Socket Programming

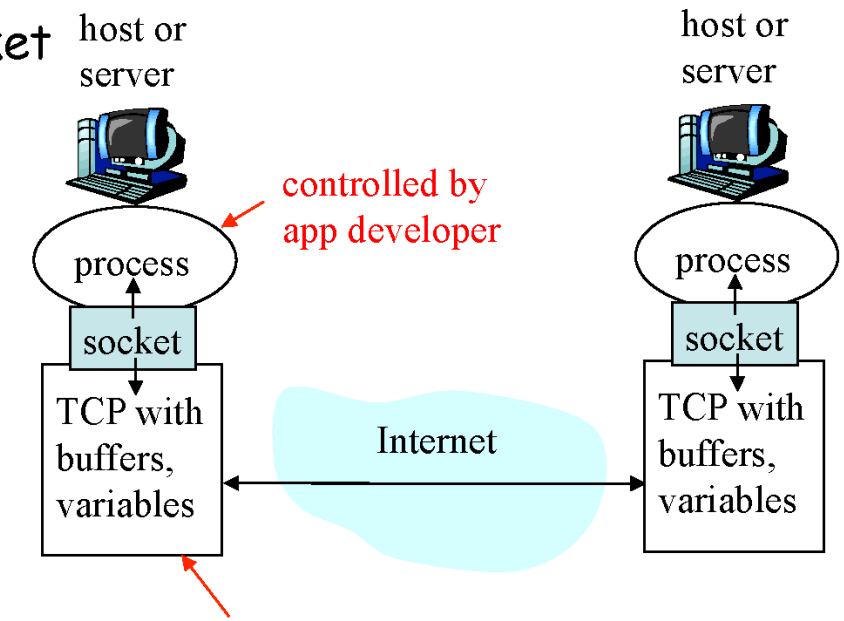
- What is a socket?

- Using sockets
  - Types (Protocols)
  - Associated functions
  - Styles

  - Socket programming reference:
    - TCP/IP 소켓 프로그래밍 - C버전, Michael J. Donahoo, (박준철 번역), 사이텍미디어

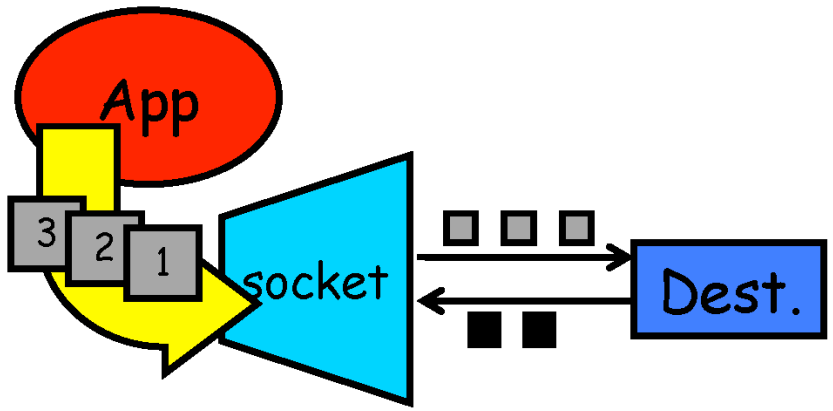
What is a socket?

- An interface between application and network
  - The application creates a socket
  - The socket *type* dictates the style of communication
    - reliable vs. best effort
    - connection-oriented vs. connectionless
- Once configured, the application can
  - pass data to the socket for network transmission
  - receive data from the socket (transmitted through the network by some other host)

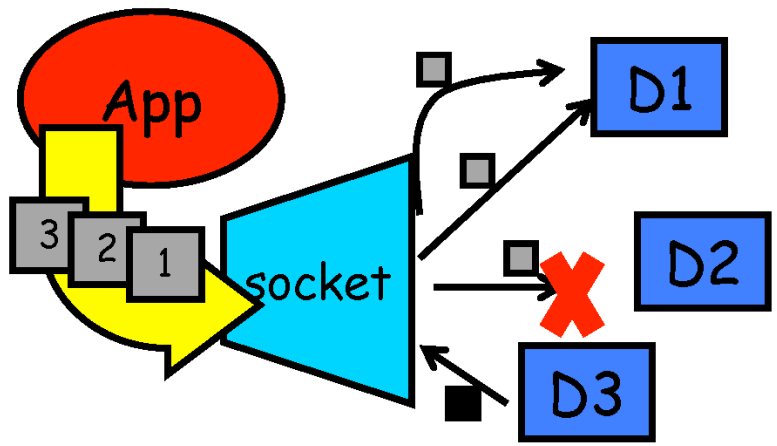


Two essential types of sockets

- SOCK_STREAM
  - a.k.a. TCP
  - reliable delivery
  - in-order guaranteed
  - connection-oriented
  - bidirectional



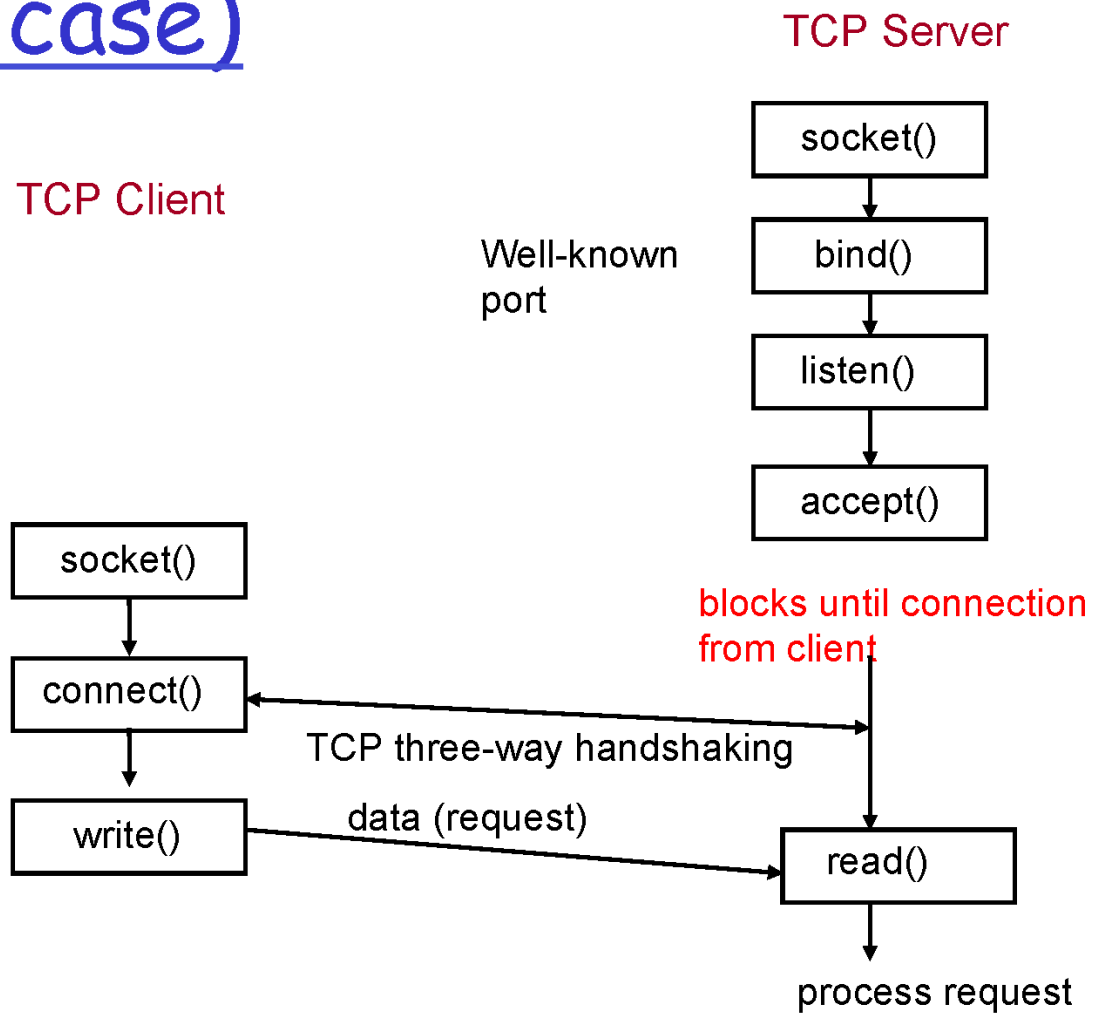
- SOCK_DGRAM
  - a.k.a. UDP
  - unreliable delivery
  - no order guarantees
  - no notion of "connection" – app indicates dest. for each packet
  - can send or receive



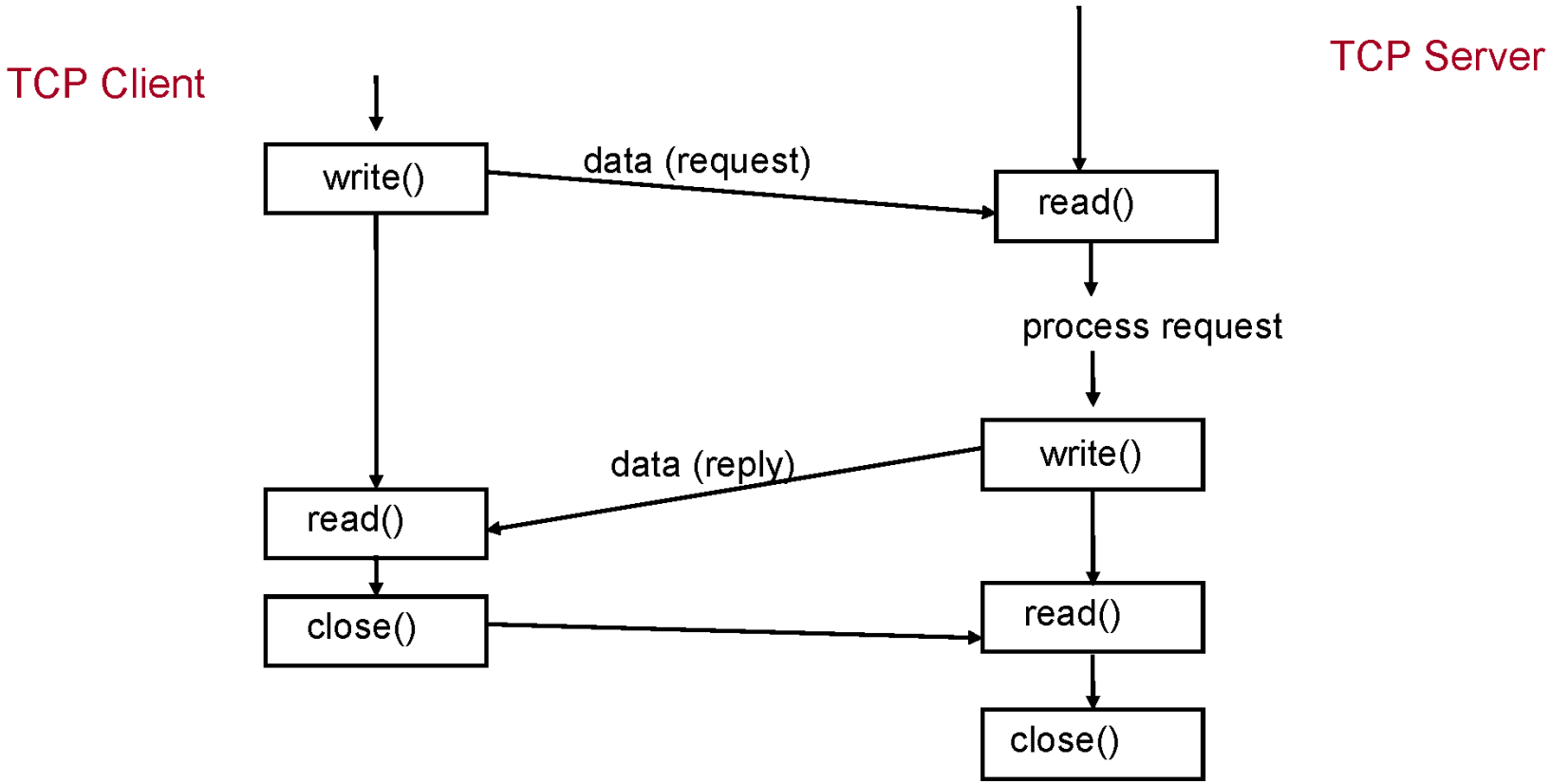
Sockets API

- Creation and Setup
- Establishing a Connection (TCP)
- Sending and Receiving Data
- Tearing Down a Connection (TCP)

Big picture: Socket Functions (TCP case)



Big picture: Socket Functions (TCP case) cont.



Socket Creation and Setup

- Include file `<sys/socket.h>`
- Create a socket
  - `int socket (int domain, int type, int protocol);`
    - Returns file descriptor or -1.
- Bind a socket to a local IP address and port number
  - `int bind (int sockfd, struct sockaddr* myaddr, int addrlen);`
- Put socket into passive state (wait for connections rather than initiate a connection).
  - `int listen (int sockfd, int backlog);`
- Accept connections
  - `int accept (int sockfd, struct sockaddr* cliaddr, int* addrlen);`
    - Returns file descriptor or -1.

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Function: socket

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

- Create a socket.
  - Returns file descriptor or -1. Also sets `errno` on failure.
  - `domain`: protocol family (same as address family)
    - `PF_INET` for IPv4 (typicall used)
    - other possibilities: `PF_INET6` (IPv6), `PF_UNIX` or `PF_LOCAL` (Unix socket), `PF_ROUTE` (routing)
  - `type`: style of communication
    - `SOCK_STREAM` for TCP (with `PF_INET`)
    - `SOCK_DGRAM` for UDP (with `PF_INET`)
  - `protocol`: protocol within family
    - Typically set to 0
    - getprotobyname(), /etc/protocols for list of protocols

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Function: bind

```
int bind (int sockfd, struct sockaddr*
  myaddr, int addrlen);
```

- Bind a socket to a local IP address and port number.
  - Returns 0 on success, -1 and sets `errno` on failure.
  - `sockfd`: socket file descriptor (returned from `socket`)
  - `myaddr`: includes IP address and port number
    - IP address: set by kernel if value passed is `INADDR_ANY`, else set by caller
    - port number: set by kernel if value passed is 0, else set by caller
  - `addrlen`: length of address structure
    - `= sizeof (struct sockaddr_in)`

Function: listen

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

- Put socket into passive state (wait for connections rather than initiate a connection).
  - Returns 0 on success, -1 and sets `errno` on failure.
  - `sockfd`: socket file descriptor (returned from `socket`)
  - `backlog`: bound on length of unaccepted connection queue (connection backlog); kernel will cap, thus better to set high
  - `Listen is non-blocking:` returns immediately

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Function: accept

```
int accept (int sockfd, struct sockaddr*
  cliaddr, int* addrlen);
```

- Accept a new connection.
  - Returns file descriptor or -1. Also sets `errno` on failure.
  - `sockfd`: socket file descriptor (returned from `socket`)
  - `cliaddr`: IP address and port number of client (returned from call)
  - `addrlen`: length of address structure = pointer to `int` set to `sizeof (struct sockaddr_in)`

- **Accept is blocking**
  - Waits for connection before returning

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Function: connect

```
int connect (int sockfd, struct sockaddr*
  servaddr, int addrlen);
```

- Connect to another socket.
  - Returns 0 on success, -1 and sets `errno` on failure.
  - `sockfd`: socket file descriptor (returned from `socket`)
  - `servaddr`: IP address and port number of ***server***
  - `addrlen`: length of address structure
    - = `sizeof (struct sockaddr_in)`
- Connect is **blocking**

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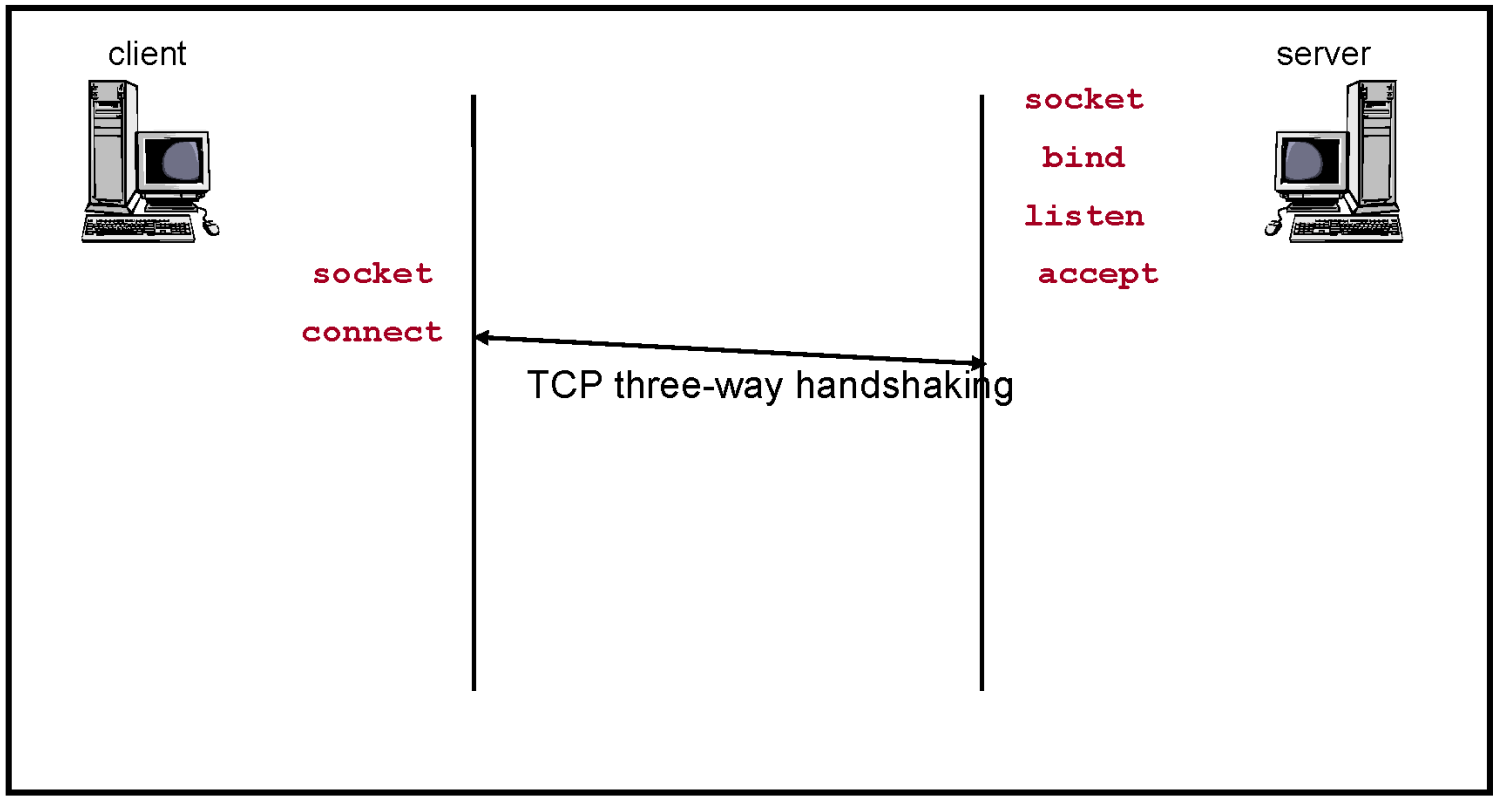
Recap: TCP socket connection setup



Sample code: server

```
#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <string.h>
#include <sys/types.h>
#include <netinet/in.h>
#include <sys/socket.h>
#include <sys/wait.h>
#define PORT 3490
#define BACKLOG 10       /* how many pending
                            connections queue
                            will hold */
```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server

```
main()
{
   int sockfd, new_fd;      /* listen on sock_fd, new
                               connection on new_fd */
   struct sockaddr_in my_addr;    /* my address */
   struct sockaddr_in their_addr; /* connector addr */
   int sin_size;

   if ((sockfd = socket(PF_INET, SOCK_STREAM, 0))==-1){
       perror("socket");
       exit(1);
   }
```


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server

- The Internet-specific:

```
struct sockaddr_in {
        short sin_family;
        u_short sin_port;
        struct in_addr sin_addr;
        };
```

  - sin_family = AF_INET
  - sin_port: port # (0-65535)
  - sin_addr: IP-address

```
my_addr.sin_family = AF_INET;
my_addr.sin_port = htons(MYPORT); /* short, network
                                     byte order */
my_addr.sin_addr.s_addr = htonl(INADDR_ANY);
/* INADDR_ANY allows clients to connect to any one of
the host's IP address */


if (bind(sockfd, (struct sockaddr *)&my_addr,
         sizeof(struct sockaddr)) == -1) {
    perror("bind");
    exit(1);
}
```


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server

```
if (listen(sockfd, BACKLOG) == -1) {
    perror("listen");
    exit(1);
}
while(1) { /* main accept() loop */
    sin_size = sizeof(struct sockaddr_in);
    if ((new_fd = accept(sockfd, (struct sockaddr*)
                    &their_addr,&sin_size)) == -1) {
        perror("accept");
        continue;
    }
    printf("server: got connection from %s\n",
                        inet_ntoa(their_addr.sin_addr));
}
```


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client

```
if ((sockfd = socket (PF_INET, SOCK_STREAM, 0)) == -1) {
     perror ("socket");
     exit (1);
}

their_addr.sin_family = AF_INET;
their_addr.sin_port = htons (Server_Portnumber);
their_addr.sin_addr = htonl(Server_IP_address);


if (connect (sockfd, (struct sockaddr*)&their_addr,
                sizeof (struct sockaddr)) == -1) {
     perror ("connect");
     exit (1);
}
```

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Functions: write

```
int write (int sockfd, char* buf, size_t
  nbytes);
```

- Write data to a stream (TCP).
  - Returns number of bytes written or -1. Also sets `errno` on failure.
  - `sockfd`: socket file descriptor (returned from `socket`)
  - `buf`: data buffer
  - `nbytes`: number of bytes to try to write
- write is **blocking**; returns only after data is sent

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Functions: read

```
int read (int sockfd, char* buf, size_t
  nbytes);
```

- Read data from a stream (TCP).
  - Returns number of bytes read or -1. Also sets `errno` on failure.
  - Returns 0 if socket closed.
  - `sockfd`: socket file descriptor (returned from `socket`)
  - `buf`: data buffer
  - `nbytes`: number of bytes to try to read
- read is **blocking**; returns only after data is received

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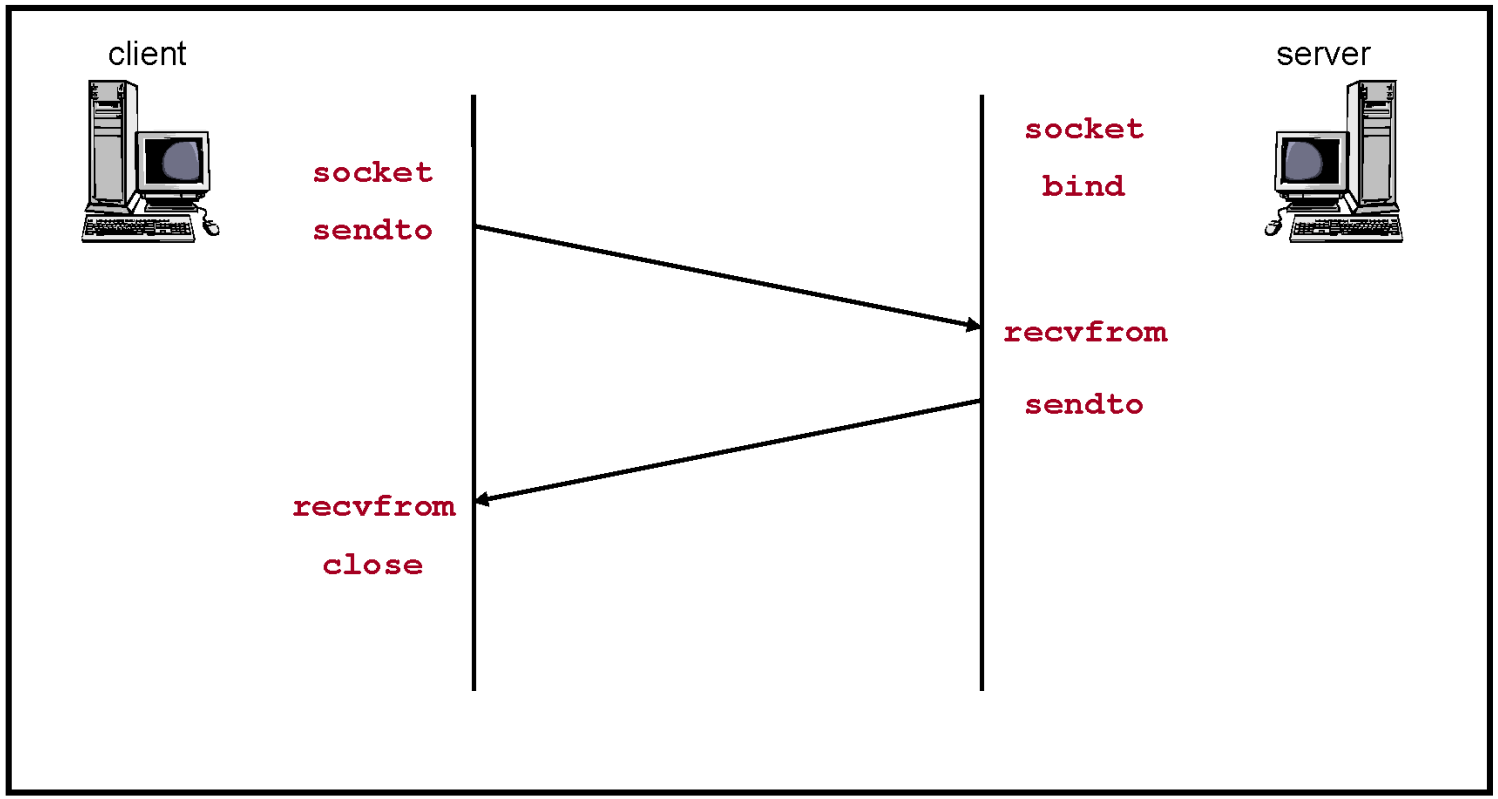
Big picture: UDP Socket Functions



Sockets API

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Function: close

```
int close (int sockfd);
```

- When finished using a socket, the socket should be closed:
  - returns 0 if successful, -1 if error
  - sockfd: the file descriptor (socket being closed)
- Closing a socket
  - frees up the port used by the socket
  - closes a connection (for SOCK_STREAM)

Tip: Release of ports

- Sometimes, a "rough" exit from a program (e.g., ctrl-c) does not properly free up a port
- Eventually (after a few minutes), the port will be freed
- To reduce the likelihood of this problem, include the following code:

```
#include <signal.h>
void cleanExit(){exit(0);}
```

  - in socket code:

```
signal(SIGTERM, cleanExit);
signal(SIGINT, cleanExit);
```

Chapter 3 outline

- 3.1 Transport-layer services
- 3.2 Multiplexing and demultiplexing
- 3.3 Connectionless transport: UDP
- 3.4 Principles of reliable data transfer
- 3.5 Connection-oriented transport: TCP
  - segment structure
  - reliable data transfer
  - flow control
  - connection management
- 3.6 Principles of congestion control
- 3.7 TCP congestion control

Multiplexing/demultiplexing

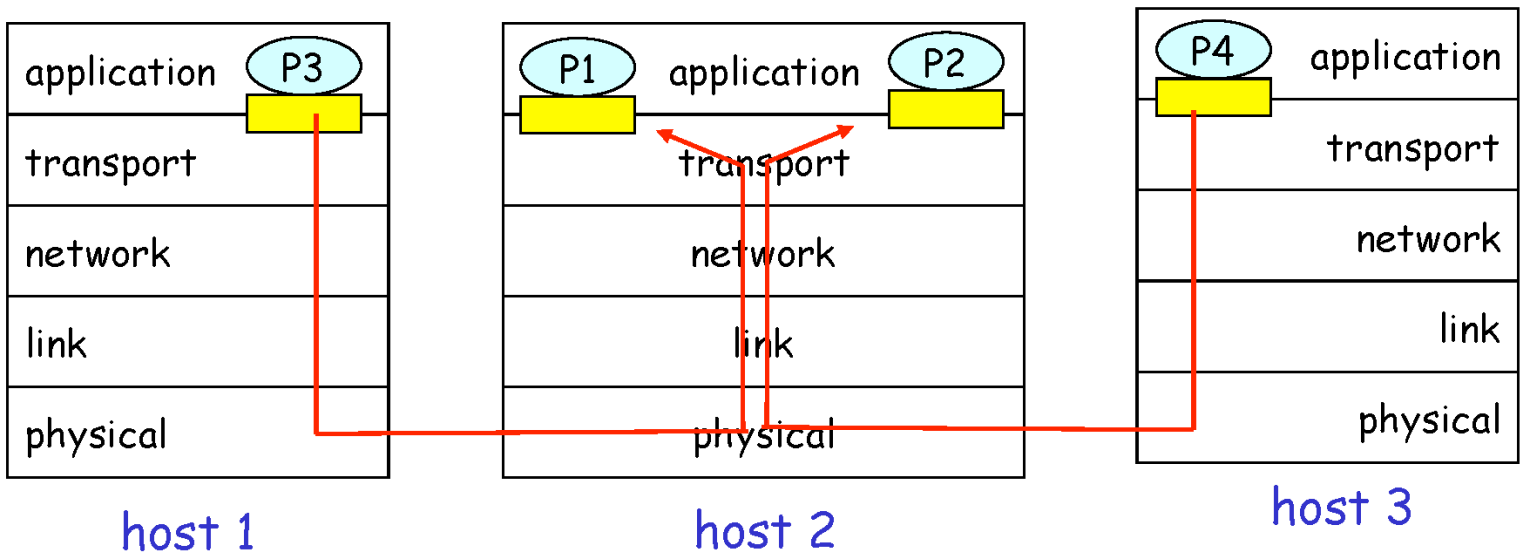
Demultiplexing at rcv host:

delivering received segments to correct socket

Multiplexing at send host:

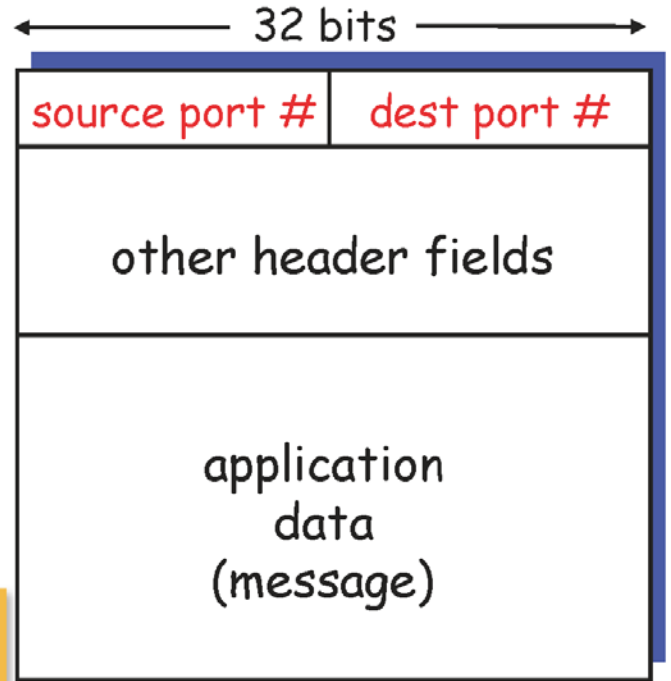
gathering data from multiple sockets, enveloping data with header (later used for demultiplexing)

= socket = process



How demultiplexing works

- host receives IP datagrams
  - each datagram has source IP address, destination IP address
  - each datagram carries 1 transport-layer segment
  - each segment has source, destination port number
- host uses IP addresses & port numbers to direct segment to appropriate socket

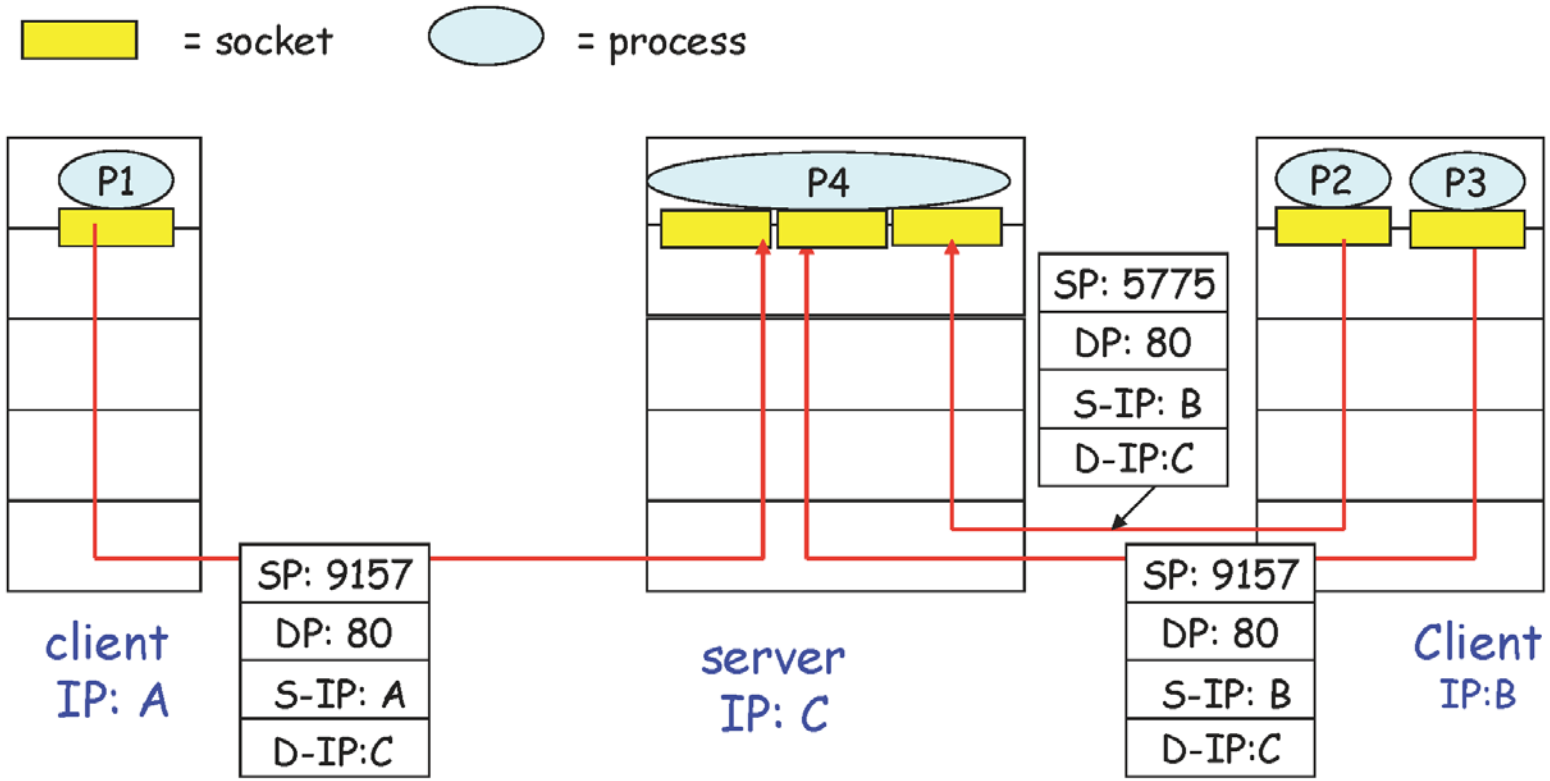


TCP/UDP segment format

Analogous to airport shuttles

Shuttles MUX passengers and take them to downtown -- DeMUX at different locations

Connection-oriented demux: Threaded Web Server



Modify the airport shuttle analogy to distinguish between UDP and TCP

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UDP: User Datagram Protocol [RFC 768]

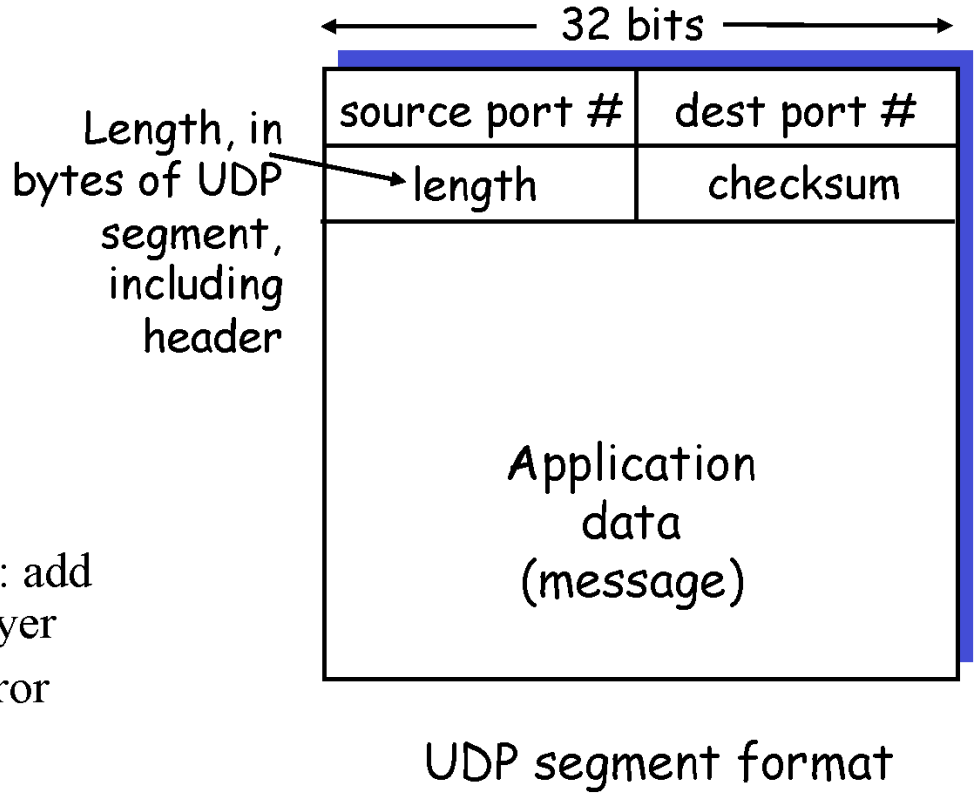
- "no frills," "bare bones" Internet transport protocol
- "best effort" service, UDP segments may be:
  - lost
  - delivered out of order to app
- *connectionless:*
  - no handshaking between UDP sender, receiver
  - each UDP segment handled independently of others

Why is there a UDP?

- no connection establishment (which can add delay)
- simple: no connection state at sender, receiver
- small segment header
- no congestion control: UDP can blast away as fast as desired

UDP: more

- often used for streaming multimedia apps
  - loss tolerant
  - rate sensitive
- other UDP uses
  - DNS
  - SNMP
- reliable transfer over UDP: add reliability at application layer
  - application-specific error recovery!



UDP segment format