

Sockets

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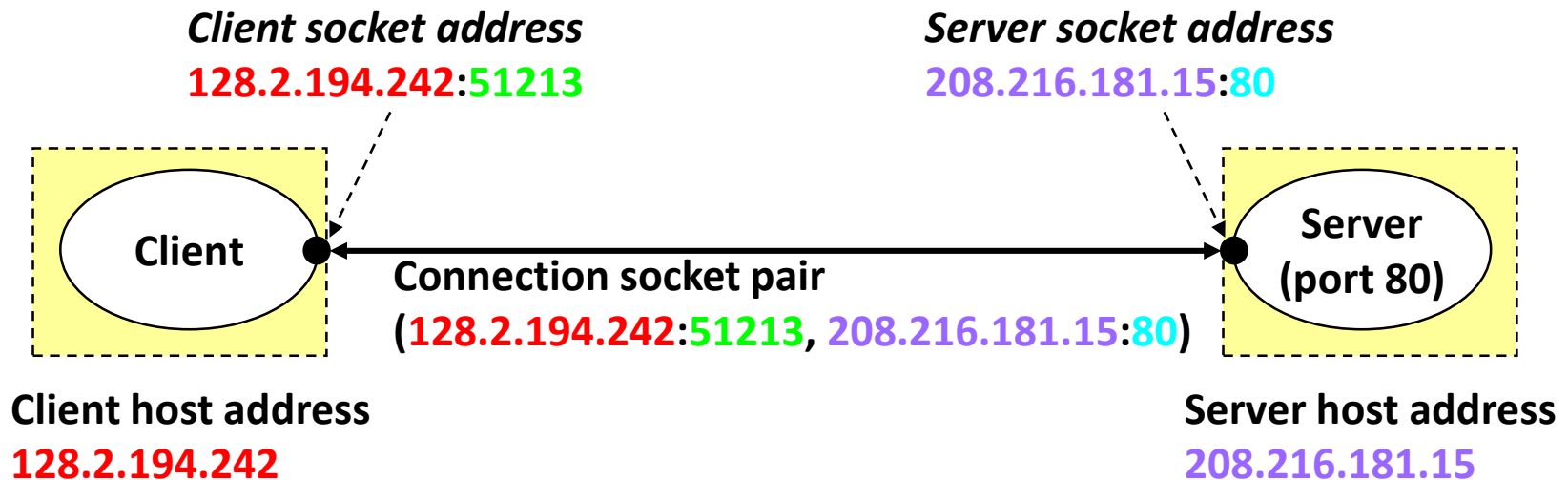
Internet Connections (1)



■ Connection

- Clients and servers communicate by sending streams of bytes over connections:
 - Point-to-point, full-duplex, and reliable.
- A **socket** is an endpoint of a connection
 - Socket address is an <IP address : port> pair
- A **port** is a 16-bit integer that identifies a process
 - **Ephemeral port**: assigned automatically on client when client makes a connection request
 - **Well-known port**: associated with some service provided by a server (e.g. port 80 is associated with web servers.)
- A connection is uniquely identified by the socket addresses of its endpoints (**socket pair**)
 - <client IP:client port, server IP:server port>

Internet Connections (2)

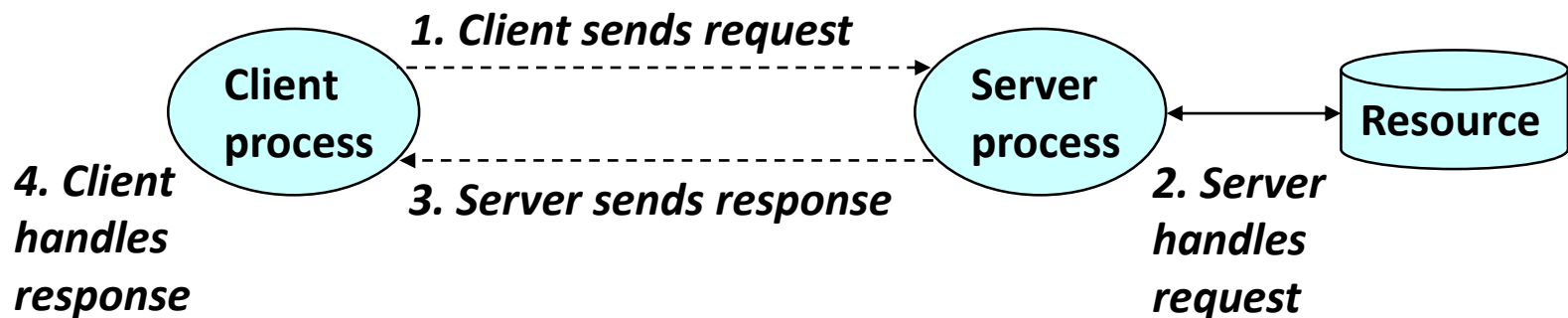


Note: 51213 is an ephemeral port allocated by the kernel

Note: 80 is a well-known port associated with Web servers

Client-Server Model

- Most network application is based on the client-server model:
 - A **server** process and one or more **client** processes
 - Clients and servers are processes running on hosts (can be the same or different hosts)
 - Server manages some **resource**
 - Server provides **service** by manipulating resource for clients



Clients

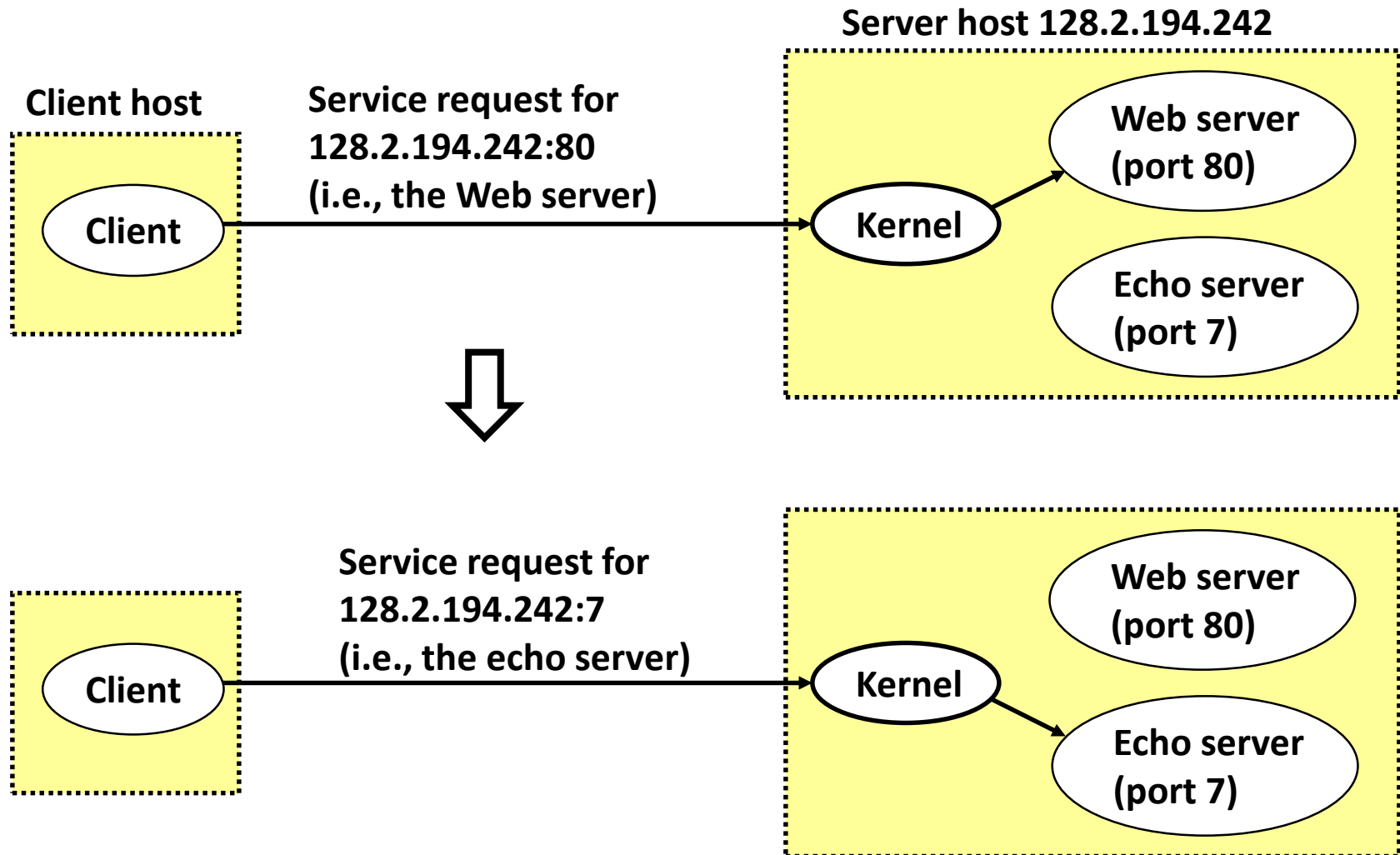
- **Examples of client programs**

- Web browsers, ftp, telnet, ssh

- **How does a client find the server?**

- The IP address in the server socket address identifies the host.
- The (well-known) port in the server socket address identifies the service, and thus implicitly identifies the server process that performs that service
- Examples of well-known ports (cf. **/etc/services**)
 - Port 21: ftp
 - Port 23: telnet
 - Port 25: mail
 - Port 80: web

Using Ports



Servers

- **Servers are long-running processes (daemons)**
 - Created at boot-time (typically) by the init process (process 1)
 - Run continuously until the machine is turned off.
- **Each server waits for requests to arrive on a well-known port associated with a particular service**
 - Port 21: ftp server
 - Port 23: telnet server
 - Port 25: mail server
 - Port 80: HTTP server
- **A machine that runs a server process is also often referred to as a “server”**

Sockets (1)



▪ Sockets interface

- Introduced in BSD4.1 UNIX, 1981.
- Provides a user-level interface to the network.
- Explicitly created, used, released by applications.
- Based on client/server paradigm
- Two types of transport service
 - Unreliable datagram
 - Reliable, connection-oriented byte stream
- Underlying basis for all Internet applications

Sockets (2)

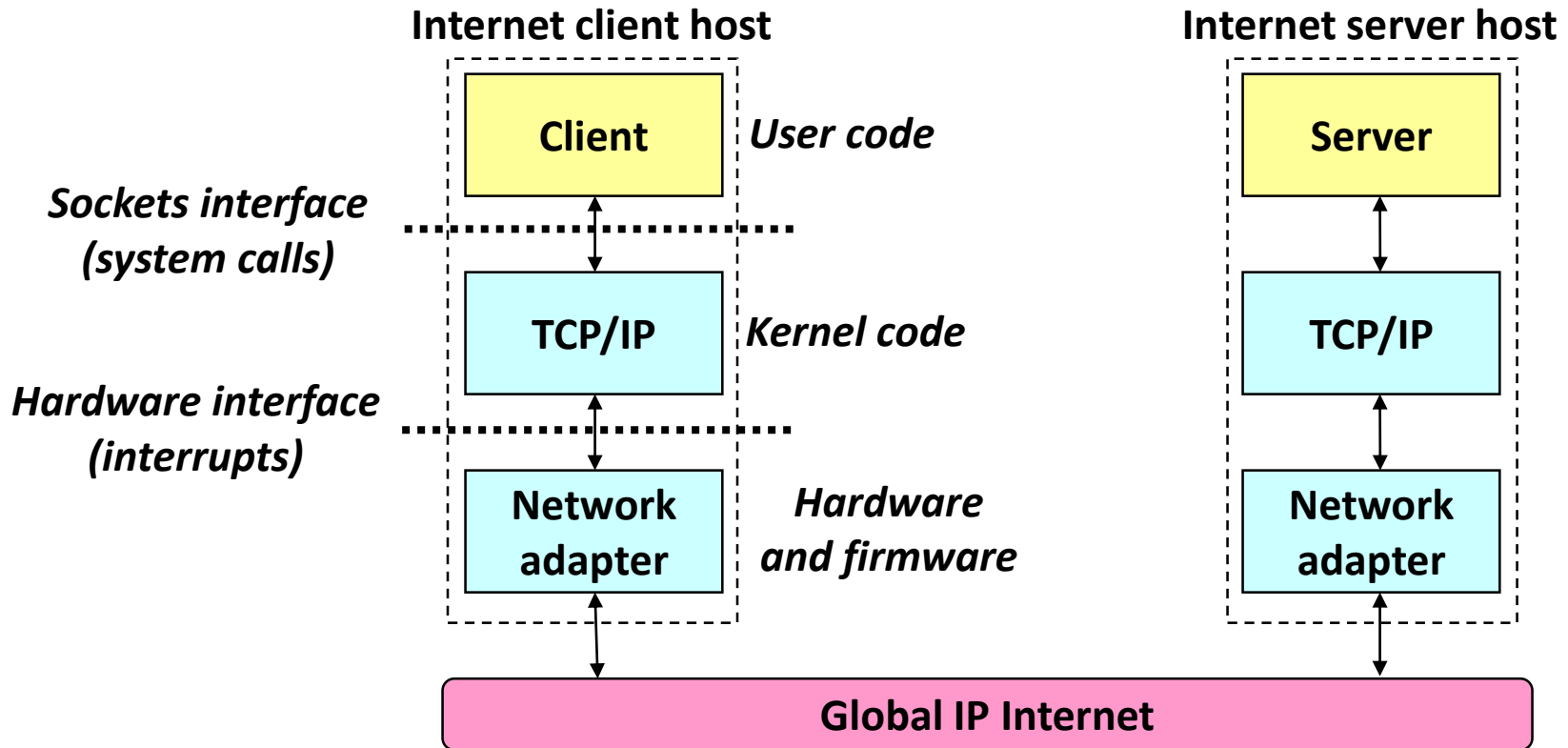


■ What is a socket?

- A host-local, application-created/owned, OS-controlled interface to network (a “door”)
 - To the kernel, a socket is an endpoint of communication.
 - To an application, a socket is a file descriptor.
 - » Applications read/write from/to the network using the file descriptor.
 - » Remember: All Unix I/O devices, including networks, are modeled as files.
- Clients and servers communicate with each 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.

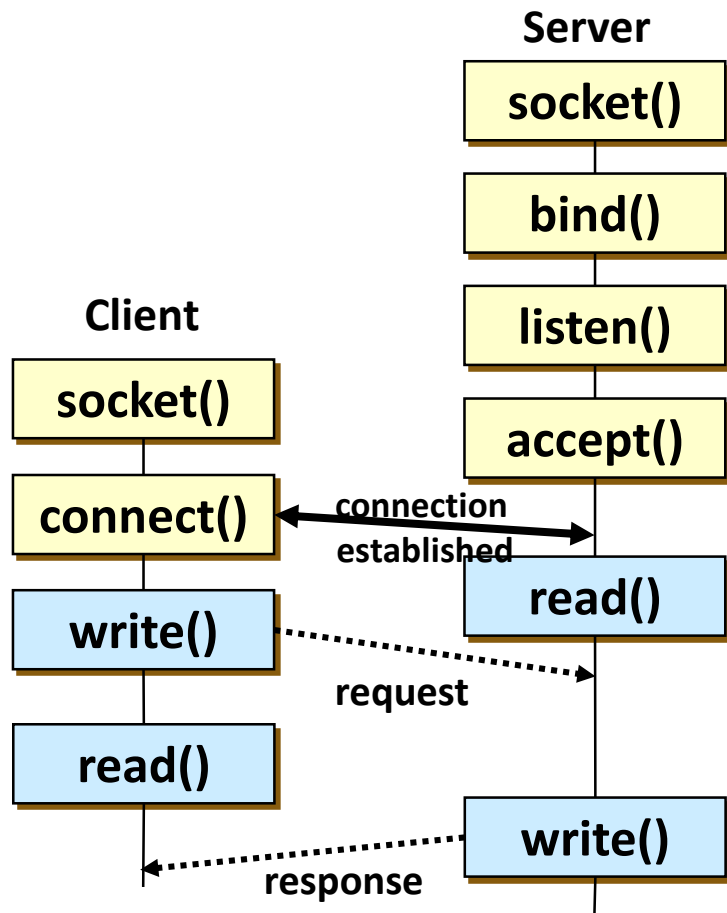
Sockets (3)

- Hardware/Software organization of an Internet application

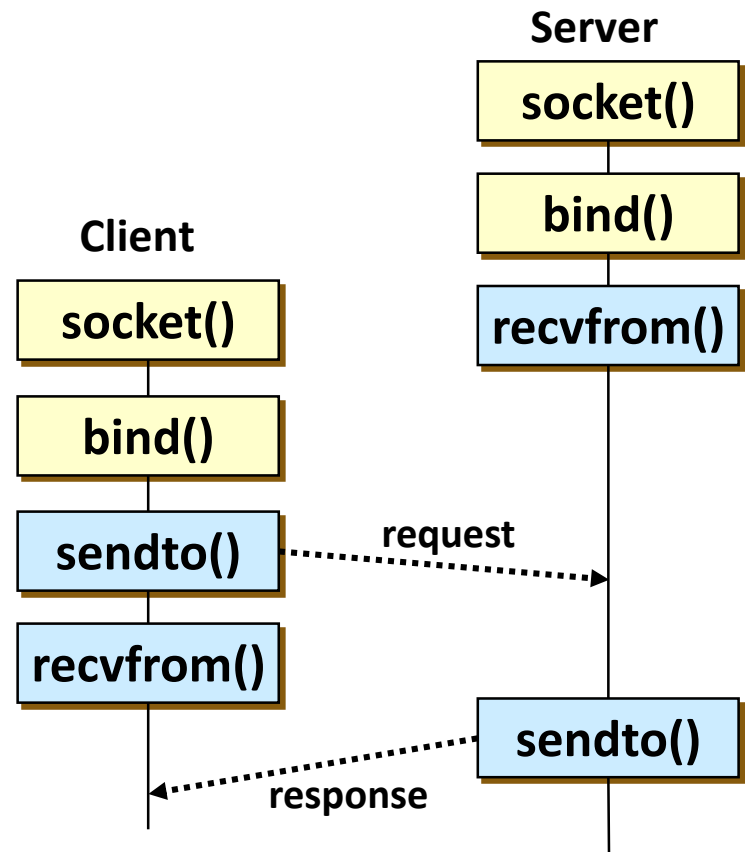


Sockets (4)

Connection-oriented service



Connectionless service



Socket Address Structure

■ Generic socket address

- For address arguments to **connect()**, **bind()**, and **accept()**

```
struct sockaddr {  
    unsigned short  sa_family;    /* protocol family */  
    char            sa_data[14]; /* address data.  */  
};
```

■ Internet-specific socket address

- Must cast (**sockaddr_in ***) to (**sockaddr ***) for **connect()**, **bind()**, and **accept()**

```
struct sockaddr_in {  
    unsigned short  sin_family; /* address family (always AF_INET) */  
    unsigned short  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) */  
};
```

socket()

- **int socket (int family, int type, int protocol)**
 - **socket()** creates a socket descriptor.
 - **family** specifies the protocol family.
 - **AF_UNIX**: Local Unix domain protocols
 - **AF_INET**: IPv4 Internet protocols
 - **type** specifies the communication semantics.
 - **SOCK_STREAM**: provides sequenced, reliable, two-way, connection-based byte streams
 - **SOCK_DGRAM**: supports datagrams (connectionless, unreliable messages of a fixed maximum length)
 - **SOCK_RAW**: provides raw network protocol access
 - **protocol** specifies a particular protocol to be used with the socket.

connect()

- **int connect (int sockfd, const struct sockaddr *servaddr, socklen_t addrlen)**
 - Used by a TCP client to establish a connection with a TCP server.
 - **servaddr** contains <IP address, port number> of the server.
 - The client does not have to call **bind()** before calling **connect()**.
 - The kernel will choose both an ephemeral port and the source IP address if necessary.
 - Client process suspends (blocks) until the connection is created.

Echo Client (1)

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <strings.h>

#define MAXLINE 80

int main (int argc, char *argv[]) {
    int n, cfd;
    struct hostent *h;
    struct sockaddr_in saddr;
    char buf[MAXLINE];
    char *host = argv[1];
    int port = atoi(argv[2]);

    if ((cfd = socket(AF_INET, SOCK_STREAM, 0)) < 0) {
        printf("socket() failed.\n");
        exit(1);
    }
}
```

Echo Client (2)

```
if ((h = gethostbyname(host)) == NULL) {
    printf("invalid hostname %s\n", host);
    exit(2);
}
bzero((char *)&saddr, sizeof(saddr));
saddr.sin_family = AF_INET;
bcopy((char *)h->h_addr, (char *)&saddr.sin_addr.s_addr, h->h_length);
saddr.sin_port = htons(port);

if (connect(cfd, (struct sockaddr *)&saddr, sizeof(saddr)) < 0) {
    printf("connect() failed.\n");
    exit(3);
}
while ((n = read(0, buf, MAXLINE)) > 0) {
    write(cfd, buf, n);
    n = read(cfd, buf, MAXLINE);
    write(1, buf, n);
}
close(cfd);
}
```


bind()

- **int bind (int sockfd, struct sockaddr *myaddr, socklen_t addrlen)**
 - **bind()** gives the socket **sockfd** the local address **myaddr**.
 - **myaddr** is **addrlen** bytes long.
 - Servers bind their well-known port when they start.
 - Normally, a TCP client let the kernel choose an ephemeral port and a client IP address.

listen()

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

- **listen()** converts an unconnected socket into a passive socket, indicating that the kernel should accept incoming connection requests.
 - When a socket is created, it is assumed to be an active socket, that is, a client socket that will issue a **connect()**.
- **backlog** specifies the maximum number of connections that the kernel should queue for this socket.
- Historically, a backlog of 5 was used, as that was the maximum value supported by 4.2BSD.
 - Busy HTTP servers must specify a much larger backlog, and newer kernels must support larger values.

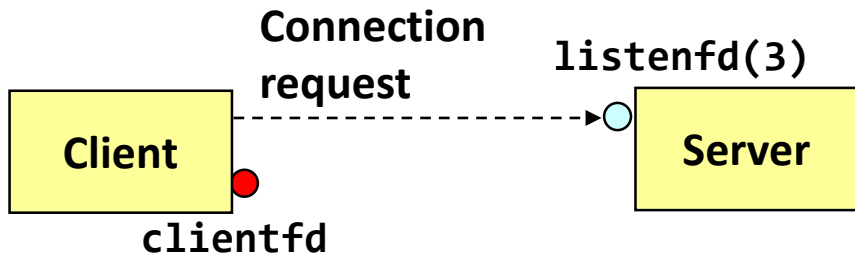
accept() (1)

- **int accept (int sockfd, struct sockaddr *cliaddr, socklen_t *addrlen)**
 - **accept()** blocks waiting for a connection request.
 - **accept()** returns a **connected descriptor** with the same properties as the **listening descriptor**.
 - The kernel creates one connected socket for each client connection that is accepted.
 - Returns when the connection between client and server is created and ready for I/O transfers.
 - All I/O with the client will be done via the connected socket.
 - The **cliaddr** and **addrlen** arguments are used to return the address of the connected peer process (the client)

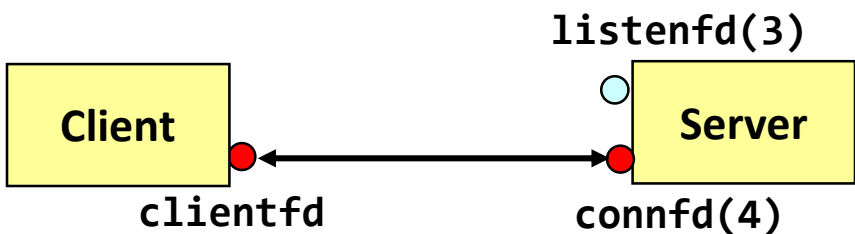
accept() (2)



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`.

accept() (3)

■ 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.

Echo Server (1)

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <strings.h>
#include <arpa/inet.h>

#define MAXLINE 80

int main (int argc, char *argv[]) {
    int n, listenfd, connfd, caddrlen;
    struct hostent *h;
    struct sockaddr_in saddr, caddr;
    char buf[MAXLINE];
    int port = atoi(argv[1]);

    if ((listenfd = socket(AF_INET, SOCK_STREAM, 0)) < 0) {
        printf("socket() failed.\n");
        exit(1);
    }
}
```

Echo Server (2)



```
bzero((char *)&saddr, sizeof(saddr));
saddr.sin_family = AF_INET;
saddr.sin_addr.s_addr = htonl(INADDR_ANY);
saddr.sin_port = htons(port);
if (bind(listenfd, (struct sockaddr *)&saddr,
        sizeof(saddr)) < 0) {
    printf("bind() failed.\n");
    exit(2);
}
if (listen(listenfd, 5) < 0) {
    printf("listen() failed.\n");
    exit(3);
}
while (1) {
    caddrlen = sizeof(caddr);
    if ((connfd = accept(listenfd, (struct sockaddr *)&caddr,
                        &caddrlen)) < 0) {
        printf("accept() failed.\n");
        continue;
    }
}
```

Echo Server (3)



```
h = gethostbyaddr((const char *)&caddr.sin_addr.s_addr,
    sizeof(caddr.sin_addr.s_addr), AF_INET);
printf("server connected to %s (%s)\n",
    h->h_name,
    inet_ntoa(*(struct in_addr *)&caddr.sin_addr));

// echo
while ((n = read(connfd, buf, MAXLINE)) > 0) {
    printf ("got %d bytes from client.\n", n);
    write(connfd, buf, n);
}

printf("connection terminated.\n");
close(connfd);
}
}
```


Echo Server (4)

