Socket Programming

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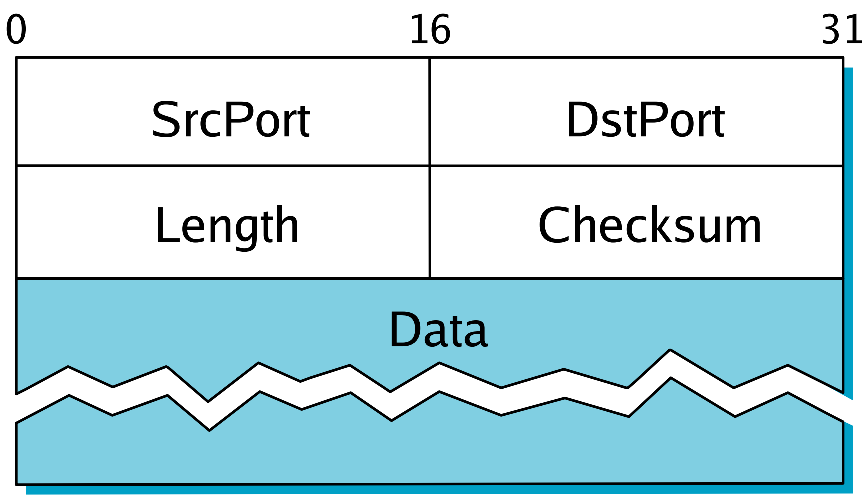
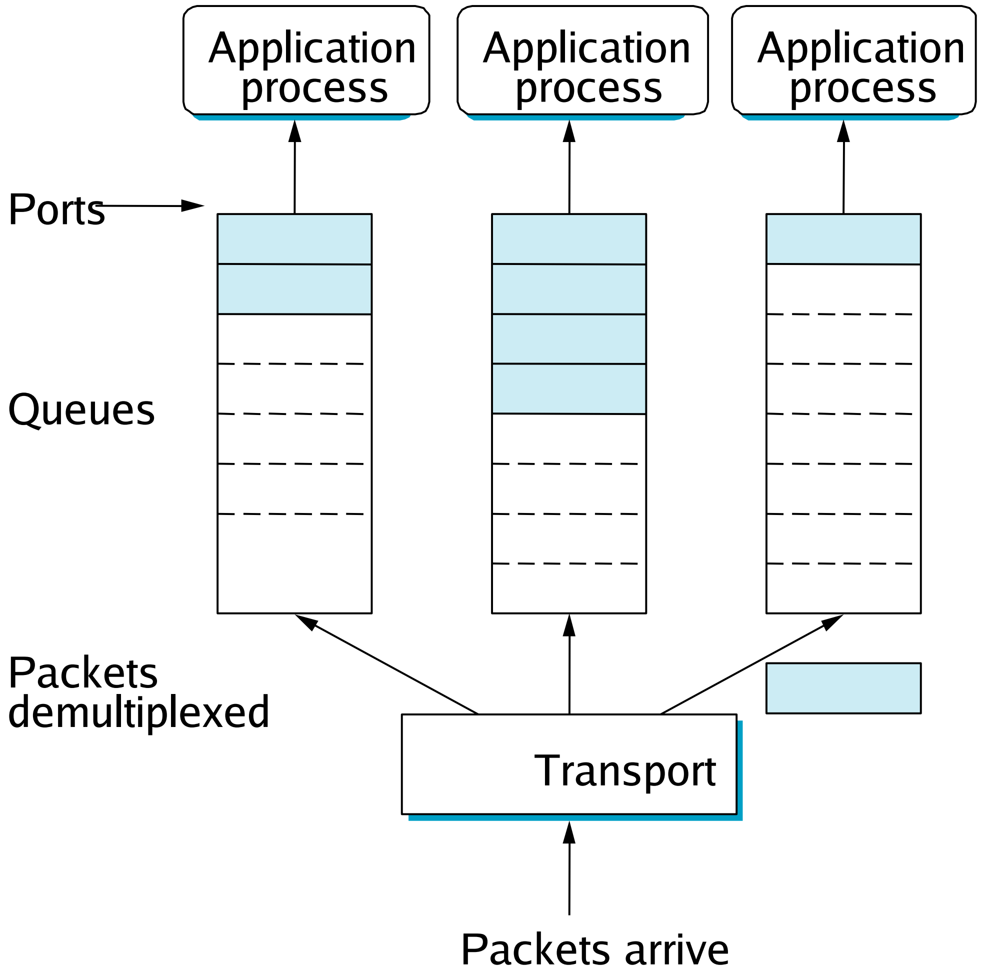
Background

Demultiplexing

- Convert host-to-host packet delivery service into a process-to-process communication channel





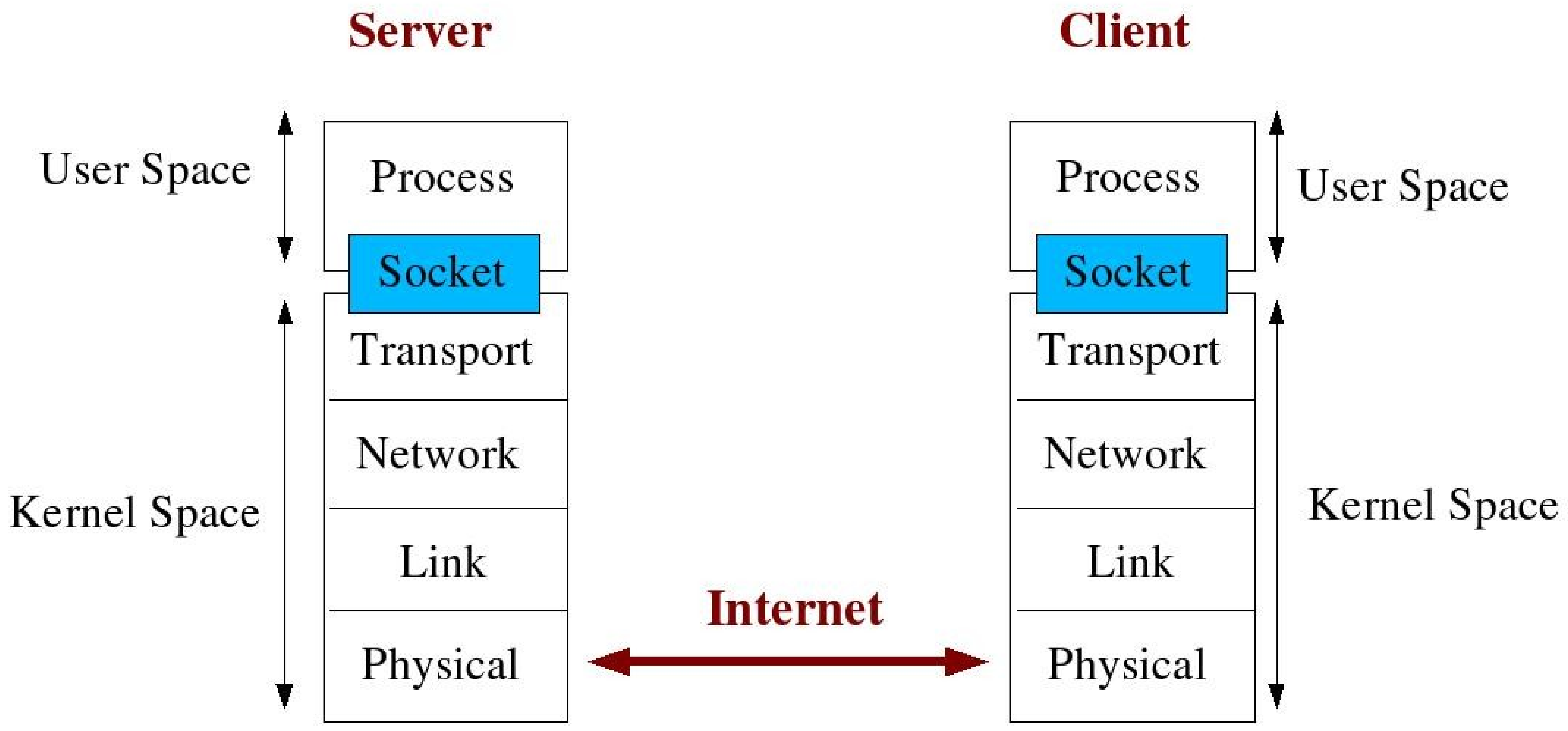
Byte Ordering

- Two types of “Byte ordering”
  - Network Byte Order: High-order byte of the number is stored in memory at the lowest address
  - Host Byte Order: Low-order byte of the number is stored in memory at the lowest address
  - Network stack (TCP/IP) expects Network Byte Order
- Conversions:
  - htons() - Host to Network Short
  - htonl() - Host to Network Long
  - ntohs() - Network to Host Short
  - ntohl() - Network to Host Long

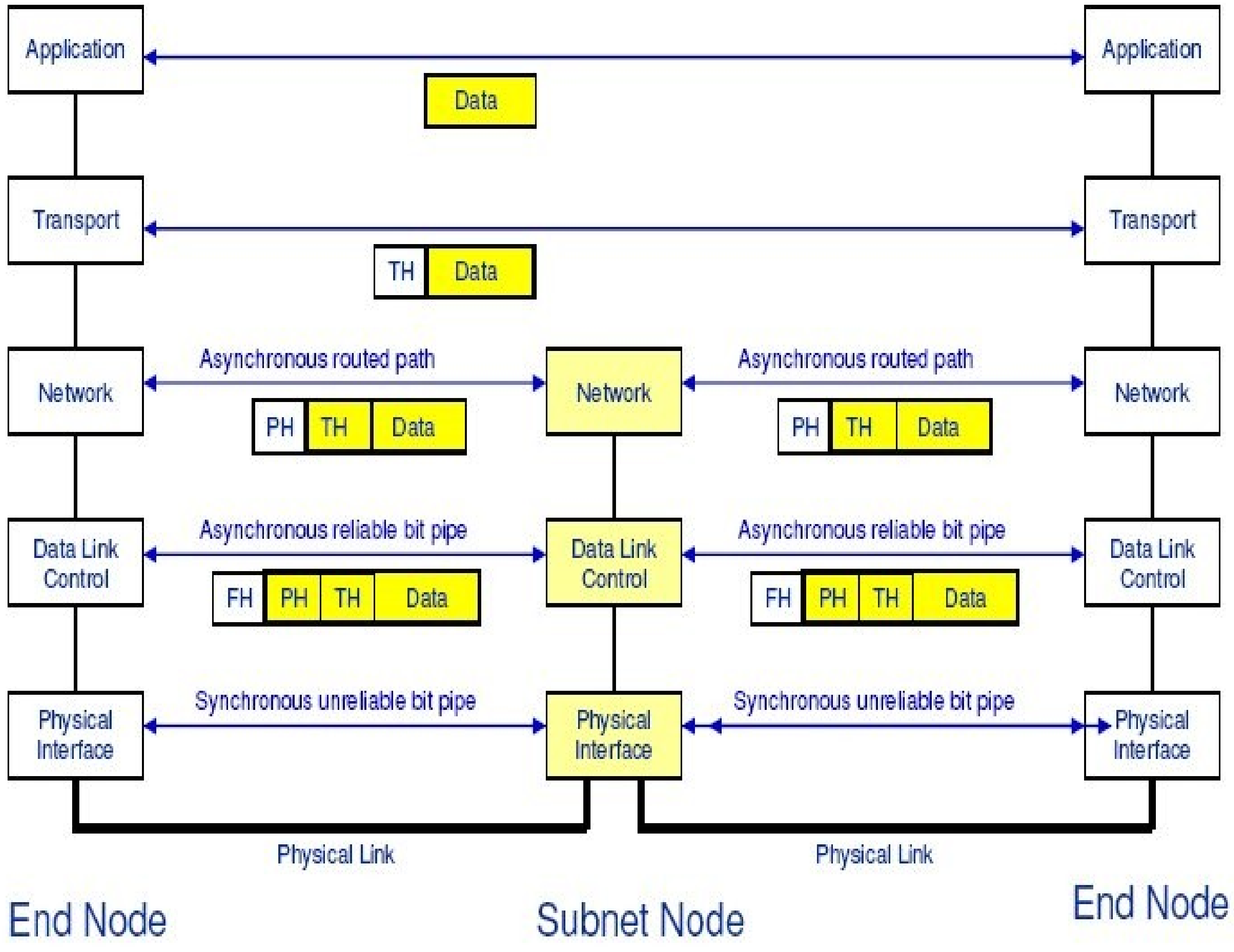
What is a socket?

- Socket: An interface between an application process and transport layer
  - The application process can send/receive messages to/from another application process (local or remote)via a socket
- In Unix jargon, a socket is a file descriptor – an integer associated with an open file
- Types of Sockets: **Internet Sockets**, unix sockets, X.25 sockets etc
  - Internet sockets characterized by IP Address (4 bytes), port number (2 bytes)

Socket Description



Encapsulation



Each layer just looks at its own header

Types of Internet Sockets

- Stream Sockets (SOCK_STREAM)
  - Connection oriented
  - Rely on TCP to provide reliable two-way connected communication
- Datagram Sockets (SOCK_DGRAM)
  - Rely on UDP
  - Connection is unreliable

socket() -- Get the file descriptor

- int socket(int domain, int type, int protocol);
  - domain should be set to PF_INET
  - type can be SOCK_STREAM or SOCK_DGRAM
  - set protocol to 0 to have socket choose the correct protocol based on type
  - socket() returns a socket descriptor for use in later system calls or -1 on error

```
int sockfd;
sockfd = socket (PF_INET, SOCK_STREAM, 0);
```

Socket Structures

- struct sockaddr: Holds socket address information for many types of sockets

```
struct sockaddr {
        unsigned short   sa_family;      //address family AF_xxx
        unsigned short   sa_data[14]; //14 bytes of protocol addr
}
```

- struct sockaddr_in: A parallel structure that makes it easy to reference elements of the socket address

```
struct sockaddr_in {
        short int              sin_family;    // set to AF_INET
        unsigned short int     sin_port;      // Port number
        struct in_addr         sin_addr;      // Internet address
        unsigned char          sin_zero[8];  //set to all zeros
}
```

- sin_port and sin_addr must be in **Network Byte Order**

Dealing with IP Addresses

-
  ```
  struct in_addr {
      unsigned long s_addr; // that's a 32-bit long, or 4 bytes
  };
  ```
- int inet_aton(const char *cp, struct in_addr *inp);

  ```
  struct sockaddr_in     my_addr;
  my_addr.sin_family = AF_INET;
  my_addr.sin_port = htons(MYPORT);
  inet_aton("10.0.0.5",&(my_addr.sin_addr));
  memset(&(my_addr.sin_zero),'\0',8);
  ```

  – inet_aton() gives non-zero on success; zero on failure
- To convert binary IP to string: inet_noa()

  ```
  printf("%s",inet_ntoa(my_addr.sin_addr));
  ```

bind() - what port am I on?

- Used to associate a socket with a port on the local machine
  - The port number is used by the kernel to match an incoming packet to a process
- int bind(int sockfd, struct sockaddr *my_addr, int addrlen)
  - sockfd is the socket descriptor returned by socket()
  - my_addr is pointer to struct sockaddr that contains information about your IP address and port
  - addrlen is set to sizeof(struct sockaddr)
  - returns -1 on error
  - my_addr.sin_port = 0; //choose an unused port at random
  - my_addr.sin_addr.s_addr = INADDR_ANY; //use my IP adr

Example

```
int sockfd;
struct sockaddr_in my_addr;
sockfd = socket(PF_INET, SOCK_STREAM, 0);
my_addr.sin_family = AF_INET;         // host byte order
my_addr.sin_port = htons(MYPORT);     // short, network byte
   order
my_addr.sin_addr.s_addr = inet_addr("172.28.44.57");
memset(&(my_addr.sin_zero), '\0', 8); // zero the rest of the struct
bind(sockfd, (struct sockaddr *)&my_addr, sizeof(struct
   sockaddr));
/******  Code needs error checking. Don't forget to do that ****** /
```

connect() - Hello!

- Connects to a remote host
- int connect(int sockfd, struct sockaddr *serv_addr, int addrlen)
  - sockfd is the socket descriptor returned by socket()
  - serv_addr is pointer to struct sockaddr that contains information on destination IP address and port
  - addrlen is set to sizeof(struct sockaddr)
  - returns -1 on error
- No need to bind(), kernel will choose a port

Example

```
#define DEST_IP   "172.28.44.57"
#define DEST_PORT 5000
main(){
   int sockfd;
   struct sockaddr_in dest_addr;   // will hold the destination addr
   sockfd = socket(PF_INET, SOCK_STREAM, 0);
    dest_addr.sin_family = AF_INET;          // host byte order
    dest_addr.sin_port = htons(DEST_PORT);   // network byte
    order
    dest_addr.sin_addr.s_addr = inet_addr(DEST_IP);
    memset(&(dest_addr.sin_zero), '\0', 8);  // zero the rest of the
    struct    connect(sockfd, (struct sockaddr *)&dest_addr,
    sizeof(struct sockaddr));
  /******* Don't forget error checking ********/
```

listen() - Call me please!

- Waits for incoming connections
- int listen(int sockfd, int backlog);
  - sockfd is the socket file descriptor returned by socket()
  - backlog is the number of connections allowed on the incoming queue
  - listen() returns -1 on error
  - Need to call bind() before you can listen()
    - socket()
    - bind()
    - listen()
    - accept()

accept() - Thank you for calling !

- accept() gets the pending connection on the port you are listen()ing on
- int accept(int sockfd, void *addr, int *addrlen);
  - sockfd is the listening socket descriptor
  - information about incoming connection is stored in addr which is a pointer to a local struct sockaddr_in
  - addrlen is set to sizeof(struct sockaddr_in)
  - accept returns *a new socket file descriptor* to use for this accepted connection and -1 on error

Example

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#define MYPORT 3490    // the port users will be connecting to
#define BACKLOG 10     // pending connections queue will hold
main(){
   int sockfd, new_fd;  // listen on sock_fd, new connection on
   new_fd
   struct sockaddr_in my_addr;    // my address information
   struct sockaddr_in their_addr; // connector's address informatio
   int sin_size;
  sockfd = socket(PF_INET, SOCK_STREAM, 0);
```

Cont...

```
my_addr.sin_family = AF_INET;        // host byte order
my_addr.sin_port = htons(MYPORT);    // short, network byte
order
my_addr.sin_addr.s_addr = INADDR_ANY; // auto-fill with my IP
memset(&(my_addr.sin_zero), '\0', 8); // zero the rest of the struct
// don't forget your error checking for these calls:
bind(sockfd, (struct sockaddr *)&my_addr, sizeof(struct
sockaddr));
listen(sockfd, BACKLOG);
sin_size = sizeof(struct sockaddr_in);
new_fd = accept(sockfd, (struct sockaddr *)&their_addr,
&sin_size);
```

send() and recv() - Let's talk!

- The two functions are for communicating over stream sockets or connected datagram sockets.
- int send(int sockfd, const void *msg, int len, int flags);
  - sockfd is the socket descriptor you want to send data to (returned by socket() or got from accept())
  - msg is a pointer to the data you want to send
  - len is the length of that data in bytes
  - set flags to 0 for now
  - sent() returns the number of bytes actually sent (may be less than the number you told it to send) or -1 on error

send() and recv() - Let's talk!

- int recv(int sockfd, void *buf, int len, int flags);
  - sockfd is the socket descriptor to read from
  - buf is the buffer to read the information into
  - len is the maximum length of the buffer
  - set flags to 0 for now
  - recv() returns the number of bytes actually read into the buffer or -1 on error
  - If recv() returns 0, the remote side has closed connection on you

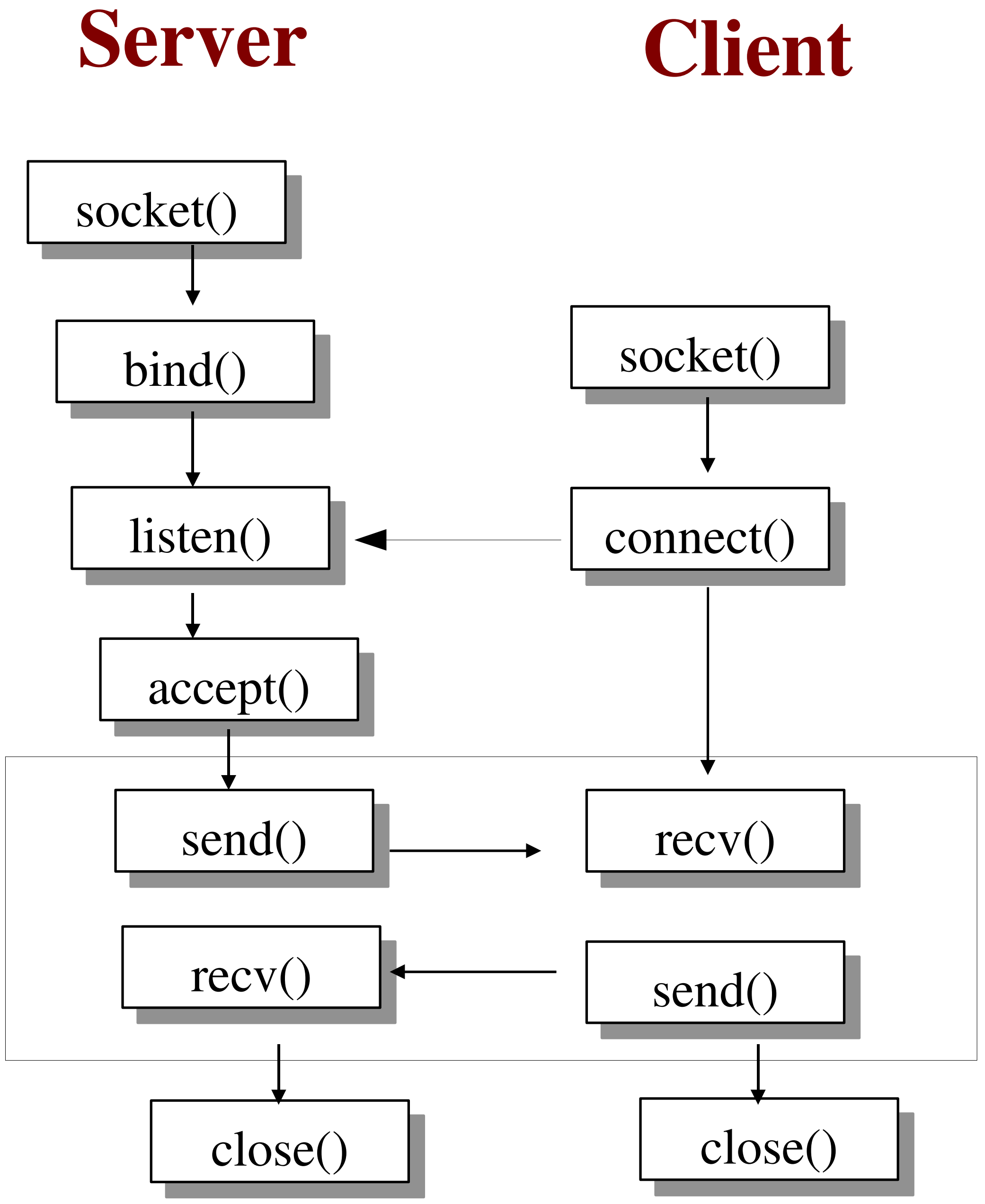
sendto() and recvfrom() - DGRAM style

- int sendto(int sockfd, const void *msg, int len, int flags, const struct sockaddr *to, int tolen);
  - *to* is a pointer to a struct sockaddr which contains the destination IP and port
  - *tolen* is sizeof(struct sockaddr)
- int recvfrom(int sockfd, void *buf, int len, int flags, struct sockaddr *from, int *fromlen);
  - *from* is a pointer to a local struct sockaddr that will be filled with IP address and port of the originating machine
  - *fromlen* will contain length of address stored in *from*

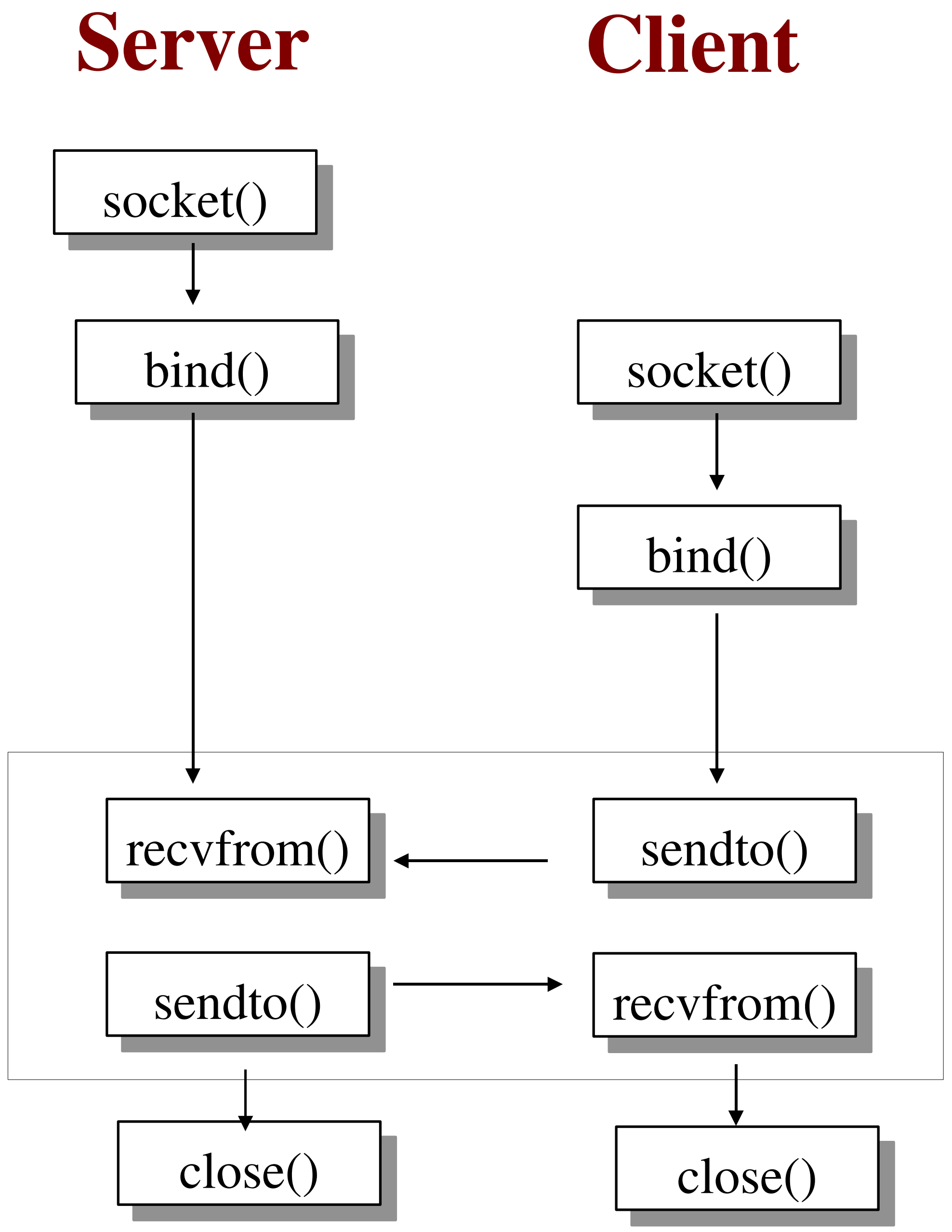
close() - Bye Bye!

- int close(int sockfd);
  - Closes connection corresponding to the socket descriptor and frees the socket descriptor
  - Will prevent any more sends and recvs

Connection Oriented Protocol



Connectionless Protocol



Miscellaneous Routines

- int getpeername(int sockfd, struct sockaddr *addr, int *addrlen);
  - Will tell who is at the other end of a connected stream socket and store that info in *addr*
- int gethostname(char *hostname, size_t size);
  - Will get the name of the computer your program is running on and store that info in hostname

Miscellaneous Routines

- struct hostent *gethostbyname(const char *name);

```
struct hostent {
      char    *h_name;       //official name of host
      char    **h_aliases;   //alternate names for the host
      int     h_addrtype;    //usually AF_NET
      int     h_length;      //length of the address in bytes
      char    **h_addr_list; //array of network addresses for the host
}
#define h_addr h_addr_list[0]
```

- Example Usage:

```
struct hostent *h;
h = gethostbyname(“www.iitk.ac.in”);
printf(“Host name : %s \n”, h->h_name);
printf(“IP Address: %s\n”,inet_ntoa(*((struct in_addr *)h->h_addr)));
```

Advanced Topics

- Blocking
- Select
- Handling partial sends
- Signal handlers
- Threading

Summary

- Sockets help application process to communicate with each other using standard Unix file descriptors
- Two types of Internet sockets: SOCK_STREAM and SOCK_DGRAM
- Many routines exist to help ease the process of communication

References

- Books:
  - Unix Network Programming, volumes 1-2 by W. Richard Stevens.
  - TCP/IP Illustrated, volumes 1-3 by W. Richard Stevens and Gary R. Wright
- Web Resources:
  - Beej's Guide to Network Programming
    - www.ecst.csuchico.edu/~beej/guide/net/