Internetworking with Sockets

Cross-host Interprocess Communication (IPC)

- Typically client-server model over network
- Server - Provides a service
- Server - Waits for clients to connect
- Clients - Connect to utilize the service
- Clients - Possibly more than one at a time

The Internet Protocol

- Each device in a network is assigned an IP address
- IPv4 32 bit, IPv6 128 bit
  - IPv4 (in dec)
    69.89.31.226 $\Leftarrow$ 4 octets
  - IPv6 (in hex)
    2001:0db8:0a0b:12f0:0000:0000:0000:0001 $\Leftarrow$ 8 16-bit blocks
- Each device may host many services
- Accessing a service requires a (IP,port) pair
- Services you know of: ssh (port 22), http (port 80), DNS (port 53), DHCP (ports 67,68)

Common Service Use Cases

Browse the World Wide Web

- Each device has a static IP
- DNS used to translate www.google.com to 216.58.213.4
- Contact service at 216.58.213.4 and port 80 (http)

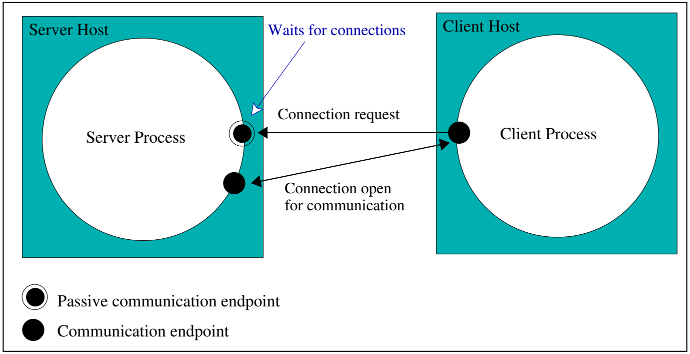
Common Service Use Cases

Your home network.

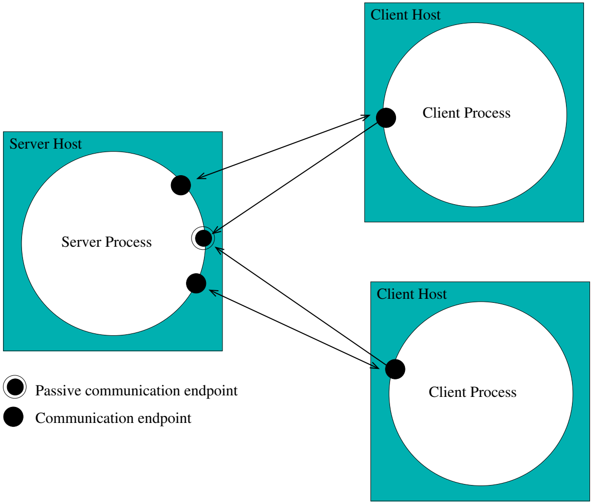
- You turn on your modem. It gets a public from you ISP (eg. 79.166.80.131)
- Your modem runs a DHCP server giving IPs in 192.168.x.y
- Your modem acts as a Internet gateway. Translates IPs from 192.168.x.y to 79.166.80.131. IP Masquerade.
- What if you need to setup a service running inside your 192.168.x.y network available to the internet?
  Do port forwarding.

The Transmission Control Protocol

- TCP Uses acknowledgments
- Non-acknowledged messages are retransmitted
- Messages re-ordered by the receiver's OS network stack
- Application sees a properly ordered *data stream*



TCP - multiple clients



◉ Passive communication endpoint

● Communication endpoint

Sockets

- A `socket` is a communication endpoint
- Processes refer to a socket using an *integer descriptor*
- Communication domain
  - Internet domain (over internet)
  - Unix domain (same host)
- Communication type
  - Stream (usually TCP)
  - Datagram (usually UDP)

TCP vs. UDP

	TCP	UDP
Connection Required	✓	✗
Reliability	✓	✗
Message Boundaries	✗	✓
In-Order Data Delivery	✓	✗
Socket Type	SOCK_STREAM	SOCK_DGRAM
Socket Domain	Internet	Internet
Latency	higher	lower
Flow Control	✓	✗

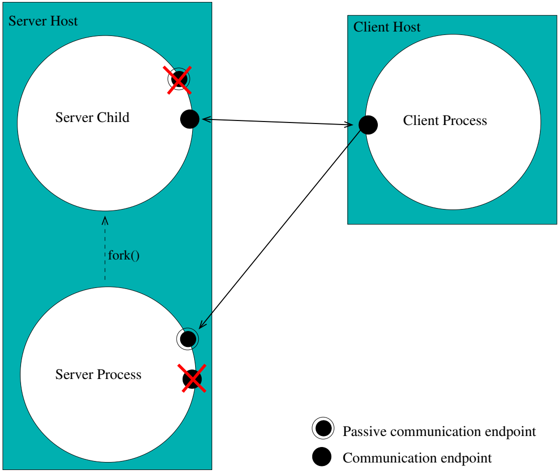
Serial Server (TCP)

```
Create listening socket $a$
**loop**
   Wait for client request on $a$
   Open two-way channel $b$ with client
   **while** request received through $b$ **do**
      Process request
      Send response through $b$
   **end while**
   Close file descriptor of $b$
**end loop**
```

Drawbacks:

- Serves only one client at a time
- Other clients are forced to wait or even fail

1 process per client model



- New process forked for each client
- Multiple clients served at the same time
- Inefficient, too many clients $\rightarrow$ too many processes

1 process per client model

Parent process

```
Create listening socket $a$
loop
    Wait for client request on $a$
    Create two-way channel $b$ with client
    Fork a child to handle the client
    Close file descriptor of $b$
end loop
```

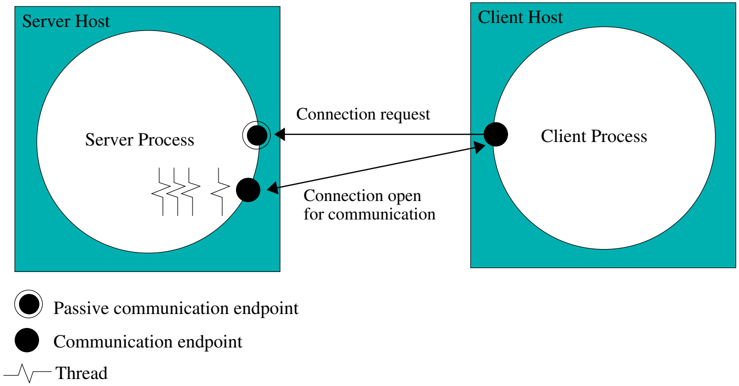
Child process

```
Close listening socket $a$
Serve client requests through $b$
Close private channel $b$
Exit
```

Parent process: why close file descriptor *b*?

- Parent doesn't need this file descriptor
- Risk of running out of file descriptors otherwise
- Enables the destruction of the channel once the other two parties (child & client) close their file descriptors
- Enables the child process to receive EOF after the client closes its end of the channel (and vice versa).

Multithreaded server model



- Multiple threads handle multiple clients concurrently
- Drawback: Requires synchronization for access to shared resources

Dealing with byte order

- Byte order poses a problem for the communication among different architectures.
- Network Protocols specify a byte ordering: ip addresses, port numbers etc. are all in what is known as *Network Byte Order*
- Convert long/short integers between *Host* and *Network Byte Order*

```
/* host to network byte order for long -32bits */
uint32_t htonl(uint32_t hostlong);
/* host to network byte order for short -16bits */
uint16_t htons(uint16_t hostshort);
/* network to host byte order for long -32bits */
uint32_t ntohl(uint32_t netlong);
/* network to host byte order for short -16bits */
uint16_t ntohs(uint16_t netshort);
```

Depicting the Byte Order `ByteOrder-p16.c`

```
#include <stdio.h>
#include <arpa/inet.h>

int main(){
        uint16_t nhost = 0xD04C, nnetwork;
        unsigned char *p;
        p=(unsigned char *)&nhost;
        printf("%x %x \n", *p, *(p+1));
        /* 16-bit number from host to network byte order */
        nnetwork=htons(nhost);
        p=(unsigned char *)&nnetwork;
        printf("%x %x \n", *p, *(p+1));
        exit(1);
}
```

- Experimenting with an Intel-based (Little-Endian) machine:

```
ad@haiku:~/src$ ./ByteOrder-p16
4c d0
d0 4c
ad@haiku:~/src$
```

- Experimenting with a Sparc (Big-Endian/Network Byte Order) machine:

```
pubsrv1:/k24-examples>./ByteOrder-p16
d0 4c
d0 4c
pubsrv1:/k24-examples>
```

From *Domain Names* to *Addresses* and back

- An *address* is needed for network communication
- We often have to *resolve* the address from a domain name.
  ex. `spiderman.di.uoa.gr` ↔ `195.134.66.107`

```
struct hostent {
    char    *h_name;        /* official name of host */
    char    **h_aliases;    /* aliases (alt. names) */
    int     h_addrtype;     /* usually AF_INET */
    int     h_length;       /* bytelength of address */
    char    **h_addr_list;  /* pointer to array of network addresses */
};

struct hostent *gethostbyname(const char *name);

struct hostent *gethostbyaddr(const void *addr, socklen_t len, int type);
```

- For error reporting use `h_error` & `hstrerror(int err)`.
- Both calls return pointers to statically allocated `hostent` structure on sucesss and `NULL` on error.

Resolving names for machines

```c
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

void main(int argc, char **argv){
int      i=0;
char     hostname[50], symbolicip[50];
struct   hostent *mymachine;
struct   in_addr **addr_list;

if (argc!=2 ) {printf("Usage: GetHostByName-p18 host-name\n"); exit(0);}

if ( (mymachine=gethostbyname(argv[1])) == NULL)
        printf("Could not resolved Name:  %s\n",argv[1]);
else    {
        printf("Name To Be  Resolved: %s\n", mymachine->h_name);
        printf("Name Length in Bytes: %d\n", mymachine->h_length);
        addr_list = (struct in_addr **) mymachine->h_addr_list;
        for(i = 0; addr_list[i] != NULL; i++) {
                strcpy(symbolicip , inet_ntoa(*addr_list[i]) );
                printf("%s resolved to %s \n",mymachine->h_name,symbolicip);
                }
        }
}
```

Resolving names

```
ad@haiku:~/src$
ad@haiku:~/src$ ./GetHostByName-p18 federal.gov.ar
Name To Be  Resolved: federal.gov.ar
Name Length in Bytes: 4
federal.gov.ar resolved to 190.210.161.110
ad@haiku:~/src$
ad@haiku:~/src$
ad@haiku:~/src$ ./GetHostByName-p18 www.bbc.co.uk
Name To Be  Resolved: www.bbc.net.uk
Name Length in Bytes: 4
www.bbc.net.uk resolved to 212.58.246.95
www.bbc.net.uk resolved to 212.58.244.71
ad@haiku:~/src$
ad@haiku:~/src$ ./GetHostByName-p18 www.nytimes.com
Name To Be  Resolved: www.gtm.nytimes.com
Name Length in Bytes: 4
www.gtm.nytimes.com resolved to 170.149.161.130
ad@haiku:~/src$
ad@haiku:~/src$ ./GetHostByName-p18 170.149.161.130
Name To Be  Resolved: 170.149.161.130
Name Length in Bytes: 4
170.149.161.130 resolved to 170.149.161.130
ad@haiku:~/src$
ad@haiku:~/src$
```

Resolving IP-addresses

```
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

int main(int argc, char *argv[]) {
struct hostent* foundhost;
struct in_addr myaddress;

/* IPv4 dot-number into  binary form (network byte order) */
inet_aton(argv[1], &myaddress);

foundhost=gethostbyaddr((const char*)&myaddress, sizeof(myaddress), AF_INET);
if (foundhost!=NULL){
        printf("IP-address:%s Resolved to: %s\n", argv[1],foundhost->h_name);
        exit(0);
        }
else    {
        printf("IP-address:%s could not be resolved\n",argv[1]);
        exit(1);
        }
}
```

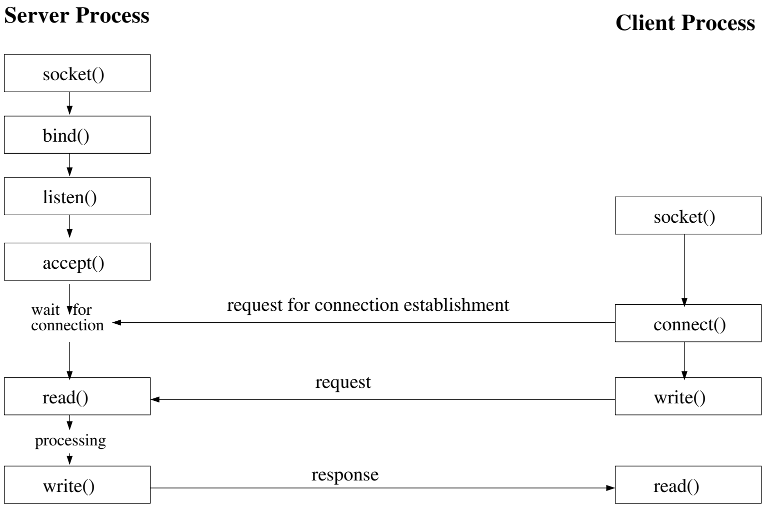
Resolving IP-addresses

```
ad@haiku:~/src$
ad@haiku:~/src$ ./GetHostByAddress 128.10.2.166
IP-address:128.10.2.166 Resolved to: merlin.cs.purdue.edu
ad@haiku:~/src$
ad@haiku:~/src$ ./GetHostByAddress 195.134.67.183
IP-address:195.134.67.183 Resolved to: sydney.di.uoa.gr
ad@haiku:~/src$
```

- `gethostbyname()` and `gethostbyaddr()` have been in use.
- *POSIX.1-2001* suggests instead the use of `getnameinfo()` and `getaddrinfo()` respectively.

Our goal

Create the communication endpoint. Use it as a file descriptor.



Address Format for Sockets

- An *address* identifies a socket in a specific communication domain.
- Addresses with different formats can be passed to the socket functions – all casted to the generic `sockaddr` structure.
- Internet addresses are defined in `<netinet/in.h>`.
- Specifically in IPv4 Internet domain (`AF_INET`), a socket address is represented by the `sockaddr_in` as follows:

```
    struct in_addr{
        in_addr_t       s_addr;         /*IPv4  address */
        };

    struct sockaddr_in{
        sa_family_t     sin_family;     /* address family */
        in_port_t       sin_port;       /* port number    */
        struct in_addr  sin_addt;       /* IPv4 address   */
        };
```

- `in_port_t` data type is `uint16_t` (defined in `<stdint.h>`)
- `in_addr_t` data type is `uint32_t` (defined in `<stdint.h>`)

Creating sockets

- `socket` creates an endpoint for communication
- returns a `descriptor` or −1 on error

```
#include <sys/socket.h>
#include <sys/type.h>
int socket(int domain, int type, int protocol);
```

`domain`	communication domain (mostly `AF_INET`)
`type`	communication semantics (often `SOCK_STREAM`, `SOCK_DGRAM`)
`protocol`	Use 0 as typically only one protocol is available

```
    if ((sock = socket(AF_INET, SOCK_STREAM, 0)) == -1)
        perror("Socket creation failed!");
```

Binding sockets to addresses

- bind requests for an address to be assigned to a socket
- You must bind a SOCK_STREAM socket to a local address before receiving connections

```
   int bind(int socket, const struct sockaddr *address,
           socklen_t address_len);
```

- We pass a sockaddr_in struct as the address that has at least the following members expressed in network byte-order:
  - sin_family: address family is AF_INET in the Internet domain
  - sin_addr.s_addr: address can be a specific IP or INADDR_ANY
  - sin_port: TCP or UDP port number

Socket binding example

```
#include <netinet/in.h> /* for sockaddr_in */
#include <sys/socket.h>
#include <sys/types.h>
#include <arpa/inet.h>  /* for hton* */

int bind_on_port(int sock, short port) {
    struct sockaddr_in server;
    server.sin_family = AF_INET;
    server.sin_addr.s_addr = htonl(INADDR_ANY);
    server.sin_port = htons(port);
    return bind(sock, (struct sockaddr *) &server, sizeof(server));
}
```

- `INADDR_ANY` is a special address (0.0.0.0) meaning “any address”
- `sock` will receive connections from all addresses of the host machine

listen, accept

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

- Listen for connections on a socket
- At most `backlog` connections will be queued waiting to be accepted

```
int accept(int socket, struct sockaddr *address,
                socklen_t *address_len);
```

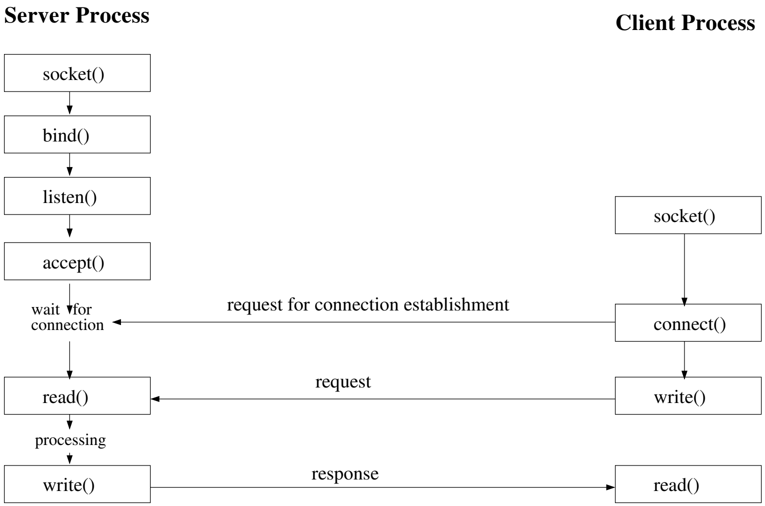
- Accepts a connection on a socket
- Blocks until a client connects/gets-interrupted by a signal
- Returns new socket descriptor to communicate with client
- Returns info on clients address through `address`.
  Pass NULL if you don't care.
- Value-result `address_len` must be set to the amount of space pointed to by `address` (or NULL).

connect

```
int connect(int socket, struct sockaddr *address,
                socklen_t address_len);
```

- When called by a client, a connection is attempted to a listening socket on the server in `address`. Normally, the server `accepts` the connection and a communication channel is established.
- If `socket` is of type `SOCK_DGRAM`, `address` specifies the peer with which the socket is to be associated (datagrams are sent/received only to/from this peer).

TCP connection



Tips and warnings

- In Solaris compile with "`-lsocket -lnsl`"
- If a process attempts to write through a socket that has been closed by the other peer, a `SIGPIPE` signal is received.
- `SIGPIPE` is by default fatal, install a signal handler to override this.
- Use system program `netstat` to view the status of sockets.

```
ad@linux03:~> netstat -ant
```

- When a server quits, the listening port remains busy (state `TIME_WAIT`) for a while
- Restarting the server *fails in bind* with "`Bind: Address Already in Use`"
- To override this, use `setsockopt()` to enable `SO_REUSEADDR` before you call `bind()`.

TCP server that receives a string and replies with the string capitalized.

```c
/*inet_str_server.c: Internet stream sockets server */
#include <stdio.h>
#include <sys/wait.h>         /* sockets */
#include <sys/types.h>        /* sockets */
#include <sys/socket.h>       /* sockets */
#include <netinet/in.h>       /* internet sockets */
#include <netdb.h>            /* gethostbyaddr */
#include <unistd.h>           /* fork */
#include <stdlib.h>           /* exit */
#include <ctype.h>            /* toupper */
#include <signal.h>           /* signal */
void child_server(int newsock);
void perror_exit(char *message);
void sigchld_handler (int sig);

void main(int argc, char *argv[]) {
    int             port, sock, newsock;
    struct sockaddr_in server, client;
    socklen_t clientlen;
    struct sockaddr *serverptr=(struct sockaddr *)&server;
    struct sockaddr *clientptr=(struct sockaddr *)&client;
    struct hostent *rem;
    if (argc != 2) {
        printf("Please give port number\n");exit(1);}
    port = atoi(argv[1]);
    /* Reap dead children asynchronously */
    signal(SIGCHLD, sigchld_handler);
    /* Create socket */
    if ((sock = socket(AF_INET, SOCK_STREAM, 0)) < 0)
        perror_exit("socket");
    server.sin_family = AF_INET;       /* Internet domain */
    server.sin_addr.s_addr = htonl(INADDR_ANY);
    server.sin_port = htons(port);      /* The given port */
    /* Bind socket to address */
    if (bind(sock, serverptr, sizeof(server)) < 0)
        perror_exit("bind");
    /* Listen for connections */
    if (listen(sock, 5) < 0) perror_exit("listen");
```

ΣΥΧΝΑ ΠΡΙΝ ΤΟ bind

```
int reuse = 1;
if (setsockopt(sock, SOL_SOCKET, SO_REUSEADDR,
                  (const char*)&reuse, sizeof(reuse)) < 0)
    perror("setsockopt(SO_REUSEADDR) failed");
    printf("Listening for connections to port %d\n", port);
    while (1) {
        /* accept connection */
        if ((newsock = accept(sock, clientptr, &clientlen)) < 0) perror_exit("
             accept");
        /* Find client's address */
        if ((rem = gethostbyaddr((char *) &client.sin_addr.s_addr, sizeof(client
             .sin_addr.s_addr), client.sin_family)) == NULL) {
        herror("gethostbyaddr"); exit(1);}
        printf("Accepted connection from %s\n", rem->h_name);
        // printf("Accepted connection\n");
        switch (fork()) {    /* Create child for serving client */
        case -1:     /* Error */
            perror("fork"); break;
        case 0:      /* Child process */
            close(sock); child_server(newsock);
            exit(0);
        }
        close(newsock); /* parent closes socket to client              */
    }
}

void child_server(int newsock) {
    char buf[1];
    while(read(newsock, buf, 1) > 0) {  /* Receive 1 char */
        putchar(buf[0]);              /* Print received char */
        /* Capitalize character */
        buf[0] = toupper(buf[0]);
        /* Reply */
        if (write(newsock, buf, 1) < 0)
            perror_exit("write");
    }
    printf("Closing connection.\n");
    close(newsock);   /* Close socket */
}

/* Wait for all dead child processes */
void sigchld_handler (int sig) {
    while (waitpid(-1, NULL, WNOHANG) > 0);
}

void perror_exit(char *message) {
    perror(message);
    exit(EXIT_FAILURE);
}
```

TCP client example. (definitions)

```c
/* inet_str_client.c: Internet stream sockets client */
#include <stdio.h>
#include <sys/types.h>        /* sockets */
#include <sys/socket.h>       /* sockets */
#include <netinet/in.h>       /* internet sockets */
#include <unistd.h>           /* read, write, close */
#include <netdb.h>            /* gethostbyaddr */
#include <stdlib.h>           /* exit */
#include <string.h>           /* strlen */

void perror_exit(char *message);

void main(int argc, char *argv[]) {
    int                port, sock, i;
    char               buf[256];
    struct sockaddr_in server;
    struct sockaddr *serverptr = (struct sockaddr*)&server;
    struct hostent *rem;
    if (argc != 3) {
        printf("Please give host name and port number\n");
        exit(1);}
```

TCP client example. (connection)

```
    /* Create socket */
    if ((sock = socket(AF_INET, SOCK_STREAM, 0)) < 0)
        perror_exit("socket");
    /* Find server address */
    if ((rem = gethostbyname(argv[1])) == NULL) {
       herror("gethostbyname"); exit(1);
    }
    port = atoi(argv[2]); /*Convert port number to integer*/
    server.sin_family = AF_INET;       /* Internet domain */
    memcpy(&server.sin_addr, rem->h_addr, rem->h_length);
    server.sin_port = htons(port);         /* Server port */
    /* Initiate connection */
    if (connect(sock, serverptr, sizeof(server)) < 0)
       perror_exit("connect");
    printf("Connecting to %s port %d\n", argv[1], port);
```

TCP client example. (transfer loop)

```
    do {
        printf("Give input string: ");
        fgets(buf, sizeof(buf), stdin); /* Read from stdin*/
        for(i=0; buf[i] != '\0'; i++) { /* For every char */
            /* Send i-th character */
            if (write(sock, buf + i, 1) < 0)
               perror_exit("write");
            /* receive i-th character transformed */
            if (read(sock, buf + i, 1) < 0)
                perror_exit("read");
        }
        printf("Received string: %s", buf);
    } while (strcmp(buf, "END\n") != 0); /* Finish on "end" */
    close(sock);                    /* Close socket and exit */
}

void perror_exit(char *message)
{
    perror(message);
    exit(EXIT_FAILURE);
}
```

Execution

Server on linux02:

```
ad@linux02:~> ./server 9002
Listening for connections to port 9002
Accepted connection from linux03.di.uoa.gr
Hello world
EnD
Closing connection.
```

Client on linux03:

```
ad@linux03:~> ./client linux02.di.uoa.gr 9002
Connecting to linux02.di.uoa.gr port 9002
Give input string: Hello world
Received string: HELLO WORLD
Give input string: EnD
Received string: END
ad@linux03:~>
```

More useful functions

`shutdown` shut down part of a full-duplex connection

```
    int shutdown(int socket, int how);
```

Can be used to tell server that we have sent the whole request.

`getsockname` returns the current address to which the socket is bound with using the buffer pointed to by `address`.

```
int getsockname(int socket,
            struct sockaddr *address,
            socklen_t *address_len);
```

`getpeername` get the name (address) of the peer connected to a socket; useful if a server has called a `fork/exec` combination and only the `socket` is known.

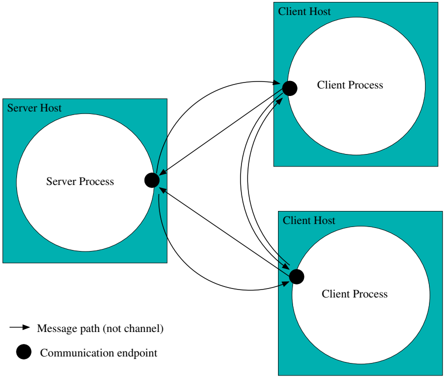
```
int getpeername(int socket,
            struct sockaddr *address,
            socklen_t *address_len);
```

Parsing and Printing Addresses

`inet_ntoa`	Convert struct `in_addr` to printable form 'a.b.c.d'
`inet_addr`	Convert IP address string in '.' notation to 32bit network address
`inet_ntop`	Convert address from network format to printable presentation format
`inet_pton`	Convert presentation format address to network format

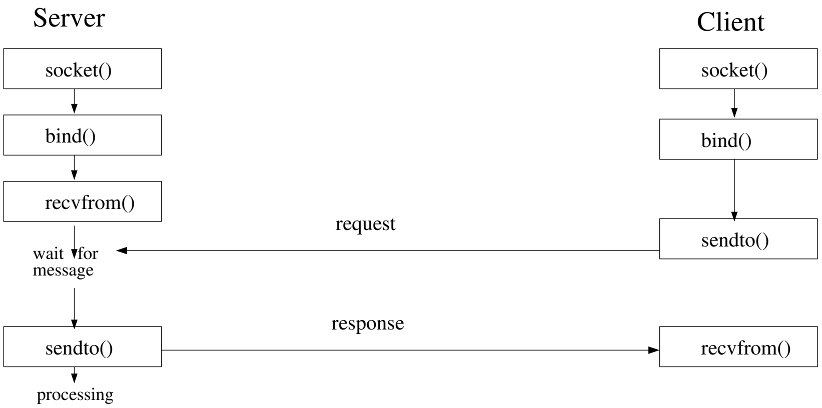
Bonus: `inet_ntop` and `inet_pton` also work with IPv6!

Internet User Datagram Protocol (UDP)



- No Connections: Think postcards, not telephone.
- `Datagrams` (messages) exchanged.
- Datagrams *either* arrive (possibly out of order) *or* get lost!

UDP communication



sendto, recvfrom

```
ssize_t sendto(int sock, void *buff, size_t length,
               int flags, struct sockaddr *dest_addr,
               socklen_t dest_len);
```

- Send a message to a socket
- Similar to `write()` & `send()` but designates destination

```
ssize_t recvfrom(int socket, void *buff,size_t length,
               int flags, struct sockaddr *address,
               socklen_t *address_len);
```

- Receive a message from a socket
- Similar to `read()` & `recv()` but designates source address
- `address_len` is value-result and must be initialized to the size of the buffer pointed to by the address pointer
- last two arguments can be `NULL`

Usually `flags = 0` ; rarely used (ex. out of band data)

A simple echoing UDP server

Client on linux03 (along with the input to send out):

```
ad@linux03:~> fortune | ./inet_dgm_client linux02 59579
Hlade's Law:
    If you have a difficult task, give it to a lazy person --
    they will find an easier way to do it.
ad@linux03:~>
```

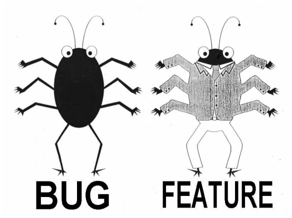
Server on linux02 (along with the bytes to receive from client):

```
ad@linux02:~> ./inet_dgm_server
Socket port: 59579
Received from linux03: Hlade's Law:
Received from linux03:  If you have a difficult task, give it to a lazy person
     --
Received from linux03:  they will find an easier way to do it.
```

```c
/* inet_dgr_server.c: Internet datagram sockets server */
#include <sys/types.h>                          /* sockets */
#include <sys/socket.h>                         /* sockets */
#include <netinet/in.h>                /* Internet sockets */
#include <netdb.h>                         /* gethostbyaddr */
#include <arpa/inet.h>                         /* inet_ntoa */
#include <stdio.h>
#include <stdlib.h>
void perror_exit(char *message);

char *name_from_address(struct in_addr addr) {
    struct hostent *rem; int asize = sizeof(addr.s_addr);
    if((rem = gethostbyaddr(&addr.s_addr, asize, AF_INET)))
        return rem->h_name;  /* reverse lookup success */
    return inet_ntoa(addr); /* fallback to a.b.c.d form */
}

void main() {
    int n, sock; unsigned int serverlen, clientlen;
    char buf[256], *clientname;
    struct sockaddr_in server, client;
    struct sockaddr *serverptr = (struct sockaddr*) &server;
    struct sockaddr *clientptr = (struct sockaddr*) &client;
    /* Create datagram socket */
    if ((sock = socket(AF_INET, SOCK_DGRAM, 0)) < 0)
        perror_exit("socket");
    /* Bind socket to address */
    server.sin_family = AF_INET;        /* Internet domain */
    server.sin_addr.s_addr = htonl(INADDR_ANY);
    server.sin_port = htons(0);        /* Autoselect a port */
    serverlen = sizeof(server);
    if (bind(sock, serverptr, serverlen) < 0)
        perror_exit("bind");
    /* Discover selected port */
    if (getsockname(sock, serverptr, &serverlen) < 0)
        perror_exit("getsockname");
    printf("Socket port: %d\n", ntohs(server.sin_port));
    while(1) { clientlen = sizeof(client);
        /* Receive message */
        if ((n = recvfrom(sock, buf, sizeof(buf), 0, clientptr, &clientlen)) <
             0)
            perror("recvfrom");
        buf[sizeof(buf)-1]='\0'; /* force str termination */
        /* Try to discover client's name */
        clientname = name_from_address(client.sin_addr);
        printf("Received from %s: %s\n", clientname, buf);
        /* Send message */
        if (sendto(sock, buf, n, 0, clientptr, clientlen)<0)
            perror_exit("sendto");
    }}

void perror_exit(char *message)
{
    perror(message);
    exit(EXIT_FAILURE);
}
```

```c
/* inet_dgr_client.c: Internet datagram sockets client    */
#include <sys/types.h>                             /* sockets */
#include <sys/socket.h>                            /* sockets */
#include <netinet/in.h>                   /* Internet sockets */
#include <netdb.h>                           /* gethostbyname */
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

void main(int argc, char *argv[]) {
   int sock; char buf[256]; struct hostent *rem;
   struct sockaddr_in server, client;
   unsigned int serverlen = sizeof(server);
   struct sockaddr *serverptr = (struct sockaddr *) &server;
   struct sockaddr *clientptr = (struct sockaddr *) &client;
   if (argc < 3) {
      printf("Please give host name and port\n"); exit(1);}
   /* Create socket */
   if ((sock = socket(AF_INET, SOCK_DGRAM, 0)) < 0) {
      perror("socket"); exit(1); }
   /* Find server's IP address */
   if ((rem = gethostbyname(argv[1])) == NULL) {
      herror("gethostbyname"); exit(1); }
   /* Setup server's IP address and port */
   server.sin_family = AF_INET;          /* Internet domain */
   memcpy(&server.sin_addr, rem->h_addr, rem->h_length);
   server.sin_port = htons(atoi(argv[2]));
   /* Setup my address */
   client.sin_family = AF_INET;          /* Internet domain */
   client.sin_addr.s_addr=htonl(INADDR_ANY); /*Any address*/
   client.sin_port = htons(0);           /* Autoselect port */
   /* Bind my socket to my address*/
   if (bind(sock, clientptr, sizeof(client)) < 0) {
      perror("bind"); exit(1); }
   /* Read continuously messages from stdin */
   while (fgets(buf, sizeof buf, stdin)) {
      buf[strlen(buf)-1] = '\0';            /* Remove '\n' */
      if (sendto(sock, buf, strlen(buf)+1, 0, serverptr, serverlen) < 0) {
         perror("sendto"); exit(1); }       /* Send message */
      bzero(buf, sizeof buf);               /* Erase buffer */
      if (recvfrom(sock, buf, sizeof(buf), 0, NULL, NULL) < 0) {
         perror("recvfrom"); exit(1); }     /* Receive message */
      printf("%s\n", buf);
      }
}
```

- Everything looks good and runs ok BUT there is a BUG!
- Remember that UDP is *unreliable*



rlsd: a remote file/dir-listing server

Server on linux02:

```
ad@linux02:~> ./rlsd
```

Client on linux03:

```
ad@linux03:~> ./rls linux02.di.uoa.gr /usr/share/dict
README
connectives
propernames
web2
web2a
words
ad@linux03:~>
```

rlsd.c remote ls server (TCP)

fdopen allows buffered I/O by opening socket as file stream

```c
/* rlsd.c - a remote ls server - with paranoia */
#include  <stdio.h>
#include  <stdlib.h>
#include  <unistd.h>
#include  <sys/types.h>
#include  <sys/socket.h>
#include  <netinet/in.h>
#include  <netdb.h>
#include  <time.h>
#include  <string.h>
#include  <ctype.h>
#define PORTNUM  15000       /* rlsd listens on this port */

void perror_exit(char *msg);
void sanitize(char *str);
```

```
int main(int argc, char *argv[]) {
    struct sockaddr_in myaddr;  /* build our address here */
    int c, lsock, csock;  /* listening and client sockets */
    FILE    *sock_fp;              /* stream for socket IO */
    FILE    *pipe_fp;               /* use popen to run ls */
    char    dirname[BUFSIZ];                /* from client */
    char    command[BUFSIZ];                /* for popen() */

    /** create a TCP a socket **/
    if ((lsock = socket( AF_INET, SOCK_STREAM, 0)) < 0)
        perror_exit( "socket" );
    /** bind address to socket. **/
    myaddr.sin_addr.s_addr = htonl(INADDR_ANY);
    myaddr.sin_port = htons(PORTNUM);/*port to bind socket*/
    myaddr.sin_family = AF_INET;  /* internet addr family */
    if(bind(lsock,(struct sockaddr *)&myaddr, sizeof(myaddr)))
           perror_exit( "bind" );
    /** listen for connections with Qsize=5 **/
    if ( listen(lsock, 5) != 0 )
        perror_exit( "listen" );
    while ( 1 ){ /* main loop: accept - read - write */
            /* accept connection, ignore client address */
           if ( (csock = accept(lsock, NULL, NULL)) < 0 )
               perror_exit("accept");
           /* open socket as buffered stream */
           if ((sock_fp = fdopen(csock,"r+")) == NULL)
               perror_exit("fdopen");
           /* read dirname and build ls command line */
           if (fgets(dirname, BUFSIZ, sock_fp) == NULL)
               perror_exit("reading dirname");
           sanitize(dirname);      /* clear wild characters */
           snprintf(command, BUFSIZ, "ls %s", dirname);
           /* Invoke ls through popen */
           if ((pipe_fp = popen(command, "r")) == NULL )
               perror_exit("popen");
           /* transfer data from ls to socket */
           while( (c = getc(pipe_fp)) != EOF )
               putc(c, sock_fp);
           pclose(pipe_fp);
           fclose(sock_fp);
    }
    return 0;
}
```

```c
/* it would be very bad if someone passed us an dirname like
 * "; rm *"  and we naively created a command  "ls ; rm *".
 * So..we remove everything but slashes and alphanumerics.
 */
void sanitize(char *str)
{
    char *src, *dest;
    for ( src = dest = str ; *src ; src++ )
        if ( *src == '/' || isalnum(*src) )
            *dest++ = *src;
    *dest = '\0';
}

/* Print error message and exit */
void perror_exit(char *message)
{
    perror(message);
    exit(EXIT_FAILURE);
}
```

rls.c sends a directory name to rlsd and reads back a directory listing (TCP)

write_all guarantees to send all the bytes requested, provided no error occurs, by repeatedly calling `write()`

```
#include <sys/types.h>                            /* sockets */
#include <sys/socket.h>                           /* sockets */
#include <netinet/in.h>                  /* internet sockets */
#include <netdb.h>                           /* gethostbyname */
#define  PORTNUM 15000
#define  BUFFSIZE 256
void perror_exit(char *msg);

/* Write() repeatedly until 'size' bytes are written */
int write_all(int fd, void *buff, size_t size) {
    int sent, n;
    for(sent = 0; sent < size; sent+=n) {
        if ((n = write(fd, buff+sent, size-sent)) == -1)
            return -1; /* error */
    }
    return sent;
}
```

```
int main(int argc, char *argv[]) {
    struct sockaddr_in  servadd; /* The address of server */
    struct hostent *hp;           /* to resolve server ip */
    int     sock, n_read;     /* socket and message length */
    char    buffer[BUFFSIZE];         /* to receive message */

    if ( argc != 3 ) {
        puts("Usage: rls <hostname> <directory>");exit(1);}
    /* Step 1: Get a socket */
    if ((sock = socket(AF_INET, SOCK_STREAM, 0)) == -1 )
        perror_exit( "socket" );
    /* Step 2: lookup server's address and connect there */
    if ((hp = gethostbyname(argv[1])) == NULL) {
        herror("gethostbyname"); exit(1);}
    memcpy(&servadd.sin_addr, hp->h_addr, hp->h_length);
    servadd.sin_port = htons(PORTNUM); /* set port number */
    servadd.sin_family = AF_INET ;     /* set socket type */
    if (connect(sock, (struct sockaddr*) &servadd, sizeof(servadd)) !=0)
        perror_exit( "connect" );
    /* Step 3: send directory name + newline */
    if ( write_all(sock, argv[2], strlen(argv[2])) == -1)
        perror_exit("write");
    if ( write_all(sock, "\n", 1) == -1 )
        perror_exit("write");
    /* Step 4: read back results and send them to stdout */
    while( (n_read = read(sock, buffer, BUFFSIZE)) > 0 )
        if (write_all(STDOUT_FILENO, buffer, n_read)<n_read)
            perror_exit("fwrite");
    close(sock);
    return 0;
}
```

Select

When listening for connections on sockfd, we can probe multiple connections for input:

- Use function select()
- Select probes a bitmap (fd_set) of active file descriptors for input
- Input to sockfd means that there is a new connection attempt => accept the connection
- Input from another fd means that data can be read from it
- When read() from an fd returns 0, we have EOF => close the corresponding connection
- Useful for multithreaded server model

Select

```
#include <stdio.h>
#include <errno.h>
#include <stdlib.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <netdb.h>

#define PORT    5555
#define MAXMSG  512

int
read_from_client (int filedes)
{
  char buffer[MAXMSG];
  int nbytes;

  nbytes = read (filedes, buffer, MAXMSG);
  if (nbytes < 0)
    {
      /* Read error. */
      perror ("read");
      exit (EXIT_FAILURE);
    }
  else if (nbytes == 0)
    /* End-of-file. */
    return -1;
  else
    {
      /* Data read. */
      fprintf (stderr, "Server: got message: `%s'\n", buffer);
      return 0;
    }
}
```

Select

```
int
main (void)
{
  extern int make_socket (uint16_t port);
  int sock;
  fd_set active_fd_set, read_fd_set;
  int i;
  struct sockaddr_in clientname;
  size_t size;

  /* Create the socket and set it up to accept connections. */
  sock = make_socket (PORT);
  if (listen (sock, 1) < 0)
    {
      perror ("listen");
      exit (EXIT_FAILURE);
    }
```

Select

```
/* Initialize the set of active sockets. */
FD_ZERO (&active_fd_set);
FD_SET (sock, &active_fd_set);

while (1)
  {
    /* Block until input arrives on one or more active sockets. */
    read_fd_set = active_fd_set;
    if (select (FD_SETSIZE, &read_fd_set, NULL, NULL, NULL) < 0)
      {
        perror ("select");
        exit (EXIT_FAILURE);
      }

    /* Service all the sockets with input pending. */
    for (i = 0; i < FD_SETSIZE; ++i)
      if (FD_ISSET (i, &read_fd_set))
        {
```

Select

```
/* Service all the sockets with input pending. */
for (i = 0; i < FD_SETSIZE; ++i)
  if (FD_ISSET (i, &read_fd_set))
    {
      if (i == sock)
        {
          /* Connection request on original socket. */
          int new;
          size = sizeof (clientname);
          new = accept (sock,
                        (struct sockaddr *) &clientname,
                        &size);
          if (new < 0)
            {
              perror ("accept");
              exit (EXIT_FAILURE);
            }
          fprintf (stderr,
                   "Server: connect from host %s, port %hd.\n",
                   inet_ntoa (clientname.sin_addr),
                   ntohs (clientname.sin_port));
          FD_SET (new, &active_fd_set);
        }
```

Select

```
                }
              else
                {
                  /* Data arriving on an already-connected socket. */
                  if (read_from_client (i) < 0)
                    {
                      close (i);
                      FD_CLR (i, &active_fd_set);
                    }
                }
            }
      }
  }
```