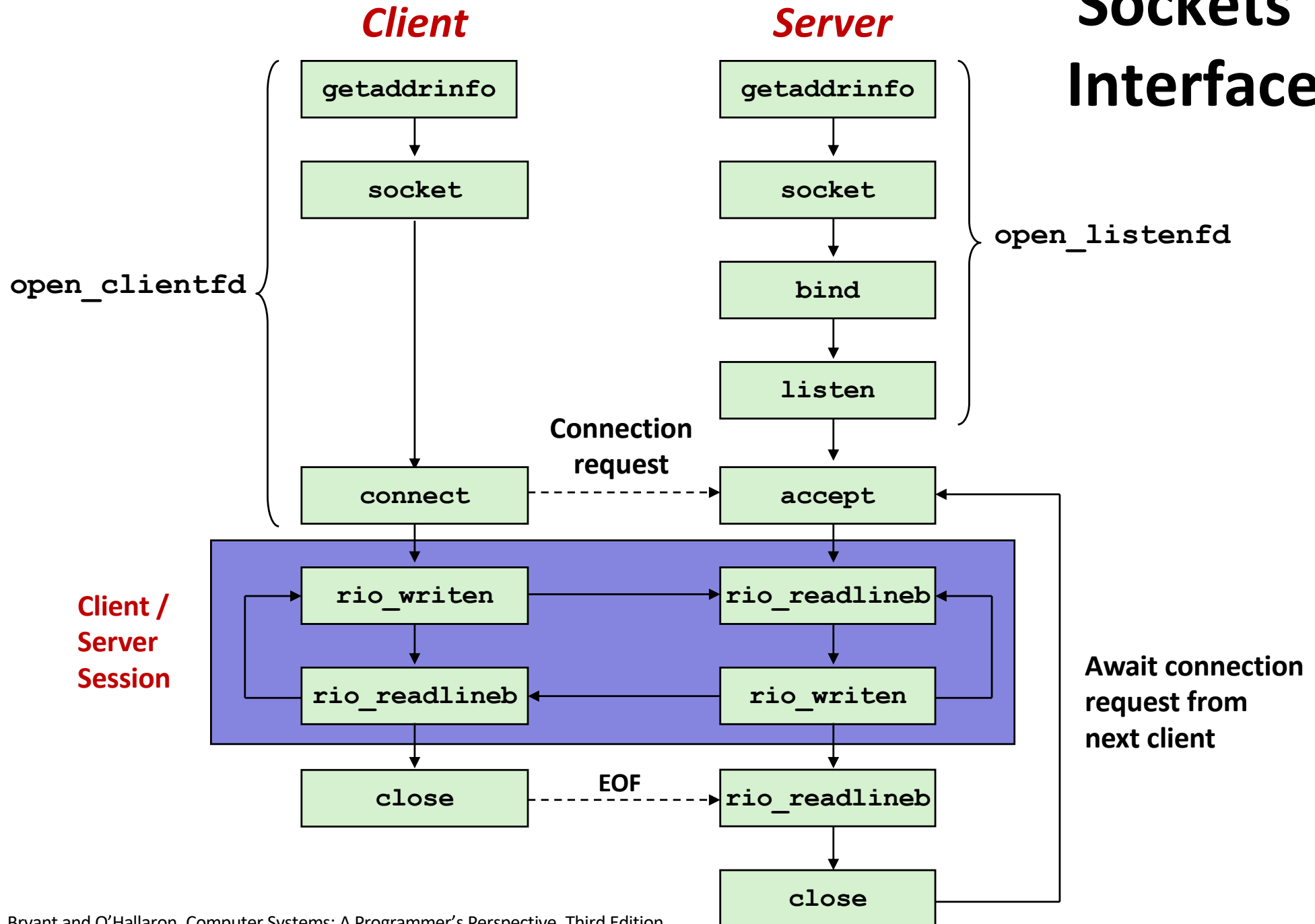
## ■ Connected descriptor

- 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

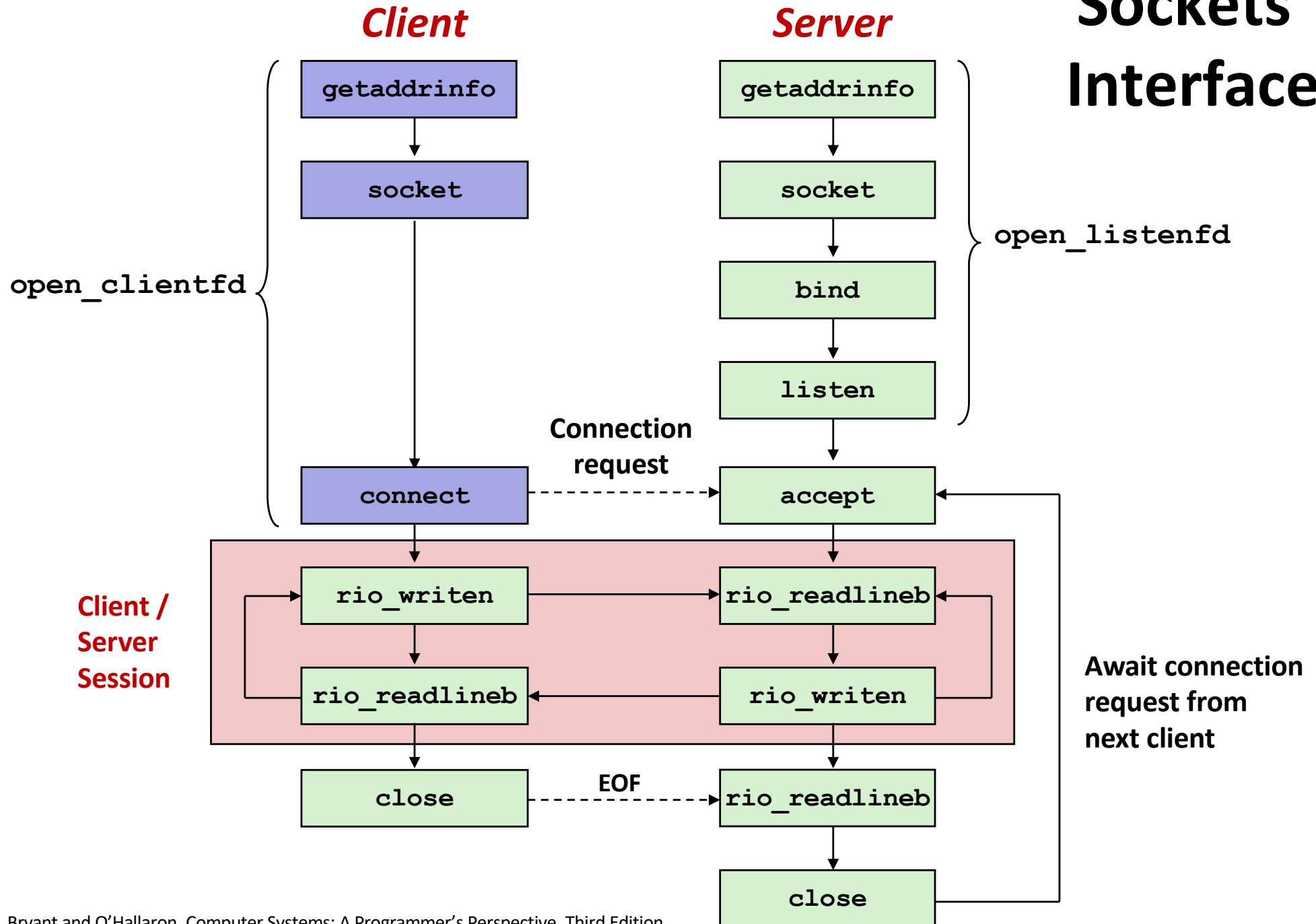
## ■ Why the distinction?

- 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



# Sockets Interface





# 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)

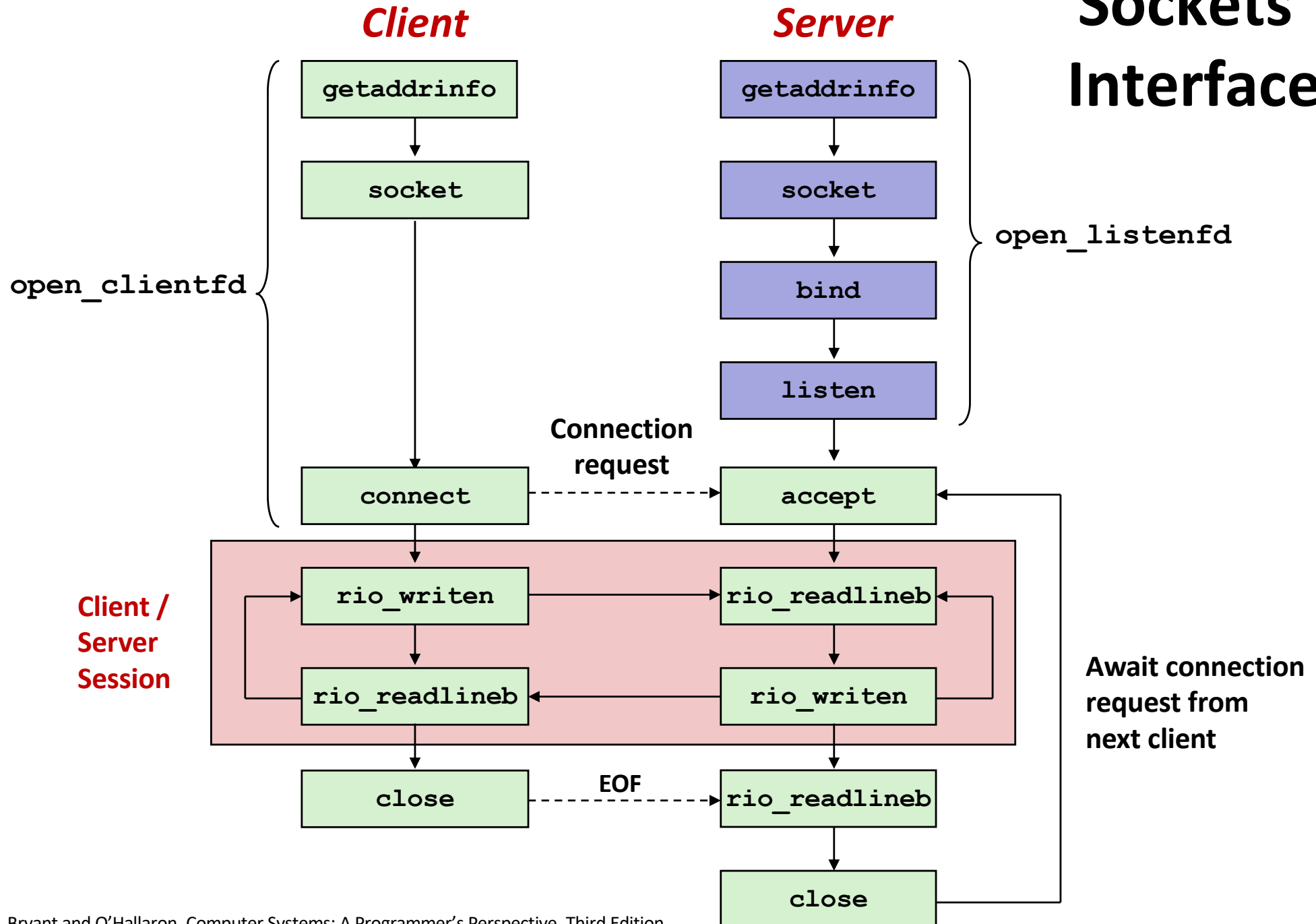
```
/* Walk the list for one that we can successfully connect to */
for (p = listp; p; p = p->ai_next) {
    /* Create a socket descriptor */
    if ((clientfd = socket(p->ai_family, p->ai_socktype,
                          p->ai_protocol)) < 0)
        continue; /* Socket failed, try the next */

    /* 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 */

    /* Eliminates "Address already in use" error from bind */
    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)
{
    int clientfd;
    char *host, *port, buf[MAXLINE];
    rio_t rio;

    host = argv[1];
    port = argv[2];

    clientfd = Open_clientfd(host, port);
    Rio_readinitb(&rio, clientfd);

    while (Fgets(buf, MAXLINE, stdin) != NULL) {
        Rio_writen(clientfd, buf, strlen(buf));
        Rio_readlineb(&rio, buf, MAXLINE);
        Fputs(buf, stdout);
    }
    Close(clientfd);
    exit(0);
}
```

echoclient.c

# Iterative Echo Server: Main Routine

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

int main(int argc, char **argv)
{
    int listenfd, connfd;
    socklen_t clientlen;
    struct sockaddr_storage clientaddr; /* Enough room for any addr */
    char client_hostname[MAXLINE], client_port[MAXLINE];

    listenfd = Open_listenfd(argv[1]);
    while (1) {
        clientlen = sizeof(struct sockaddr_storage); /* Important! */
        connfd = Accept(listenfd, (SA *)&clientaddr, &clientlen);
        Getnameinfo((SA *)&clientaddr, clientlen,
                    client_hostname, MAXLINE, client_port, MAXLINE, 0);
        printf("Connected to (%s, %s)\n", client_hostname, client_port);
        echo(connfd);
        Close(connfd);
    }
    exit(0);
}
```

echoserveri.c



# Echo Server: echo function

- The server uses RIO to read and echo text lines until EOF (end-of-file) condition is encountered.
  - EOF condition caused by client calling `close(clientfd)`

```
void echo(int connfd)
{
    size_t n;
    char buf[MAXLINE];
    rio_t rio;

    Rio_readinitb(&rio, connfd);
    while((n = Rio_readlineb(&rio, buf, MAXLINE)) != 0) {
        printf("server received %d bytes\n", (int)n);
        Rio_writen(connfd, buf, n);
    }
}
```

echo.c