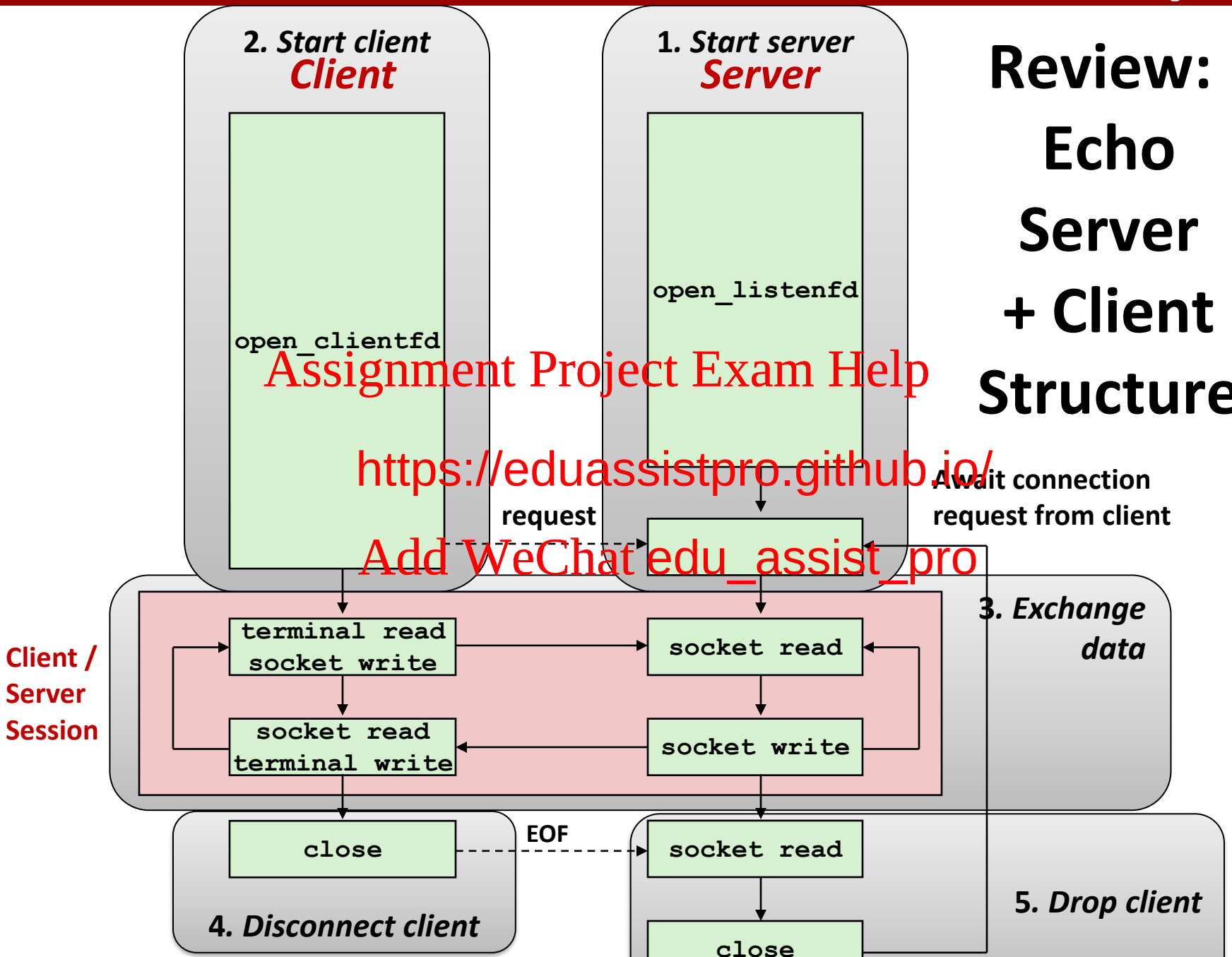
14-513 18-613

Network Programming: Part II

15-213/18-213/14-5
Introduction to Com
23rd Lecture, Novem

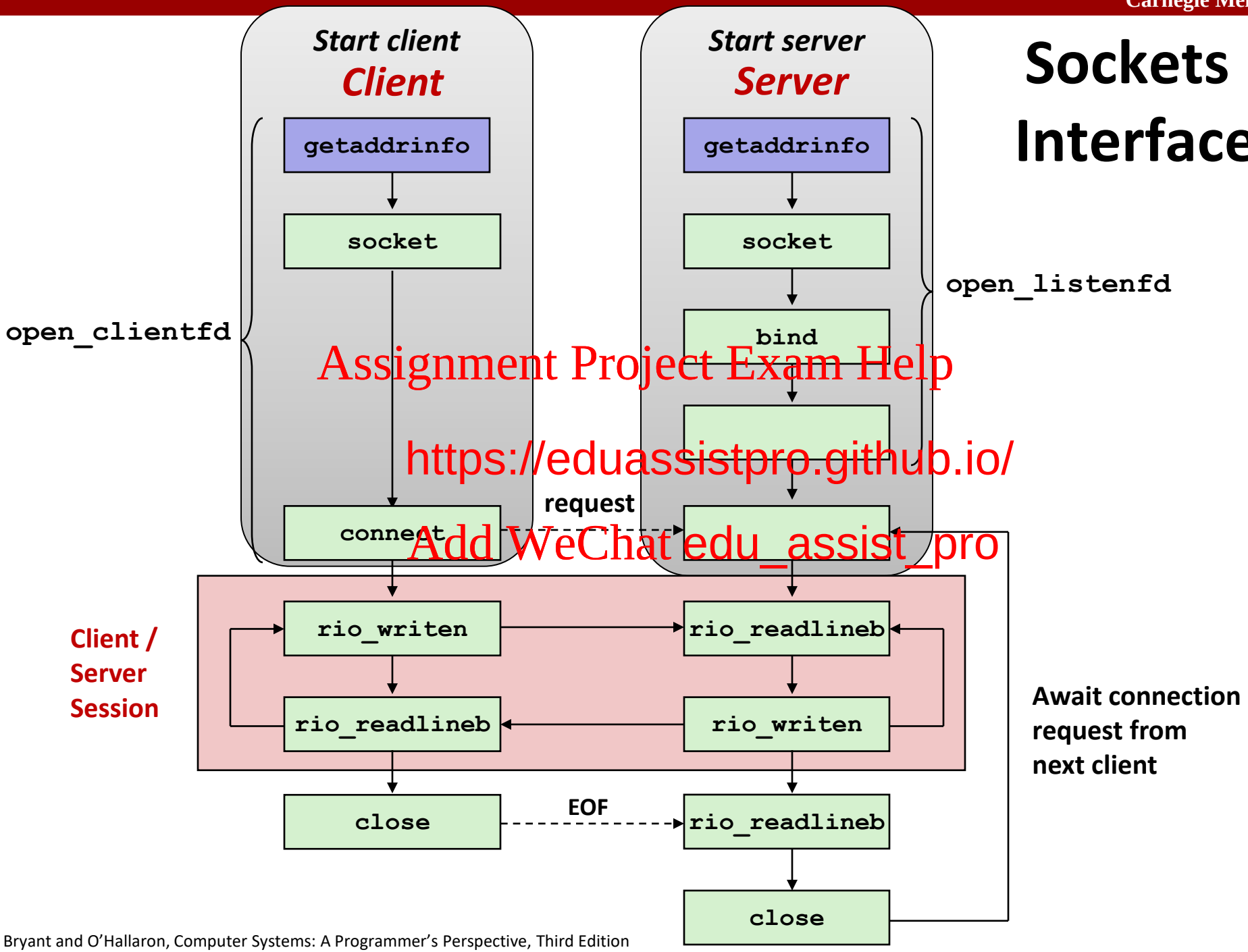
Review: Echo Server + Client Structure



Today

- **The Sockets Interface** — CSAPP 11.4
- Web Servers — CSAPP 11.5.1-11.5.3
- The Tiny Web Server — CSAPP 11.6
- Serving Dynami — CSAPP 11.5.4

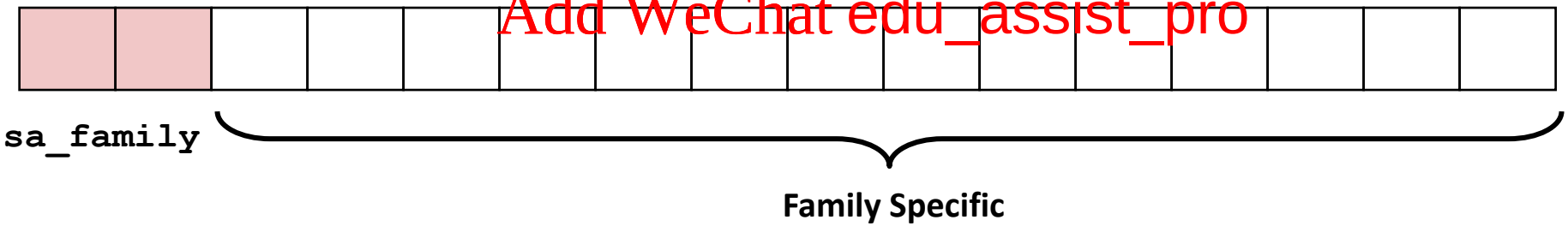
Sockets Interface



Review: Generic Socket Address

- **Generic socket address:**
  - For address arguments to **`connect`**, **`bind`**, and **`accept`**

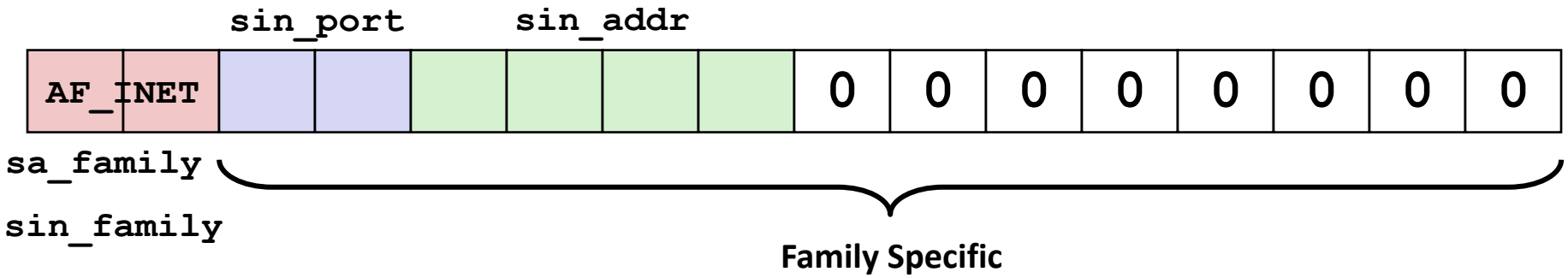
```
struct sockaddr {
  uint16_t  s                                  amily */
  char      s                                  ta.  */
};
```

Review: Socket Address Structures

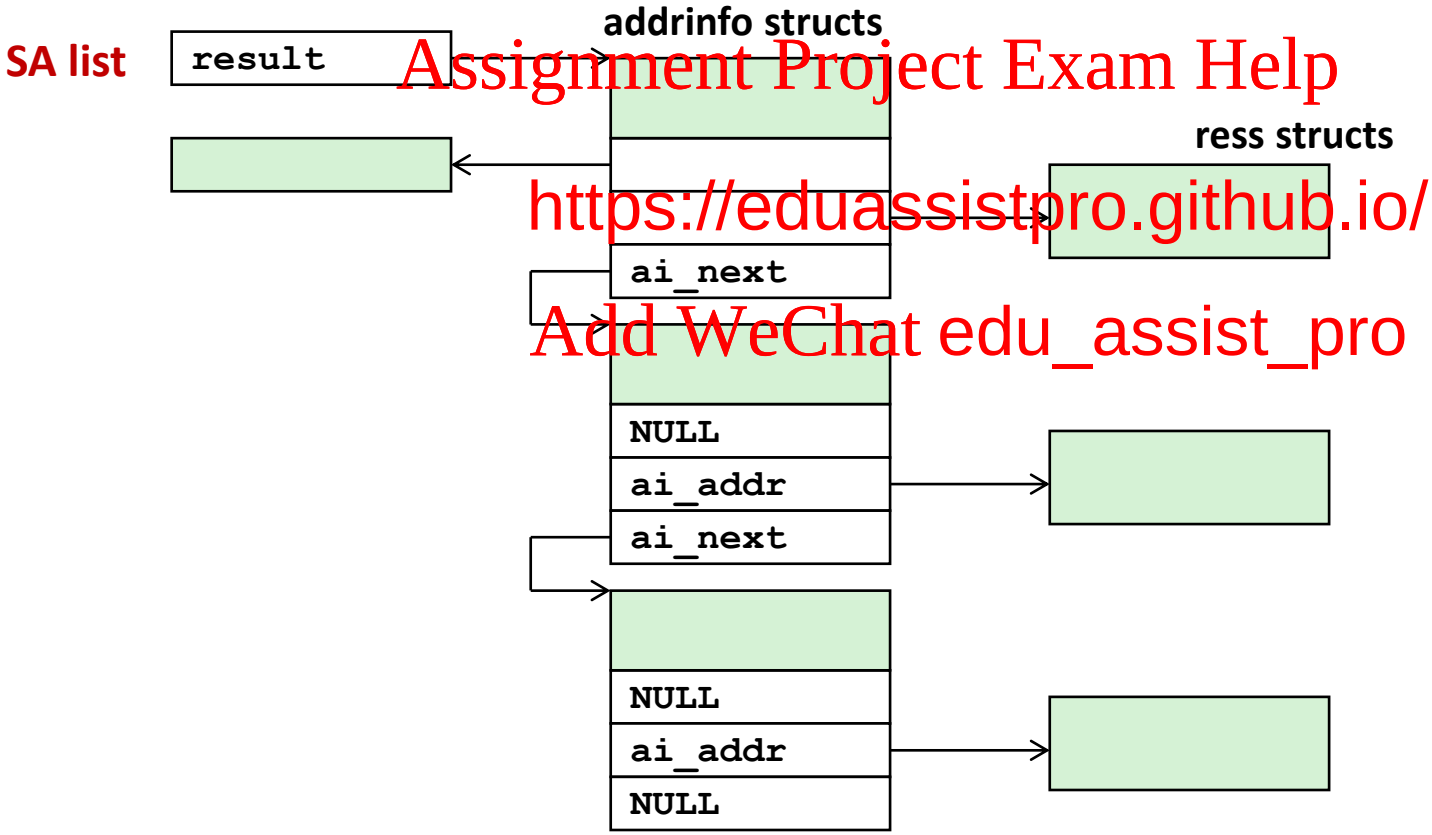
- **Internet (IPv4) specific socket address:**
  - Must cast (**`struct sockaddr_in *`**) to (**`struct sockaddr *`**) for functions that take socket address arguments.


```
struct sockaddr_in  {
  uint16_t        sin                    ly (always AF_INET) */
  uint16_t        sin                    etwork byte order */
  struct in_addr  sin_addr;     /* IP       ork byte order */
  unsigned char   sin_zero[8];  /* Pad      truct sockaddr) */
};
```

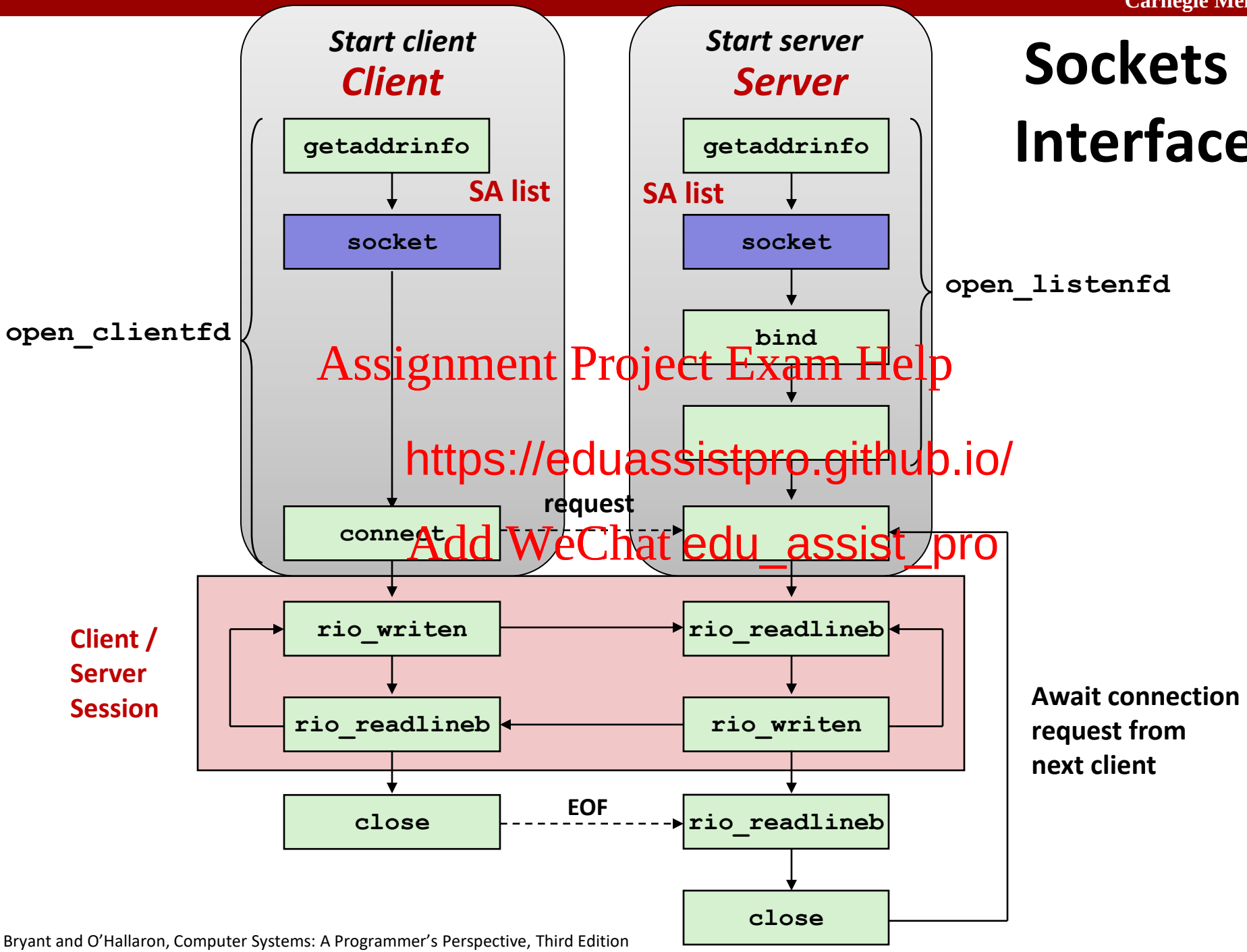


Review: `getaddrinfo`

- `getaddrinfo` converts string representations of hostnames, host addresses, ports, service names to socket address structures



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:

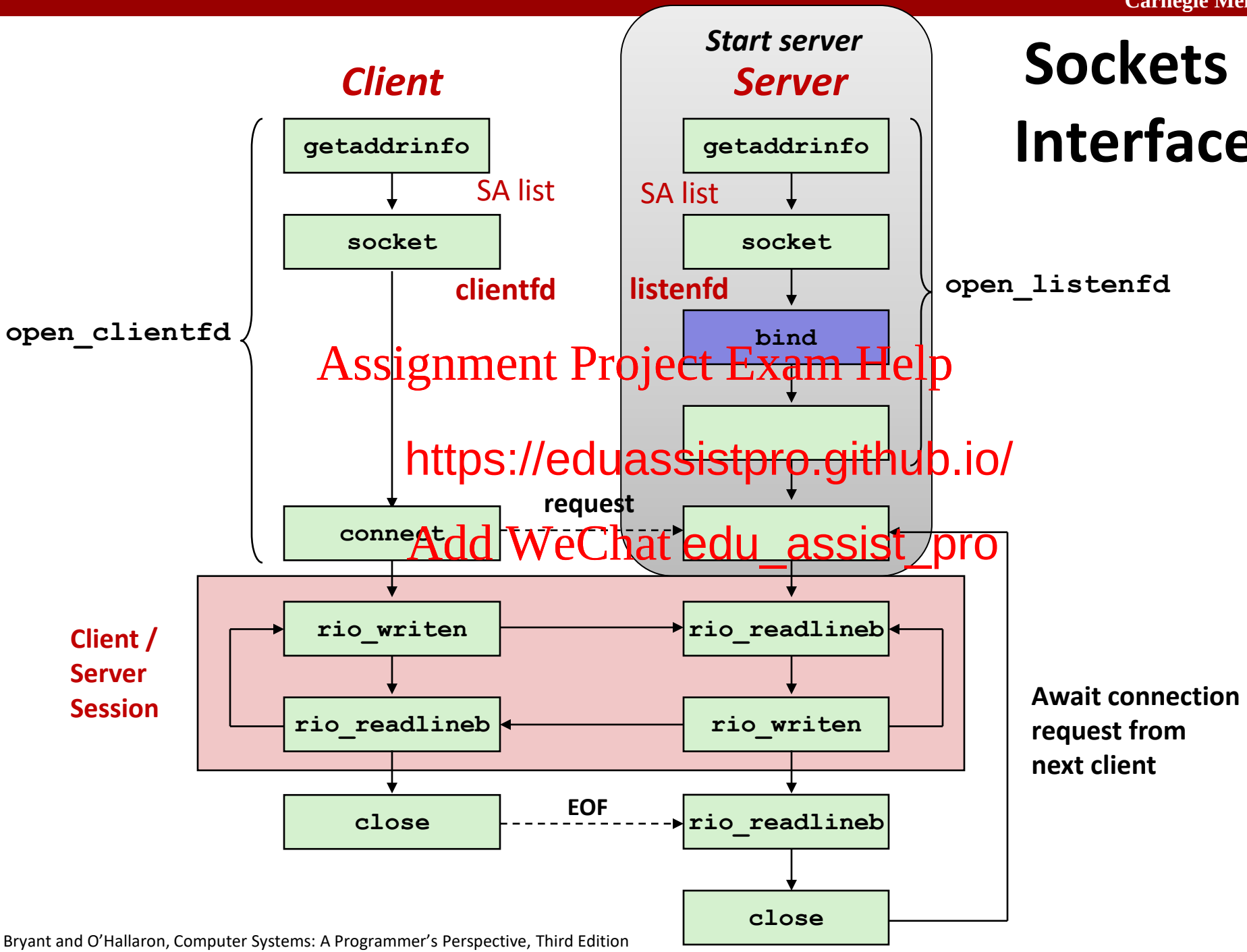
```
int clientfd = soc                                    0);
```


Indicates that we are using 32-bit IPV4 addresses

the socket will be the end point of a reliable (TCP) 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`

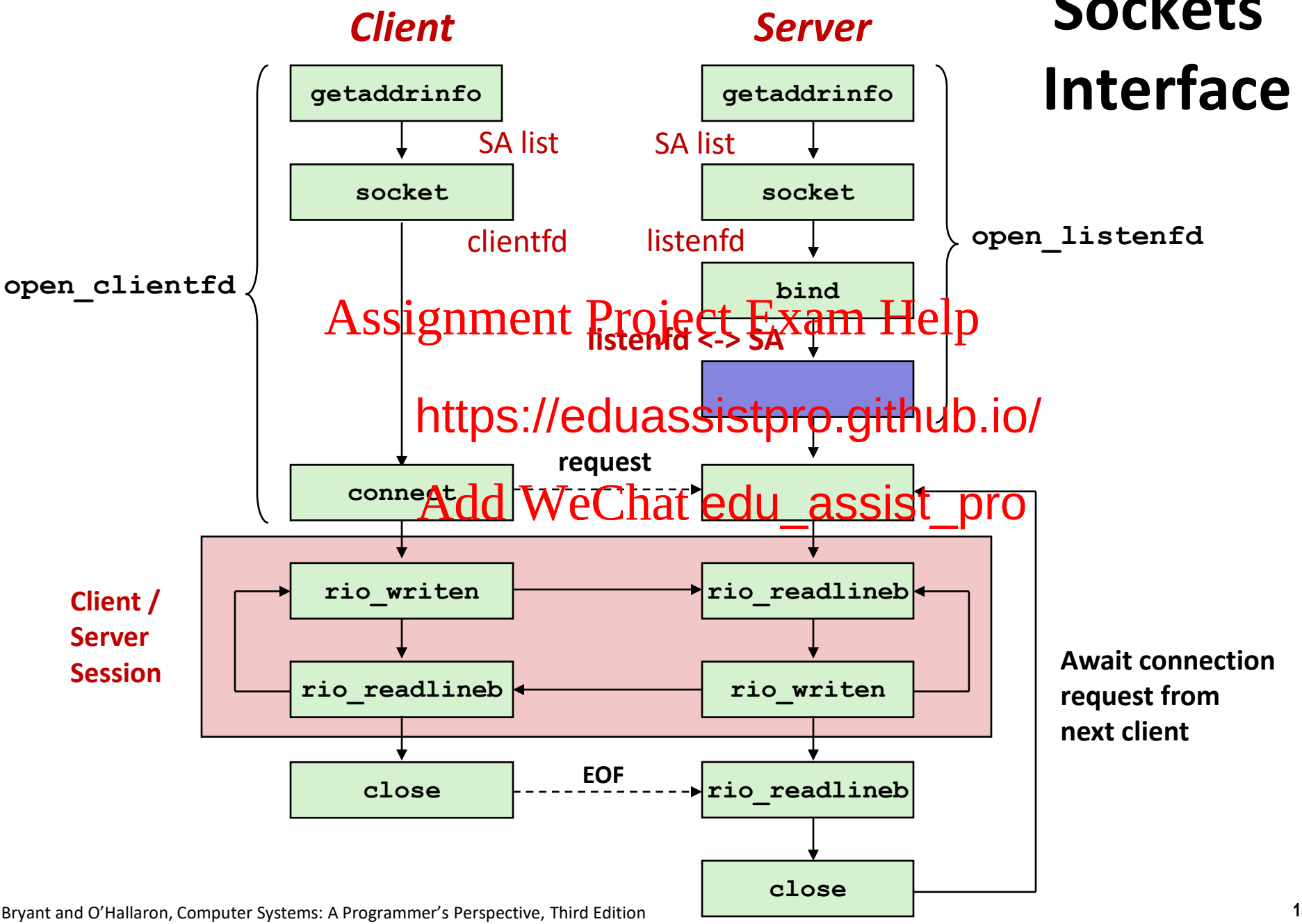
- A server uses `bind` to ask the kernel to associate the server's socket address with a socket descriptor:

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


Our convention: `typedef struct sockaddr SA;`

- Process can rea connection whose endpoint is `add` by reading f tor `sockfd`
- Similarly, writes to `sockfd` are along connection whose endpoint is `addr`

Sockets Interface



Sockets Interface: `listen`

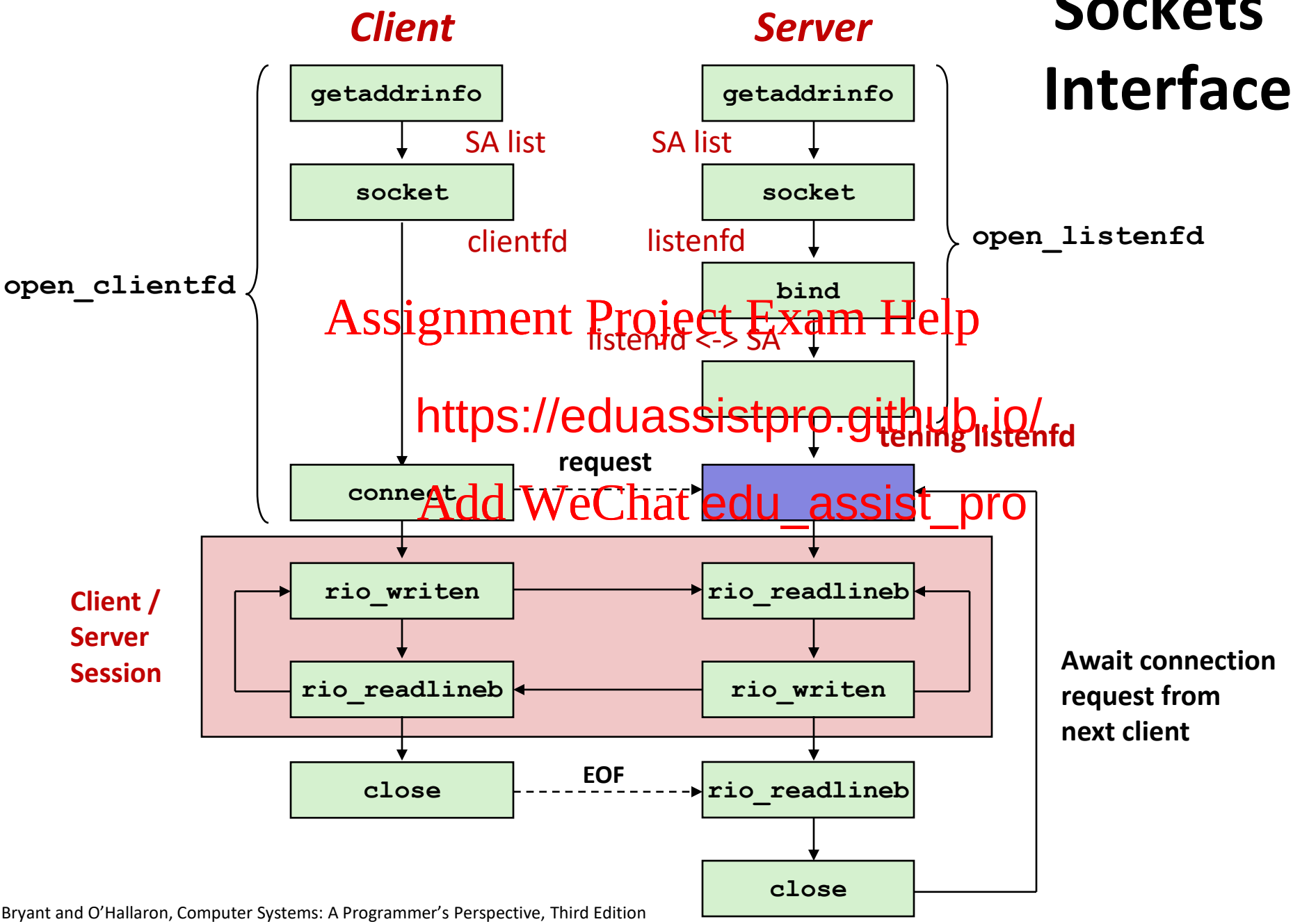
- Kernel assumes that descriptor from socket function is an ***active socket*** that will be on the client end
- A server calls the listen function to tell the kernel that a descriptor will be used by a server rather than a client:


```
int lis                                    g);
```


- Converts `sockfd` from an activ 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 (128-ish by default)

Sockets Interface



Sockets Interface: `accept`

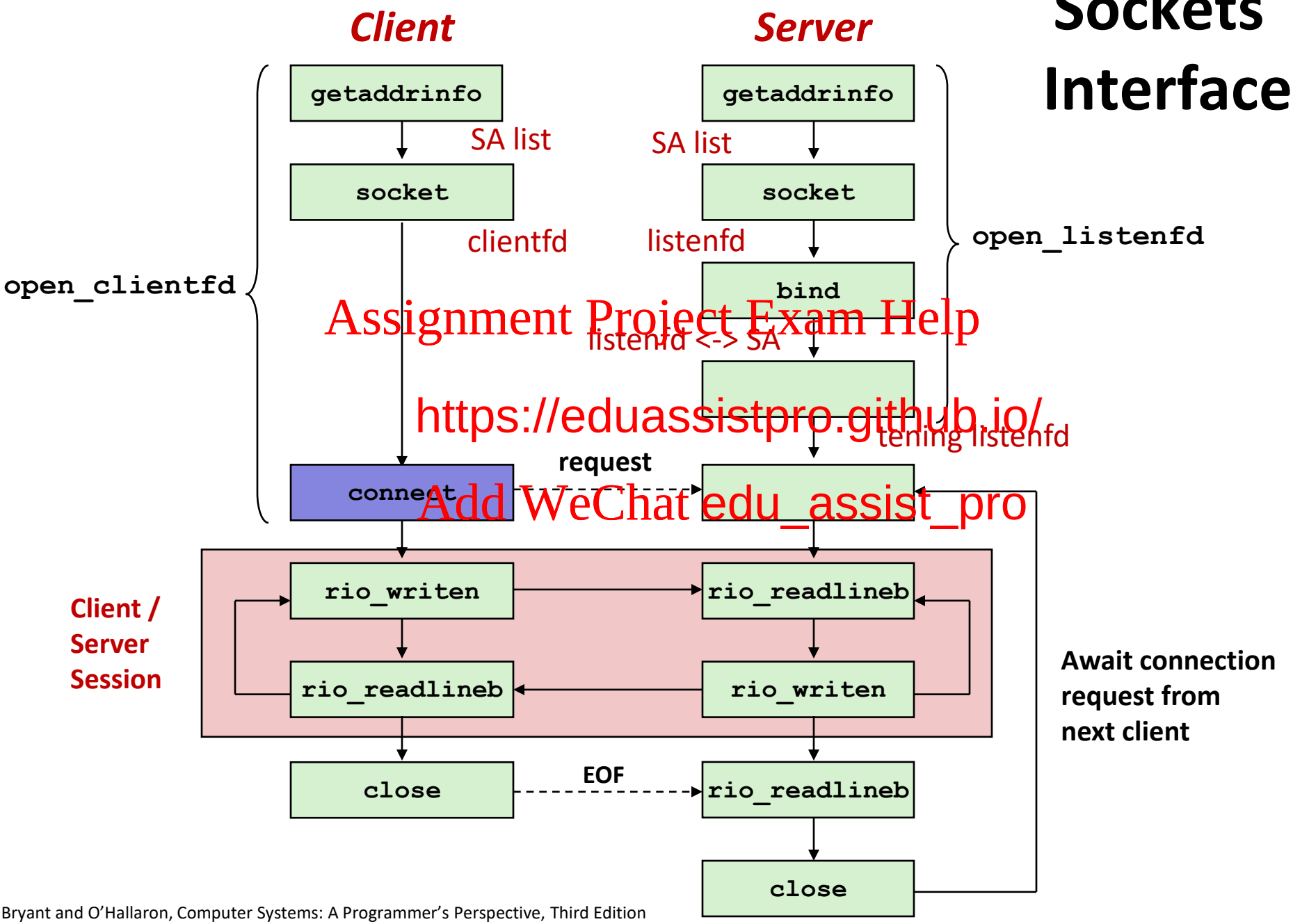
- Servers wait for connection requests from clients by calling `accept`:

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


- Waits for conne the connection bound to `list` , then fills cket address in `addr` and size of the socket a `addrlen`.

- Returns a ***connected descriptor*** `connfd` 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`**

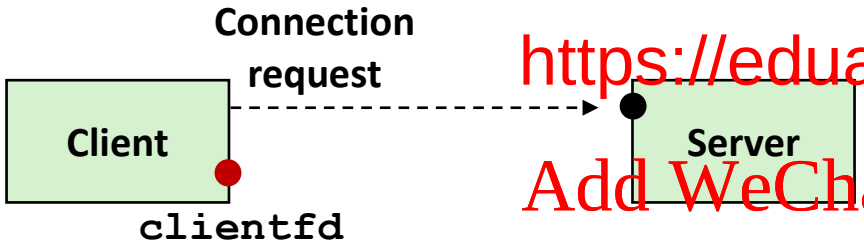
  - If successful, th reading and writing
  - Resulting connection is characteriz air

    (`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`.

connect/accept Illustrated

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



akes connection request by locking in `connect`

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

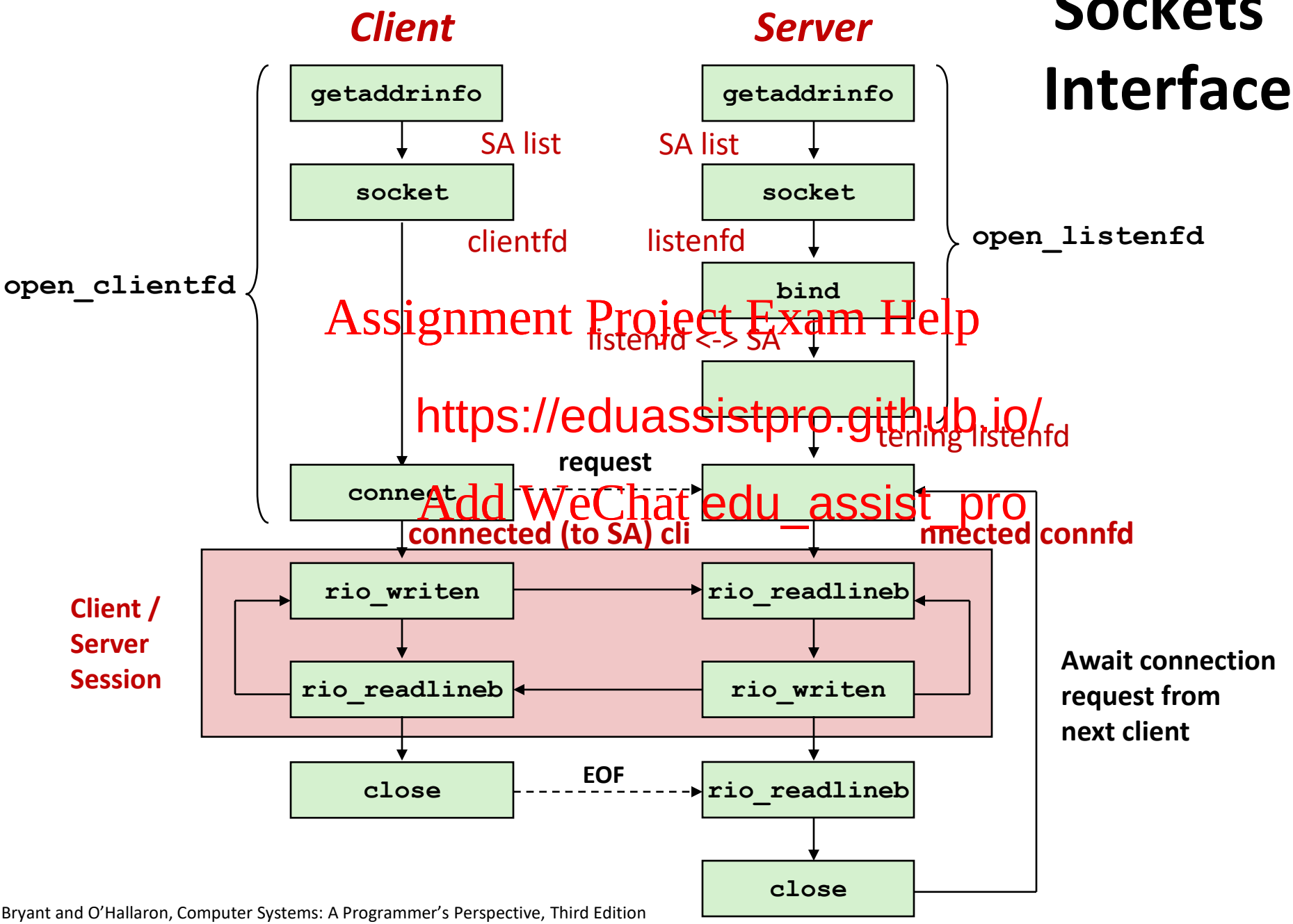
Connected vs. Listening Descriptors

- **Listening descriptor**
  - End point for client connection requests
  - Created once and exists for lifetime of the server

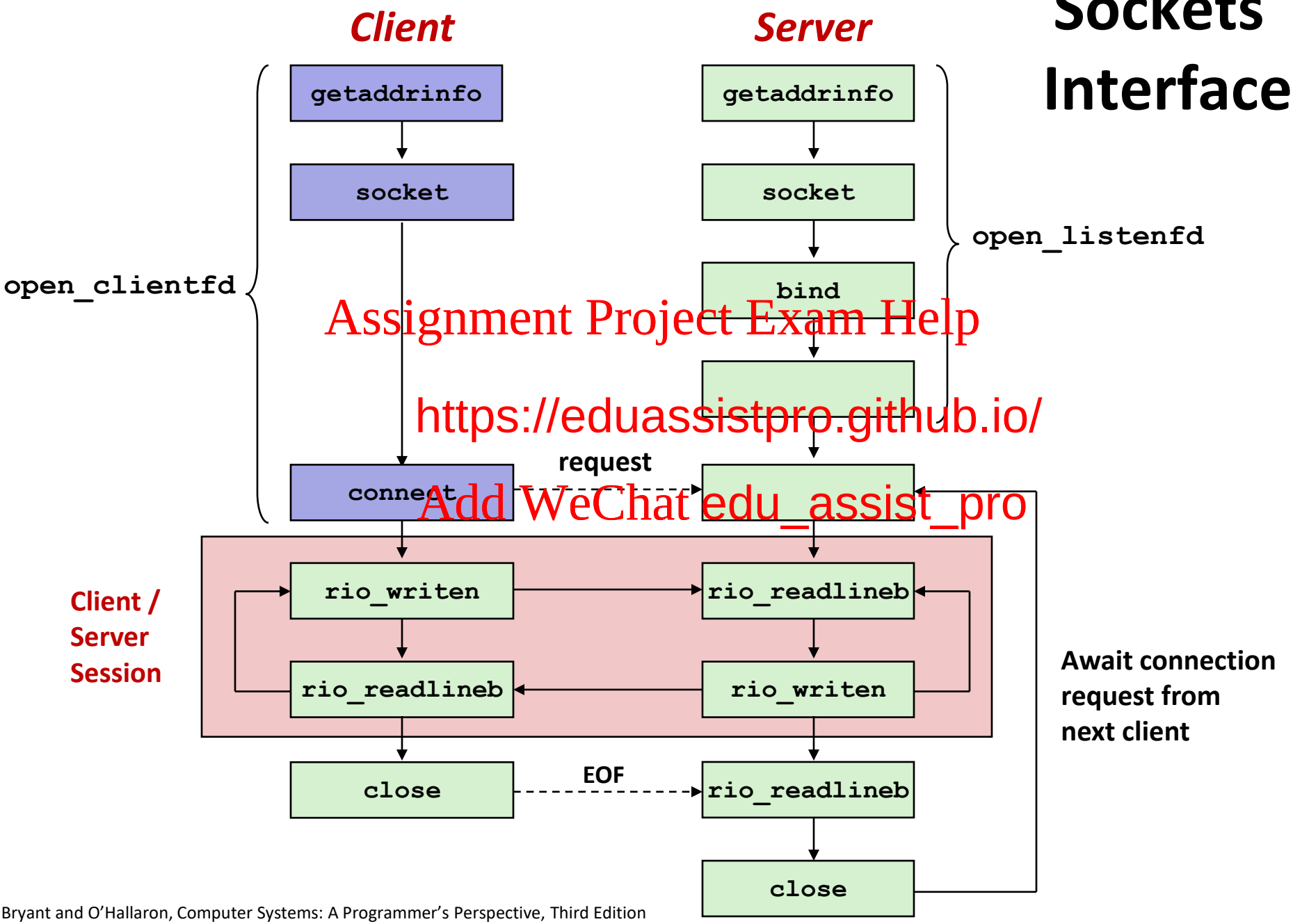
- **Connected descr**
  - End point of the connection between client and server
  - A new descriptor is created each time the server accepts a connection request from a client
  - Exists only as long as it takes to service client

- **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

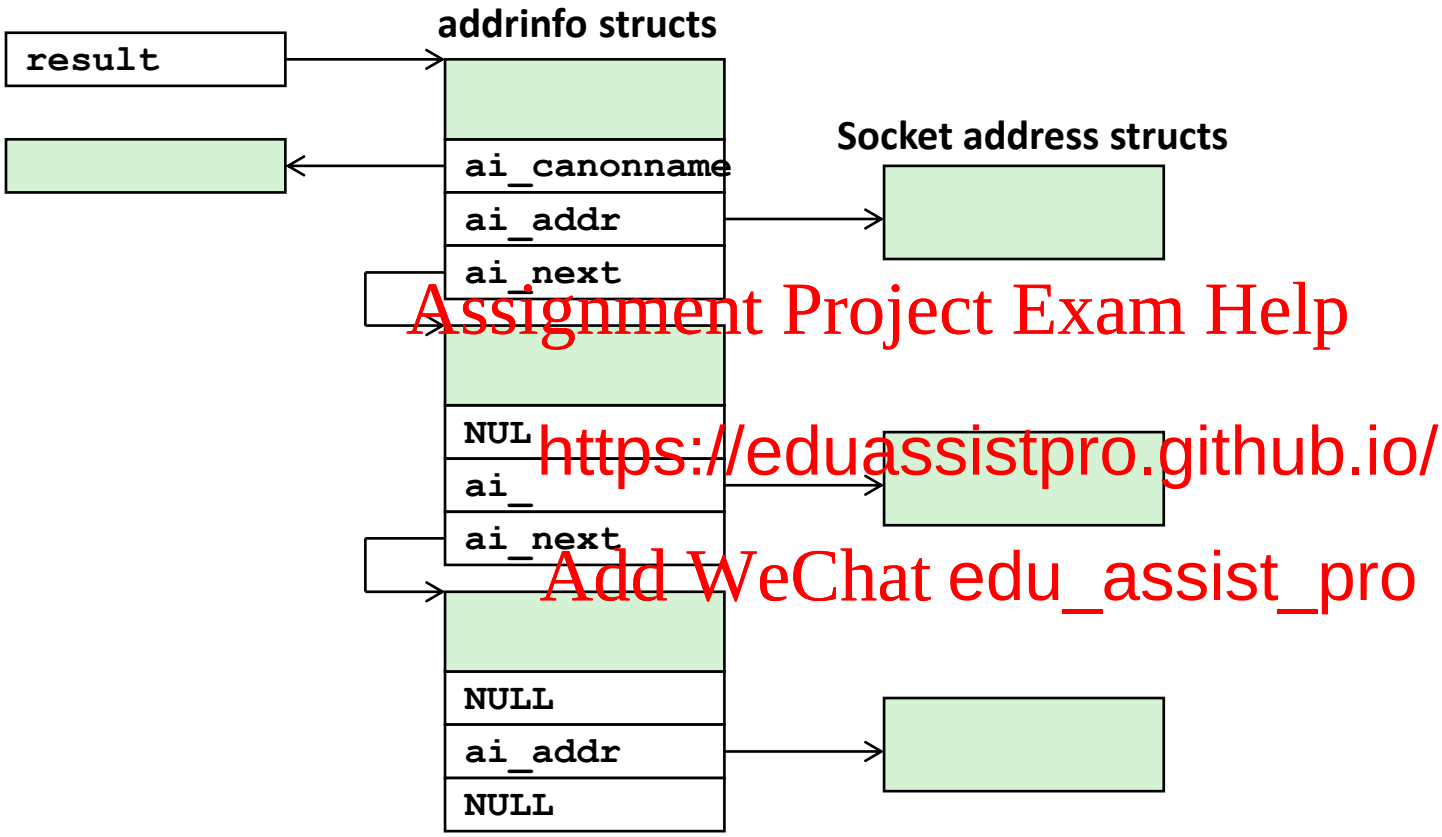
```
int open_clientfd(char *hostname, char *port) {
  int clientfd;
  struct addrinfo hints, *listp, *p;

  /* Get a list of pot
  memset(&hints, 0, si
  hints.ai_socktype =                          nnection */
  hints.ai_flags = AI_NUMERICSERV;  /*          ric port arg. */
  hints.ai_flags |= AI_ADDRCONFIG;  /*          for connections */
  Getaddrinfo(hostname, port, &hints, &listp);
```

csapp.c

`AI_ADDRCONFIG` – uses your system's address type.
You have at least one IPV4 iface? IPV4. At least one IPV6? IPV6.

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.

Sockets Helper: `open_clientfd` (cont)

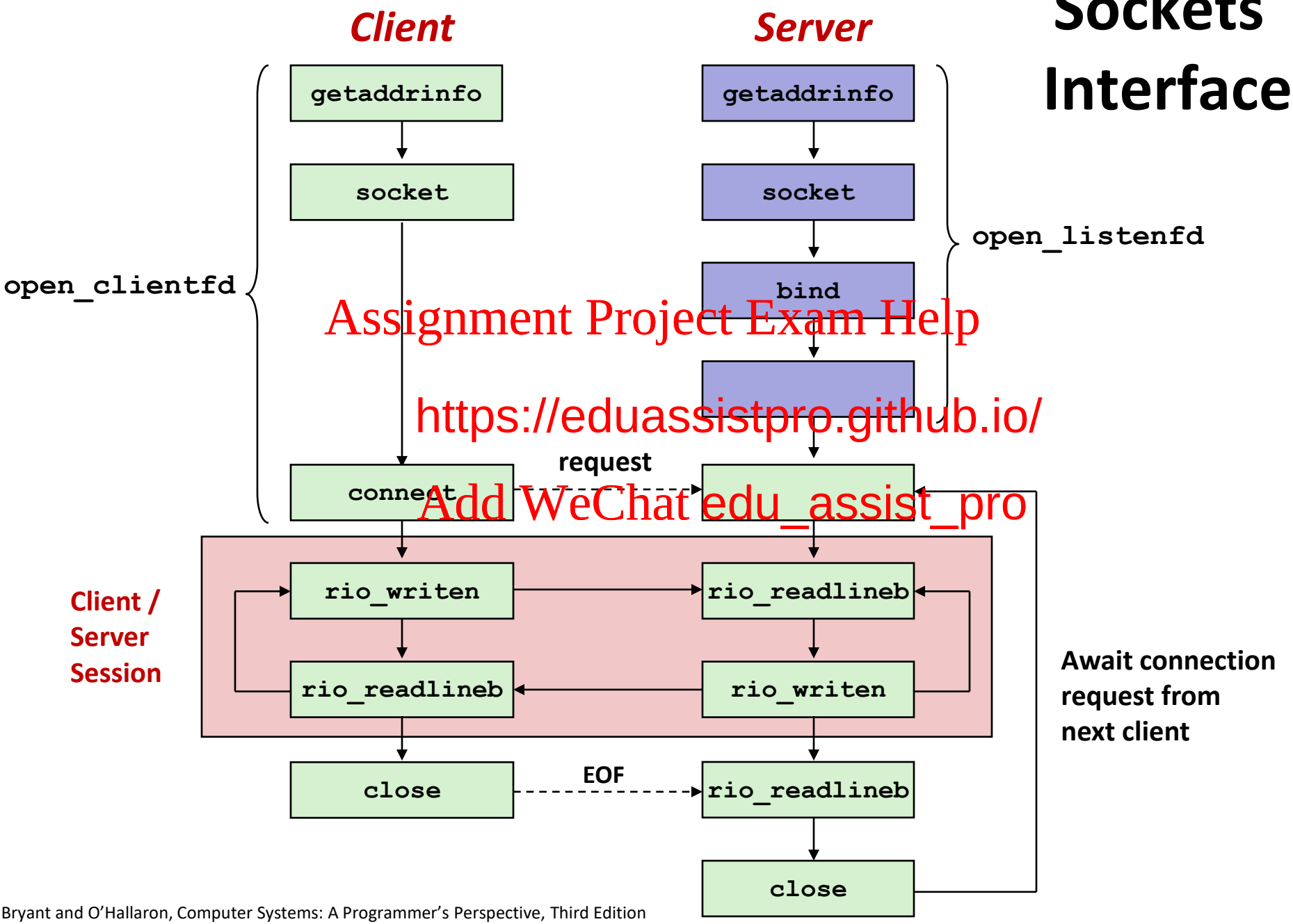
```
    /* Walk the list for one that we can successfully connect to */
    for (p = listp; p; p = p->ai_next) {
        /* Create a socket descriptor */
        if ((clientfd = socket(p->ai_family, p->ai_socktype,
                               p->ai_protocol)) < 0)
            continue; /* Socket failed,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

        /* Connect t                                          */
        if (connect(clientfd, p->ai_                    ddrlen) != -1)
            break; /* Success */
        Close(clientfd); /* Connect                    nother */
    }

    /* 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 h
    int listenfd, opt

    /* Get a list of potential server
    memset(&hints, 0, sizeof(struct a
    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(listenf
        Close(listenfd
        return -1;
    }
    return listenfd;
}
```

csapp.c

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

Testing Servers Using `telnet`

- **The `telnet` program is invaluable for testing servers that transmit ASCII strings over Internet connections**
  - Our simple echo server
  - Web servers
  - Mail servers

- **Usage:**
  - **`linux> telnet <host> <portnumber>`**
  - Creates a connection with a server running on ***`<host>`*** and listening on port ***`<portnumber>`***

Testing the Echo Server With `telnet`

```
whaleshark> ./echoserveri 15213
Connected to (MAKOSHARK.ICS.CS.CMU.EDU, 50280)
server received 11 bytes
server received 8 bytes
```



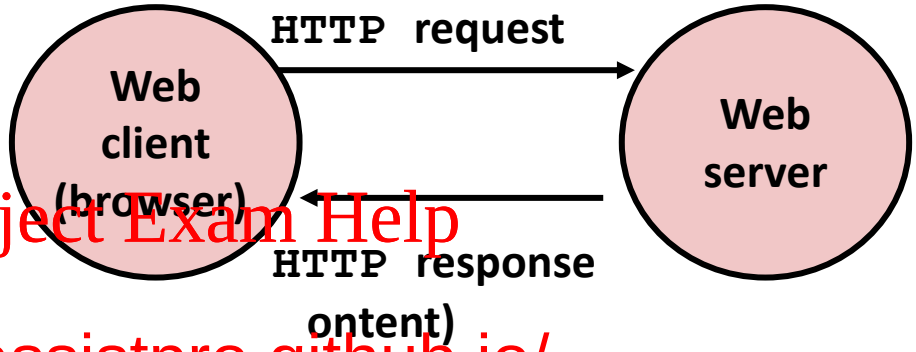
```
makoshark> telnet w                                    5213
Trying 128.2.210.17
Connected to whales                                    .210.175).
Escape character is '^]'.
Hi there!
Hi there!
Howdy!
Howdy!
^]
telnet> quit
Connection closed.
makoshark>
```

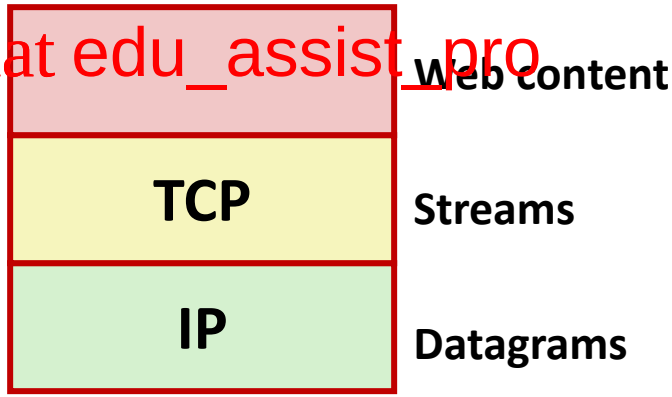
Today

- The Sockets Interface
- **Web Servers**
- The Tiny Web Server
- Serving Dynami

Web Server Basics

- **Clients and servers communicate using the HyperText Transfer Protocol (HTTP)**
  - Client and server establish TCP connection
  - Client requests content
  - Server responds with requested content
  - Client and server close connection (eventually)
- **Current version is HTTP/1.1**
  - RFC 2616, June, 1999.





`http://www.w3.org/Protocols/rfc2616/rfc2616.html`

Web Content

- **Web servers return *content* to clients**
  - *content:* a sequence of bytes with an associated MIME (Multipurpose Internet Mail Extensions) type

- **Example MIME t**
  - `text/html` ent
  - `text/plain` ext
  - `image/gif` ncoded in GIF format
  - `image/png` Binary image encoded in PNG format
  - `image/jpeg` Binary image encoded in JPEG format

You can find the complete list of MIME types at:
`http://www.iana.org/assignments/media-types/media-types.xhtml`

Static and Dynamic Content

- **The content returned in HTTP responses can be either *static* or *dynamic***
  - *Static content*: content stored in files and retrieved in response to an HTTP request
    - Examples: HT ascript programs
    - Request identi
  - *Dynamic content*: content produced sponse to an HTTP request
    - Example: content produced by a program executed by the server on behalf of the client
    - Request identifies file containing executable code
- ***Web content associated with a file that is managed by the server***

URLs and how clients and servers use them

- **Unique name for a file: URL (Universal Resource Locator)**
- **Example URL: `http://www.cmu.edu:80/index.html`**
- **Clients use *prefix* (`http://www.cmu.edu:80`) to infer:**
  - What kind (protocol) of server to contact (HTTP)
  - Where the serve
  - What port it is lis
- **Servers use *suffix* (`/index.ht`):**
  - Determine if request is for static or dynamic content.
    - No hard and fast rules for this
    - One convention: executables reside in **`cgi-bin`** directory
  - Find file on file system
    - Initial "**`/`**" in suffix denotes home directory for requested content.
    - Minimal suffix is "**`/`**", which server expands to configured default filename (usually, **`index.html`**)

HTTP Requests

- **HTTP request is a *request line*, followed by zero or more *request headers***

- **Request line: `<method> <uri> <version>`**
  - **`<method>`** is **`GET`**, **`POST`**, **`OPTIONS`**, **`HEAD`**, **`PUT`**, **`DELETE`**, or **`TRACE`**
  - **`<uri>`** is typically URL for proxies, servers
    - A URL is a type of URI (Uniform Resource Identifier)
    - See http://www.ietf.org/rfc/rfc2396.txt
  - **`<version>`** is HTTP version of request (**`HTTP/1.0`** or **`HTTP/1.1`**)

- **Request headers: `<header name>: <header data>`**
  - Provide additional information to the server

HTTP Responses

- **HTTP response is a *response line* followed by zero or more *response headers*, possibly followed by *content*, with blank line (“\r\n”) separating headers from content.**

- **Response line:**

  `<version` `status msg>`

  - <version> is HT
  - <status code> is numeric status
  - <status msg> is corresponding Eng
    - **`200 OK`** Request was handled without error
    - **`301 Moved`** Provide alternate URL
    - **`404 Not found`** Server couldn’t find the file

- **Response headers: `<header name>: <header data>`**
  - Provide additional information about response
  - **`Content-Type:`** MIME type of content in response body
  - **`Content-Length:`** Length of content in response body

Example HTTP Transaction

```
whaleshark> telnet www.cmu.edu 80          Client: open connection to server
Trying 128.2.42.52...                      Telnet prints 3 lines to terminal
Connected to WWW-CMU-PROD-VIP.ANDREW.cmu.edu.
Escape character is '^]'.
GET / HTTP/1.1                             Client: request line
Host: www.cmu.edu                          Client: required HTTP/1.1 header
                                           Client: blank line terminates headers
HTTP/1.1 301 Moved Permanently             Server: response line
Date: Wed, 05 Nov 2014 17:05:11 GMT        Server: followed by 5 response headers
Server: Apache/1.3.42 (U                             is an Apache server
Location: http://www.cmu                             e has moved here
Transfer-Encoding: chunk                             onse body will be chunked
Content-Type: text/html; charset=...       S           HTML in response body
                                           S           ine terminates headers
15c                                        S           ine in response body
<HTML><HEAD>                               Server: start of HTML content
...
</BODY></HTML>                             Server: end of HTML content
0                                          Server: last line in response body
Connection closed by foreign host.         Server: closes connection
```


- HTTP standard requires that each text line end with "\r\n"
- Blank line ("\r\n") terminates request and response headers

Example HTTP Transaction, Take 2

```
whaleshark> telnet www.cmu.edu 80        Client: open connection to server
Trying 128.2.42.52...                    Telnet prints 3 lines to terminal
Connected to WWW-CMU-PROD-VIP.ANDREW.cmu.edu.
Escape character is '^]'.
GET /index.shtml HTTP/1.1                Client: request line
Host: www.cmu.edu                        Client: required HTTP/1.1 header
                                         Client: blank line terminates headers

HTTP/1.1 200 OK                                  onse line
Date: Wed, 05 Nov 2014 1                         owed by 4 response headers
Server: Apache/1.3.42 (U
Transfer-Encoding: chunked
Content-Type: text/html; charset=...

                                         S              ine terminates headers
1000                                     Server: begin response body
<html ..>                                Server: first line of HTML content
…
</html>
0                                        Server: end response body
Connection closed by foreign host.       Server: close connection
```

Example HTTP(S) Transaction, Take 3

```
whaleshark> openssl s_client www.cs.cmu.edu:443
CONNECTED(00000005)
…
Certificate chain
…
-
Server certificate
-----BEGIN CERTIFICATE-----
MIIGDjCCBPagAwIBAgIRAMiF7UBPDoySi1nNoU+mp+gwDQYJKoZIhvcNAQELBQAw
djELMAkGA1UEBhMCVVMxCzAJBgNVBAgTAk1JMRIwEAYDVQQHEwlBbm4gQXJib3Ix
EjAQBgNVBAoTCUludGVybmV0                              HzAdBgNVBAMT
wkWkvDVBBCwKXrShVxQNsj6J
…
-----END CERTIFICATE-----
subject=/C=US/postalCode=15213/ST=PA/L=Pi              t=5000 Forbes
Ave/O=Carnegie Mellon University/OU=School of Computer
Science/CN=www.cs.cmu.edu          issuer=/C=US/ST=MI/L=Ann
Arbor/O=Internet2/OU=InCommon/CN=InCommon RSA Server CA
SSL handshake has read 6274 bytes and written 483 bytes
…
>GET / HTTP/1.0

HTTP/1.1 200 OK
Date: Tue, 12 Nov 2019 04:22:15 GMT
Server: Apache/2.4.10 (Ubuntu)
Set-Cookie: SHIBLOCATION=scsweb; path=/; domain=.cs.cmu.edu
... HTML Content Continues Below ...
```

Quiz Time!

Check out:

https://canvas.cmu.edu/courses/17808

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- The Sockets Interface
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- **The Tiny Web Server**
- Serving Dynami

Tiny Web Server

- **Tiny Web server described in text**
  - Tiny is a sequential Web server
  - Serves static and dynamic content to real browsers
    - text files, HTML files, GIF, PNG, and JPEG images
  - 239 lines of co
  - Not as comple rver
    - You can break it with poorly requests (e.g., terminate lines with "**\n**" instead of "**\r\n**")

Tiny Operation

- **Accept connection from client**
- **Read request from client (via connected socket)**
- **Split into <method> <uri> <version>**
  - If method not GET, then return error
- **If URI contains "namic content**
  - (Would do wrong thing if had file "`o.html`")
  - Fork process to execute program
- **Otherwise serve static content**
  - Copy file to output

Tiny Serving Static Content

```
void serve_static(int fd, char *filename, int filesize)
{
    int srcfd;
    char *srcp, filetype[MAXLINE], buf[MAXBUF];

    /* Send response headers to client */
    get_filetype(filename, filetype);
    sprintf(buf, "H
    sprintf(buf, "%                                    \r", buf);
    sprintf(buf, "%                                  uf);
    sprintf(buf, "%sContent-length:                  f, filesize);
    sprintf(buf, "%sContent-type:%                   buf, filetype);
    Rio_writen(fd, buf, strlen(buf)

    /* Send response body to client */
    srcfd = Open(filename, O_RDONLY, 0);
    srcp = Mmap(0, filesize, PROT_READ, MAP_PRIVATE, srcfd, 0);
    Close(srcfd);
    Rio_writen(fd, srcp, filesize);
    Munmap(srcp, filesize);
}
```

tiny.c

Today

- The Sockets Interface
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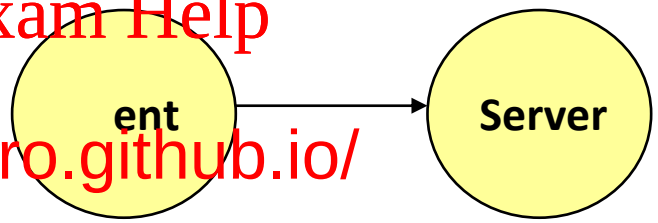
Serving Dynamic Content

- Client sends request to server

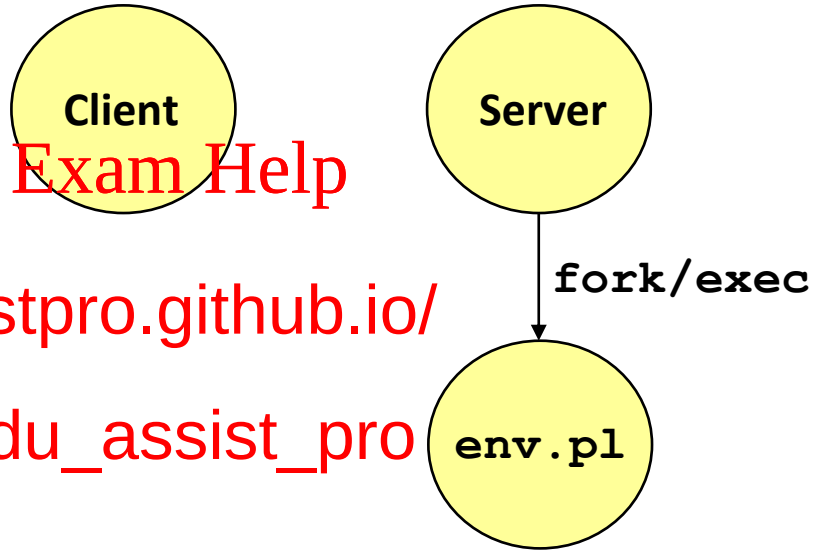
```
GET /cgi-bin/env.pl HTTP/1.1
```

- If request URI co
  string "`/cgi-bi`
  server assumes that the
  request is for dynamic content

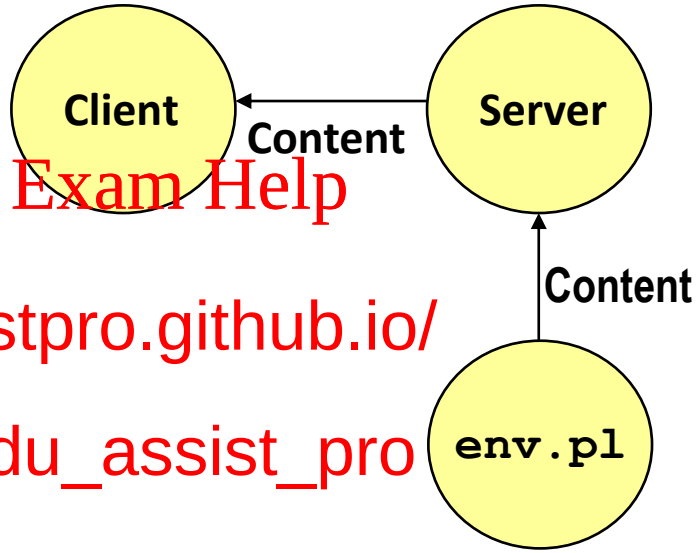
Serving Dynamic Content (cont)

- The server creates a child process and runs the program identifi
URI in that proce



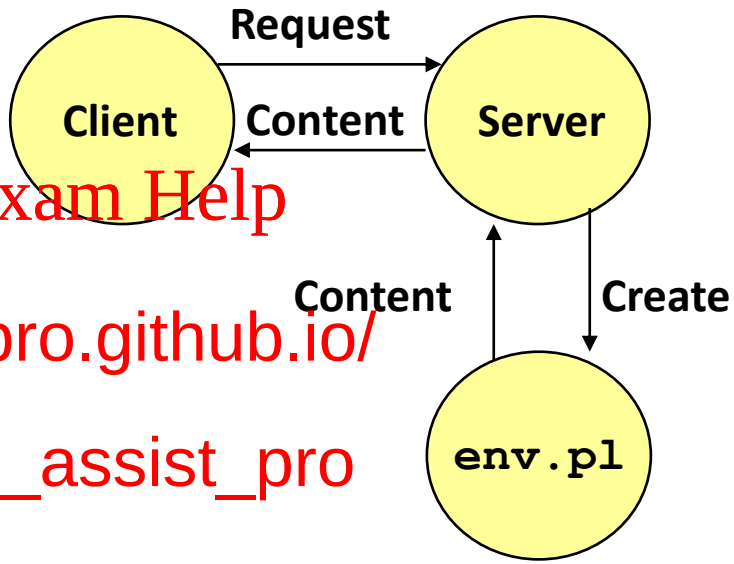
Serving Dynamic Content (cont)

- The child runs and generates the dynamic content
- The server captu content of the child and forwards it without modification to the client



Issues in Serving Dynamic Content

- How does the client pass program arguments to the server?
- How does the server pass these arguments to the child?
- How does the se
relevant to the request to the c
- How does the server capture th
content produced by the child?
- These issues are addressed by the **Common Gateway Interface (CGI)** specification.



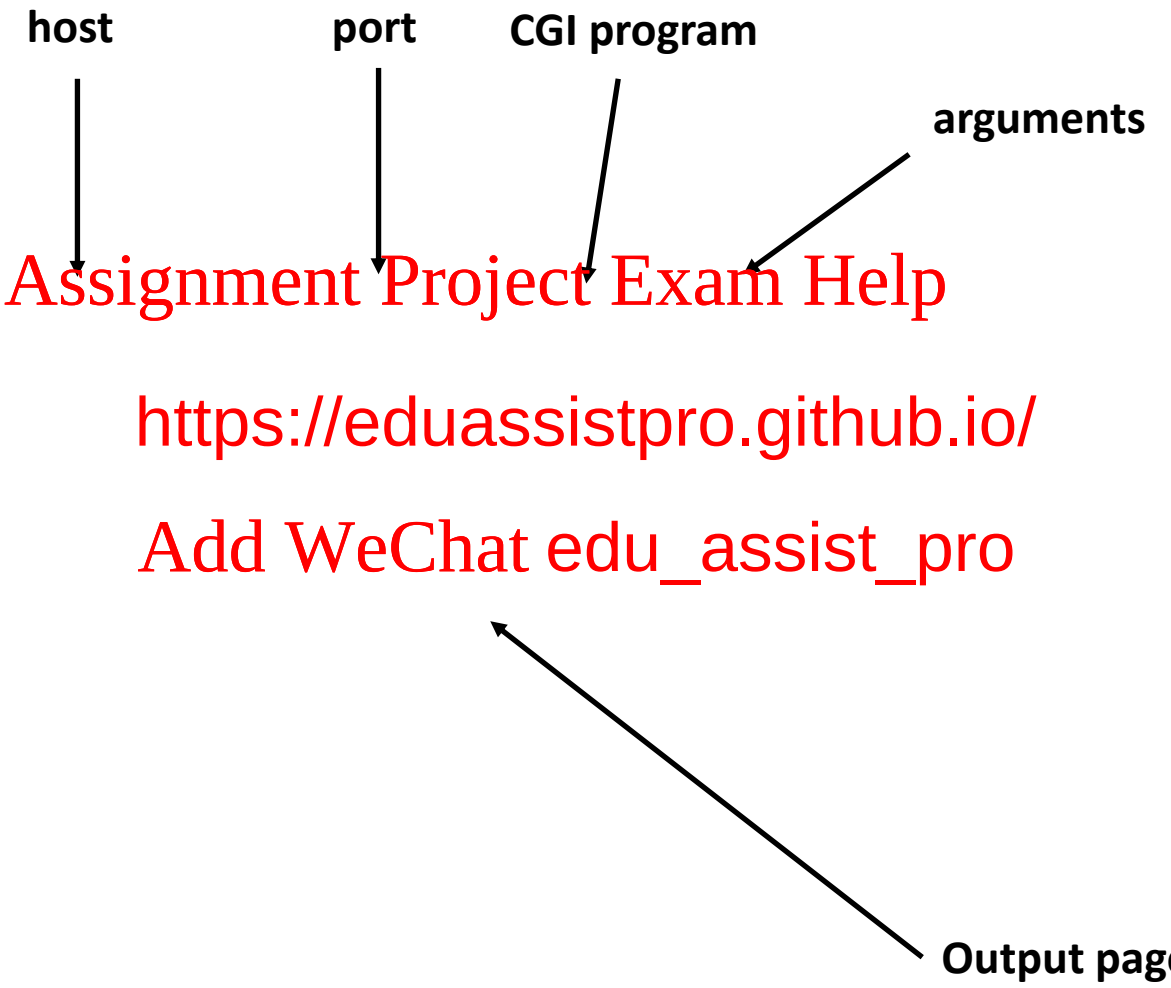
CGI

- Because the children are written according to the CGI spec, they are often called ***CGI programs.***

- However, CGI really defines a simple standard for transferring info nt (browser), the server, and t

- CGI is the original standard for generating dynamic content. Has been largely replaced by other, faster techniques:
  - E.g., fastCGI, Apache modules, Java servlets, Rails controllers
  - Avoid having to create process on the fly (expensive and slow).

The add.com Experience



Serving Dynamic Content With GET

- **Question:** How does the client pass arguments to the server?
- **Answer:** The arguments are appended to the URI

- Can be encoded directly in a URL typed to a browser or a URL in an HTML link
  - `http://add` 213&18213
  - **`adder`** is the CGI program on the l do the addition.
  - argument list starts with "**?**"
  - arguments separated by "**&**"
  - spaces represented by "**+**" or "**%20**"

Serving Dynamic Content With GET

- **URL suffix:**
  - `cgi-bin/adder?15213&18213`

- **Result displayed on browser:**


```
Welcome to the Internet
addition portal.

The answer is: 15213 + 18213 = 33426

Thanks for visiting!
```

Serving Dynamic Content With GET

- **Question: How does the server pass these arguments to the child?**
- **Answer: In environment variable QUERY_STRING**
  - A single string containing everything after the "?"
  - For add: **QUE** 3"


```
/* Extract the two argume
if ((buf = getenv("QUERY_                = NULL) {
    p = strchr(buf, '&');
    *p = '\0';
    strcpy(arg1, buf);
    strcpy(arg2, p+1);
    n1 = atoi(arg1);
    n2 = atoi(arg2);
}
```

adder.c

Serving Dynamic Content with GET

- Question: How does the server capture the content produced by the child?
- Answer: The child generates its output on `stdout`. Server uses `dup2` to redirect `stdout` to its connected socket.

```
void serve_dynamic(int fd, char *filename, char *cgiargs)
{
    char buf[MAXLINE],

    /* Return first pa
    sprintf(buf, "HTTP/1.0 200 OK\r\n"
    Rio_writen(fd, buf, strlen(buf));
    sprintf(buf, "Server: Tiny Web Ser
    Rio_writen(fd, buf, strlen(buf));

    if (Fork() == 0) { /* Child */
        /* Real server would set all CGI vars here */
        setenv("QUERY_STRING", cgiargs, 1);
        Dup2(fd, STDOUT_FILENO);          /* Redirect stdout to client */
        Execve(filename, emptylist, environ); /* Run CGI program */
    }
    Wait(NULL); /* Parent waits for and reaps child */
}
```

Serving Dynamic Content with GET

- Notice that only the CGI child process knows the content type and length, so it must generate those headers.

```
/* Make the response body */
sprintf(content, "Welcome to add.com: ");
sprintf(content, "                                rtal.\r\n<p>", content);
sprintf(content, "                                %d\r\n<p>",
        content, n1, n2, n1 + n2);
sprintf(content, "%sThanks for vis                content);

/* Generate the HTTP response */
printf("Content-length: %d\r\n", (int)strlen(content));
printf("Content-type: text/html\r\n\r\n");
printf("%s", content);
fflush(stdout);

exit(0);
```

adder.c

Serving Dynamic Content With GET

```
bash:makoshark> telnet whaleshark.ics.cs.cmu.edu 15213
Trying 128.2.210.175...
Connected to whaleshark.ics.cs.cmu.edu (128.2.210.175).
Escape character is '^]'.
GET /cgi-bin/adder?15213&18213 HTTP/1.0

HTTP/1.0 200 OK
Server: Tiny Web Ser
Connection: close
Content-length: 117
Content-type: text/html

Welcome to add.com: THE Internet addition portal.
<p>The answer is: 15213 + 18213 = 33426
<p>Thanks for visiting!
Connection closed by foreign host.
bash:makoshark>
```

HTTP request sent by client

HTTP response generated by the server

HTTP response generated by the CGI program

For More Information

- **W. Richard Stevens et. al. "Unix Network Programming: The Sockets Networking API", Volume 1, Third Edition, Prentice Hall, 2003**
  - THE network programming bible.
- **Michael Kerrisk, Interface", No Starch Press, 201**
  - THE Linux programming bible.
- **Complete versions of all code in is available from the 213 schedule page.**
  - **`http://www.cs.cmu.edu/~213/schedule.html`**
  - csapp.{.c,h}, hostinfo.c, echoclient.c, echoserveri.c, tiny.c, adder.c
  - You can use any of this code in your assignments.

Additional slides

Web History

- **1989:**
  - Tim Berners-Lee (CERN) writes internal proposal to develop a distributed hypertext system
    - Connects "a web of notes with links"
    - Intended to rojects share and manage info
- **1990:**
  - Tim BL writes a graphical brows achines

Web History (cont)

- **1992**
  - NCSA server released
  - 26 WWW servers worldwide
- **1993**
  - Marc Andreess CSA Mosaic browser
  - Mosaic version , Unix)
  - Web (port 80) traffic at 1% of NS ne traffic
  - Over 200 WWW servers worldwide
- **1994**
  - Andreessen and colleagues leave NCSA to form “Mosaic Communications Corp” (predecessor to Netscape)

HTTP Versions

- **Major differences between HTTP/1.1 and HTTP/1.0**
  - HTTP/1.0 uses a new connection for each transaction
  - HTTP/1.1 also supports *persistent connections*
    - multiple transactions over the same connection
    - `Connecti`
  - HTTP/1.1 requir
    - `Host: www.cmu.edu`
    - Makes it possible to host multi single Internet host
  - HTTP/1.1 supports *chunked encoding*
    - `Transfer-Encoding: chunked`
  - HTTP/1.1 adds additional support for caching

GET Request to Apache Server From Firefox Browser

URI is just the suffix, not the entire URL

```
GET /~bryant/test.html HTTP/1.1
Host: www.cs.cmu.edu
User-Agent: Mozilla                              ws NT 6.0; en-US;
rv:1.9.2.11) Gecko/
Accept:
text/html,application/xhtml+xml,a                ml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 115
Connection: keep-alive
CRLF (\r\n)
```

GET Response From Apache Server

```
HTTP/1.1 200 OK
Date: Fri, 29 Oct 2010 19:48:32 GMT
Server: Apache/2.2.14 (Unix) mod_ssl/2.2.14 OpenSSL/0.9.7m
mod_pubcookie/3.3.2b PHP/5.3.1
Accept-Ranges: bytes
Content-Length: 47
Keep-Alive: timeou
Connection: Keep-A
Content-Type: text/html
<html>
<head><title>Some Tests</title></head>

<body>
<h1>Some Tests</h1>
  . . .
</body>
</html>
```

Data Transfer Mechanisms

- **Standard**
  - Specify total length with content-length
  - Requires that program buffer entire message
- **Chunked**
  - Break into block
  - Prefix each bloc ded)

Chunked Encoding Example

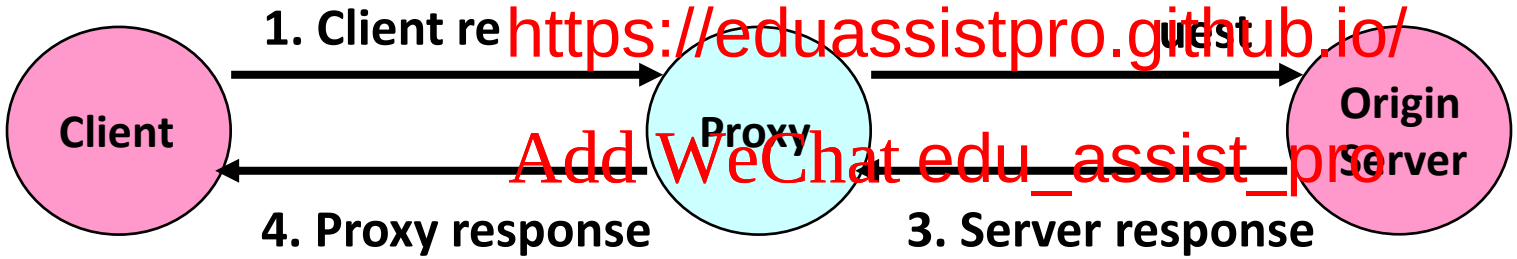
```
HTTP/1.1 200 OK\n
Date: Sun, 31 Oct 2010 20:47:48 GMT\n
Server: Apache/1.3.41 (Unix)\n
Keep-Alive: timeout=15, max=100\n
Connection: Keep-Alive\n
Transfer-Encoding: chunked\n
Content-Type: text/html\n
\r\n
d75\r\n
<html>
<head>
.<link href="http://                                .css" rel="stylesheet"
type="text/css">
</head>
<body id="calendar_body">

<div id='calendar'><table width='100%'  border='0' cellpadding='0'
cellspacing='1' id='cal'>

 . . .
</body>
</html>
\r\n
0\r\n
\r\n
```

First Ch

Second Chunk: 0 bytes (indicates last chunk)

Proxies

- A *proxy* is an intermediary between a client and an *origin server*
  - To the client, the proxy acts like a server
  - To the server, the proxy acts like a client



Why Proxies?

- **Can perform useful functions as requests and responses pass by**
  - Examples: Caching, logging, anonymization, filtering, transcoding