Internetworking with Sockets

May 2011

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
- 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

Common Service Use Cases

Browse the World Wide Web

- Each device has a static IP
- DNS used to translate www.google.com to 74.125.43.103
- Contact service at 74.125.43.103 and port 80 (http)

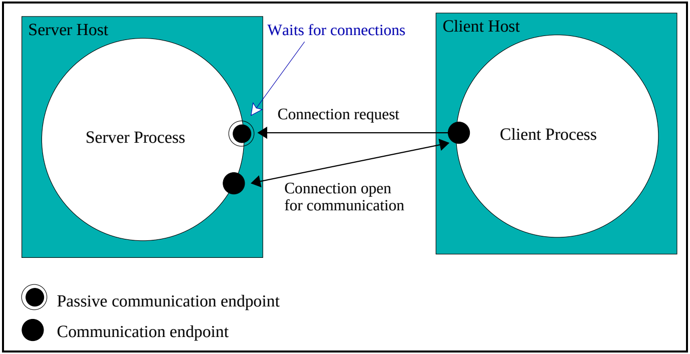
Common Service Use Cases

Your home network.

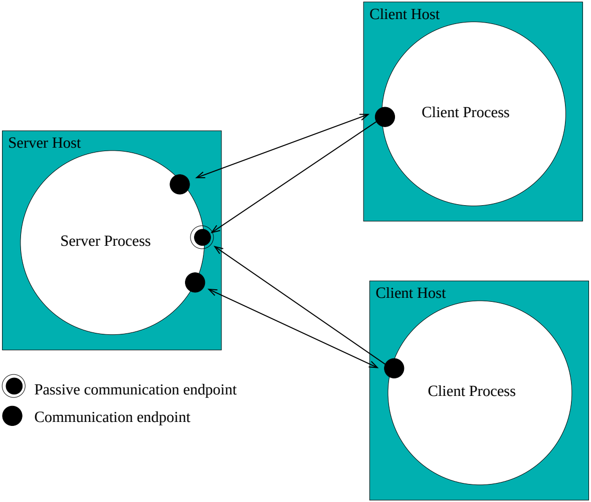
- You turn on your modem. It gets a public from you ISP (eg. 79.166.80.131)
- Your modem runs a DHCP server giving IPs in 192.168.x.y
- Your modem acts as a Internet gateway. Translates IPs from 192.168.x.y to 79.166.80.131. IP Masquerade.
- What if you need to setup a service running inside your 192.168.x.y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



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	✓	✗

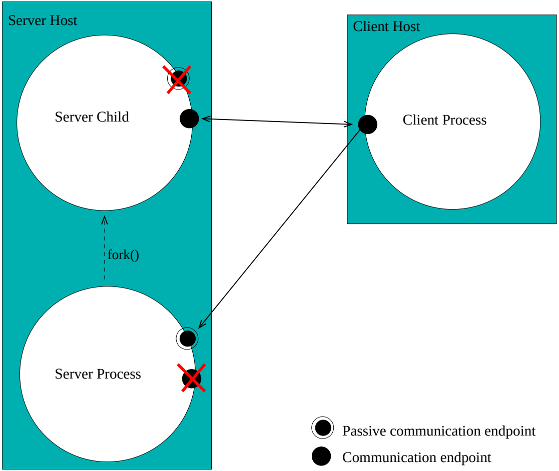
Serial Server (TCP)

```
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 → 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
```

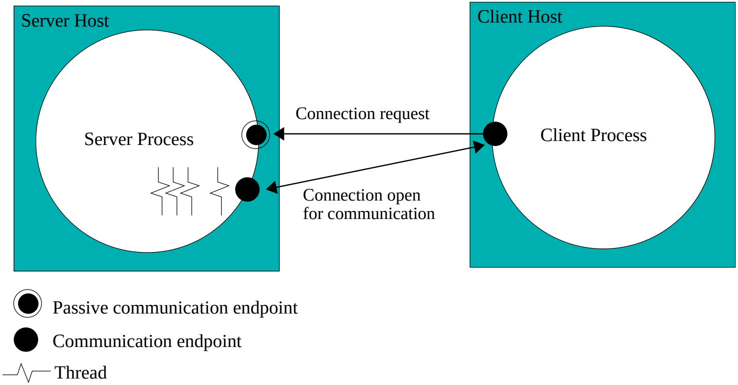
Child process

```
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.
- Convention: ip addresses, port numbers etc. in *Network Byte Order*
- Convert long/short integers between *Host* and *Network* byte order

```
    uint32_t htonl(uint32_t hostlong);
    uint16_t htons(uint16_t hostshort);
    uint32_t ntohl(uint32_t netlong);
    uint16_t ntohs(uint16_t netshort);
```

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;  /* list of addresses */
};
struct hostent *gethostbyname(const char *name);
struct hostent *gethostbyaddr(const void *addr, socklen_t len, int type);
```

- Beware, both use static storage for struct hostent. (problem?)
- For error reporting use herror & hstrerror

Creating sockets

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

```c
#include <sys/socket.h>
#include <sys/type.h>

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

domain communication domain (usual. PF_INET)

type communication semantics (usual. SOCK_STREAM, SOCK_DGRAM)

protocol Use 0 as typically only one protocol is available

```c
if ((sock = socket(PF_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);
```

Internet domain (AF_INET):

- We pass a *sockaddr_in* struct as the *address*

Interresting fields:

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

```c
#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);
```

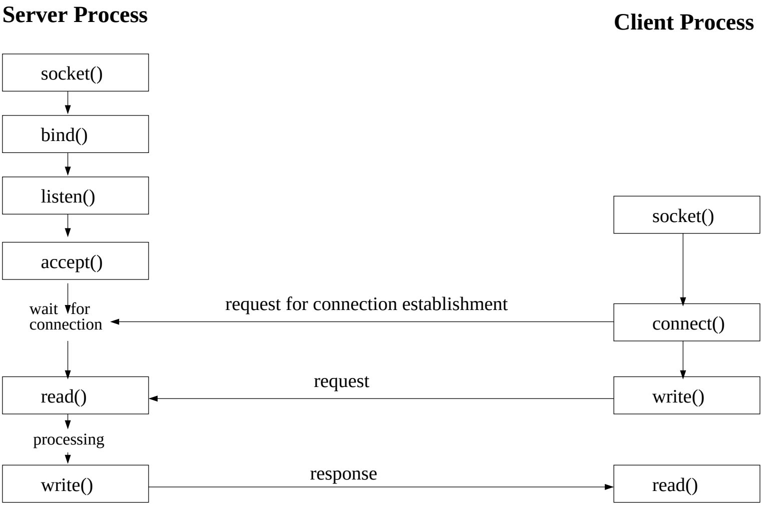
- Accept a connection on a socket
- Blocks until a client connects or interrupted by signal
- Returns new socket descriptor used to communicate with client
- Returns info on clients address through *address*.
  Pass NULL if you don't care.
- Value-result *address_len* must be set to the amount of space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

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

```
/*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(PF_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");
    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 */
```

```c
}

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(PF_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);
```

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 get the current address of a socket

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

getpeername get the name (address) of the peer connected to socket socket. (inverse of getsockname)

```
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’

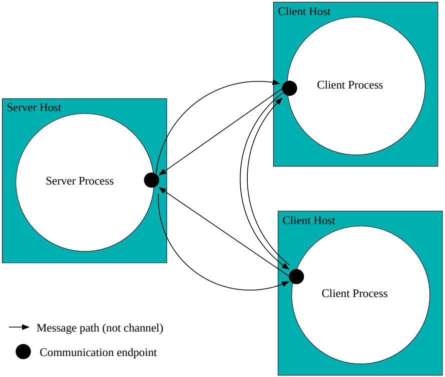
inet_addr Convert IP address string in ‘.’ notation to 32bit network address

inet_ntop Convert address from network format to printable presentation format

inet_pton Convert presentation format address to network format

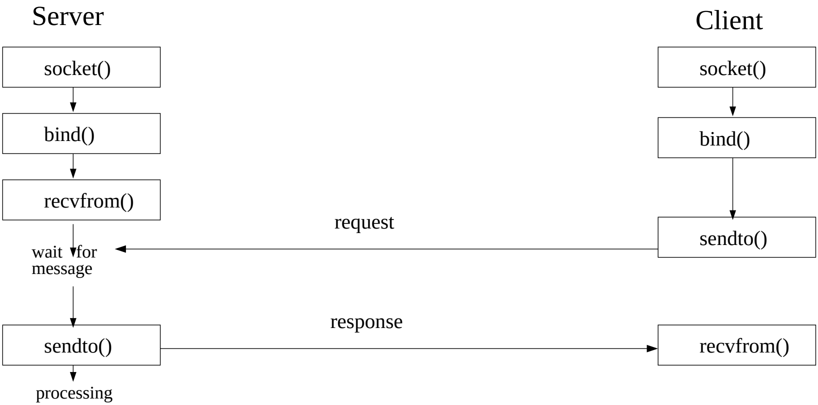
Bonus: inet_ntop and inet_pton also work with IPv6!

Internet User Datagram Protocol (UDP)



- no connections. Think postcards, not telephone.
- *Datagrams* (messages) exchanged.
- Datagrams get lost or arrive out of order

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 from a socket
- Similar to write() & send() but allows to specify 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 allows to get the 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:

```
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:

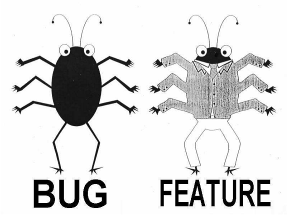
```
ad@linux02:~> ./inet_dgm_server
Socket port: 59579
Received from linux03: Hlade's Law:
Received from linux03:  If you have a difficult task, give
    it to a lazy person --
Received from linux03:  they will find an easier way to do
    it.
```

```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(PF_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");
    }}
```

```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(PF_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 ls server - with paranoia

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 with paranoia (TCP)

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

```
/* 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);
```

```c
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( PF_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);
           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()

```c
#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(PF_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" );
```

```c
    /* 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;
}
```

The ROCK PAPER SCISSORS game

- One referee process.
- Two players: a local process, a remote process
- Referee talks to the local process through pipes
- Referee talks to the remote process through sockets

Server

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <sys/wait.h>           /* For wait */
#include <sys/types.h>          /* For sockets */
#include <sys/socket.h>         /* For sockets */
#include <netinet/in.h>         /* For Internet sockets */
#include <netdb.h>          /* For gethostbyname */

#define READ    0
#define WRITE   1

int read_data (int fd, char *buffer);
int write_data (int fd, char* message);
void prs (int *score1, int *score2, int len1, int len2);
```

```c
int main(int argc, char *argv[])
{
    int n, port, sock, newsock;
    int i, pid, fd1[2], fd2[2], option, status;
    int  score1=0, score2=0;        /* Score variables */
    char buf[60], buf2[60], buf3[60];   /* Buffers */
    char *message[] = { "ROCK", "PAPER", "SCISSORS" };  /*
        prs options */

    unsigned int serverlen, clientlen;  /* Server - client
        variables */
    struct sockaddr_in server, client;
    struct sockaddr *serverptr, *clientptr;
    struct hostent *rem;

    if ( argc < 3 ){            /* At least 2 arguments */
        fprintf(stderr, "usage: %s <n> <port>\n", argv[0]);
        exit(0);
    }

    n = atoi(argv[1]);          /* Number of games */
    port = atoi(argv[2]);           /* Port */
```

```
if ((sock = socket(PF_INET, SOCK_STREAM, 0)) == -1){
    /* Create socket */
    perror("socket");
    exit(-1);
}
server.sin_family = AF_INET;    /* Internet domain */
server.sin_addr.s_addr = htonl(INADDR_ANY);
server.sin_port = htons(port);  /* The given port */
serverptr = (struct sockaddr *) &server;
serverlen = sizeof server;
if (bind(sock, serverptr, serverlen) < 0){
    perror("bind"); exit(-1);
}
if (listen(sock, 5) < 0){
    perror("listen");exit(-1);
}

printf("I am the referee with PID %d waiting for game
    request at port %d\n", (int) getpid(), port);
```

```
if (pipe (fd1) == -1){  /* First pipe: parent -> child
    */
    perror("pipe");exit(-1);
}
if (pipe (fd2) == -1){  /* Second pipe: child -> parent
    */
    perror("pipe");exit(-1);
}

if ((pid = fork()) == -1)    /* Create child for player
    1 */
{
    perror("fork");exit(-1);
}
```

```
    if ( !pid ){        /* Child process */
        close(fd1[WRITE]);close(fd2[READ]); /* Close unused
            */
        srand (getppid());
        printf("I am player 1 with PID %d\n", (int) getpid()
            );
        for(;;)         /* While read "READY" */
        {
            read_data (fd1[READ], buf); /* Read "READY" or "
                STOP" */
            option = rand()%3;
            if ( strcmp("STOP", buf)){  /* If != "STOP" */
                write_data (fd2[WRITE], message[option]);
                    /* Send random option */
                read_data (fd1[READ], buf); /* Read result
                    of this game */
                printf ("%s", buf);     /* Print result */
            }else
                break;
        }
        read_data (fd1[READ], buf); /* Read final result */
        printf("%s", buf);  /* Print final result */
        close(fd1[READ]); close(fd2[WRITE]);
    }
    else{       /* Parent process */
        clientptr = (struct sockaddr *) &client;
        clientlen = sizeof client;
        close(fd1[READ]); close(fd2[WRITE]);
        printf("Player 1 is child of the referee\n");
        if ((newsock = accept(sock, clientptr, &clientlen))
            < 0){
            perror("accept"); exit(-1);
        }
        if ((rem = gethostbyaddr((char *) &client.sin_addr.
            s_addr, sizeof client.sin_addr.s_addr, client.
            sin_family)) == NULL) {
            perror("gethostbyaddr");exit(-1);
        }
```

```
printf("Player 2 connected %s\n",rem->h_name);
write_data (newsock, "2"); /* Send player's ID (2)
    */
for(i = 1; i <= n; i++){
    write_data (fd1[WRITE], "READY");
    write_data (newsock, "READY");
    read_data (fd2[READ], buf);
    read_data (newsock, buf2);
    /* Create result string */
    sprintf (buf3, "Player 1:%10s\tPlayer 2:%10s\n",
         buf, buf2);
    write_data (fd1[WRITE], buf3);
    write_data (newsock, buf3);
    prs(&score1,&score2,strlen(buf),strlen(buf2));
}
```

```
/* Calculate final results for each player */
if ( score1 == score2 ){
    sprintf(buf, "Score = %d - %d (draw)\n", score1,
         score2);
    sprintf(buf2, "Score = %d - %d (draw)\n", score1
        , score2);
}else if (score1 > score2 ){
    sprintf(buf, "Score = %d - %d (you won)\n",
        score1, score2);
    sprintf(buf2, "Score = %d - %d (player 1 won)\n"
        , score1, score2);
}else{
    sprintf(buf, "Score = %d - %d (player 2 won)\n",
         score1, score2);
    sprintf(buf2, "Score = %d - %d (you won)\n",
        score1, score2);
}
write_data (fd1[WRITE], "STOP");
write_data (fd1[WRITE], buf);
close(fd1[WRITE]); close(fd2[READ]);
wait(&status);  /* Wait child */
write_data (newsock, "STOP");
write_data (newsock, buf2);
close(newsock); /* Close socket */
```

```c
int read_data (int fd, char *buffer){/* Read formated data
    */
    char temp;int i = 0, length = 0;
    if ( read ( fd, &temp, 1 ) < 0 )    /* Get length of
        string */
        exit (-3);
    length = temp;
    while ( i < length )    /* Read $length chars */
        if ( i < ( i+= read (fd, &buffer[i], length - i)))
            exit (-3);
    return i;   /* Return size of string */
}
int write_data ( int fd, char* message ){/* Write formated
    data */
    char temp; int length = 0;
    length = strlen(message) + 1;   /* Find length of string
         */
    temp = length;
    if( write (fd, &temp, 1) < 0 )  /* Send length first */
        exit (-2);
    if( write (fd, message, length) < 0 )   /* Send string
        */
        exit (-2);
    return length;      /* Return size of string */
}
```

```c
void prs(int *score1, int *score2, int len1, int len2)  /*
    Calculate score */
{
    int result = len1 - len2; /* len1 = buf1 length, len2 =
        buf2 length */
    if (result == 3 || result == 1 || result == -4) /* 1st
        player wins */
        (*score1)++;
    else if (result)    /* 2nd player wins */
        (*score2)++;
    return;
}
```

Client

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <strings.h>        /* For bcopy */
#include <unistd.h>
#include <sys/wait.h>       /* For wait */
#include <sys/types.h>      /* For sockets */
#include <sys/socket.h>     /* For sockets */
#include <netinet/in.h>     /* For Internet sockets */
#include <netdb.h>      /* For gethostbyname */

int read_data (int fd, char *buffer);
int write_data (int fd, char* message);
int main (int argc, char *argv[])
{
    int i, port, sock, option;
    char opt[3], buf[60], *message[] = { "PAPER", "ROCK", "
        SCISSORS" };
    unsigned int serverlen;
    struct sockaddr_in server;
    struct sockaddr *serverptr;
    struct hostent *rem;
    if (argc < 3){  /* At least 2 arguments */
        fprintf(stderr, "usage: %s <domain> <port>\n", argv
            [0]);
        exit(-1);
    }
    if ((sock = socket(PF_INET, SOCK_STREAM, 0)) < 0){
        perror("socket");
        exit(-1);
    }
    if ((rem = gethostbyname(argv[1])) == NULL){    /* Find
        server address */
        perror("gethostbyname");
        exit(-1);
    }
    port = atoi(argv[2]);
    server.sin_family = AF_INET;
    bcopy((char *) rem -> h_addr, (char *) &server.sin_addr,
         rem -> h_length);
    server.sin_port = htons(port);
    serverptr = (struct sockaddr *) &server;
    serverlen = sizeof server;
    if (connect(sock, serverptr, serverlen) < 0){
        perror("connect");exit(-1);
    }
```

```
read_data (sock, buf); /* Read player's ID (1 or 2) */
printf("I am player %d with PID %d\n", buf[0]-'0', (int)
     getpid());
for ( i = 1; ; i++ ){/* While read "READY" */
    read_data (sock, buf);  /* Read "READY" or "STOP" */
    if ( strcmp("STOP", buf) ){ /* If != "STOP" */
        printf("Give round %d play: ", i);
        scanf("%s", opt);
        switch (*opt){  /* First letter of opt */
        /* Note: The other 2 are \n and \0 */
            case 'p':option = 0; break;
            case 'r':option = 1; break;
            case 's':option = 2; break;
            default: fprintf(stderr, "Wrong option %c\n"
                , *opt);
                option = ((int)*opt)%3; break;
        }
        write_data (sock, message[option]);
        read_data (sock, buf);
        printf ("%s", buf);
    }else break;
}
read_data (sock, buf);  /* Read final score */
printf("%s", buf);
close(sock);
```

Server

```
jackal@jackal-laptop:~/Set006/src$ ./prsref 3 2323
I am the referee with PID 4587 waiting for game request at
    port 2323
I am player 1 with PID 4588
Player 1 is child of the referee
Player 2 connected localhost
Player 1:     PAPER      Player 2:     PAPER
Player 1:  SCISSORS      Player 2:  SCISSORS
Player 1:      ROCK      Player 2:  SCISSORS
Score = 1 - 0 (you won)
```

Client

```
jackal@jackal-laptop:~/Set006/src$ ./prs localhost 2323
I am player 2 with PID 4615
Give round 1 play: p
Player 1:     PAPER      Player 2:     PAPER
Give round 2 play: s
Player 1:  SCISSORS      Player 2:  SCISSORS
Give round 3 play: s
Player 1:      ROCK      Player 2:  SCISSORS
Score = 1 - 0 (player 1 won)
```