# CSE 333 – SECTION 6

Networking and sockets

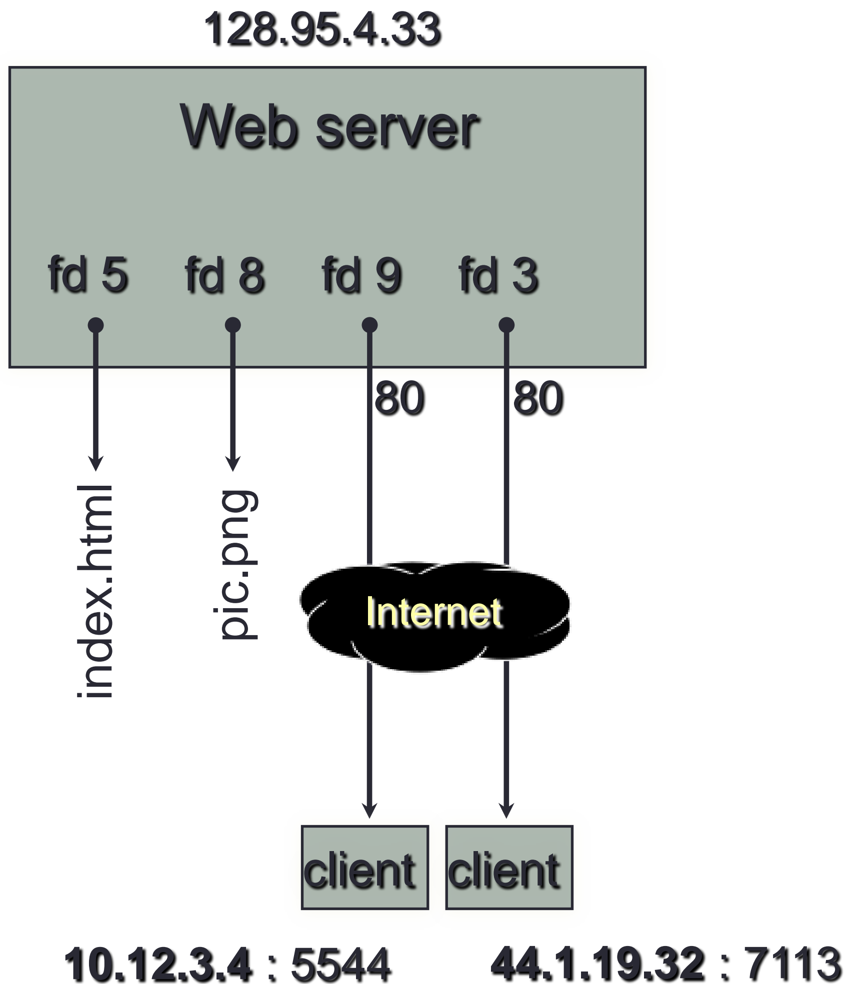
# Overview

- Network Sockets
- IP addresses and IP address structures in C/C++
- DNS – Resolving DNS names
- Demos
- Section exercise

# Sockets

- Network sockets are network interfaces
  - Endpoints in an interprocess communication flow
- Socket address = IP address + port number
- Socket API
  - Programs to control and use sockets

# Pictorially

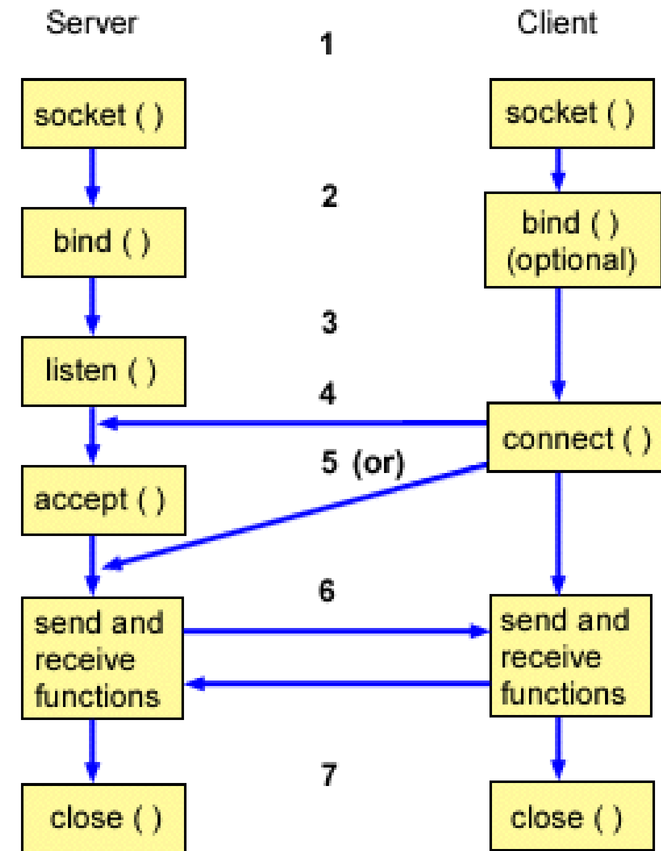



**OS's descriptor table**

| file descriptor | type | connected to? |
|---|---|---|
| 0 | pipe | stdin (console) |
| 1 | pipe | stdout (console) |
| 2 | pipe | stderr (console) |
| 3 | TCP socket | local: 128.95.4.33:80<br>remote: 44.1.19.32:7113 |
| 5 | file | index.html |
| 8 | file | pic.png |
| 9 | TCP socket | local: 128.95.4.33:80<br>remote: 102.12.3.4:5544 |

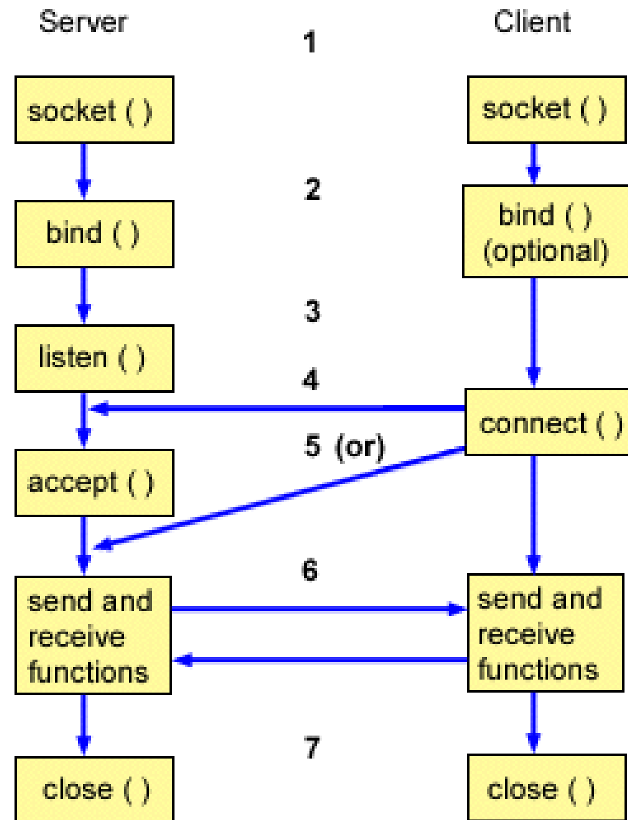
# How sockets work

- *Step 1*: The socket() API creates an endpoint for communications and returns a socket descriptor that represents the endpoint.
- *Step 2*: When an application has a socket descriptor, it can bind a unique name to the socket. Servers must bind a name to be accessible from the network.
- *Step 3*: The listen() API indicates a willingness to accept client connection requests.



# Sockets continued

- *Step 4*: The client application uses a connect() API on a stream socket to establish a connection to the server.
- *Step 5*: The server application uses the accept() API to accept a client connection request.
- *Step 6*: Use read(), write(), send(), recv(), etc to transfer data.
- *Step 7*: Issue a close() API to release any system resources acquired by the socket.



# Network Addresses

- For IPv4, an IP address is a 4-byte tuple
- - e.g., 128.95.4.1 (80:5f:04:01 in hex)
- For IPv6, an IP address is a 16-byte tuple
- - e.g., 2d01:0db8:f188:0000:0000:0000:0000:1f33
- ‣ 2d01:0db8:f188::1f33 in shorthand

# IPv4 address structures

```
// Port numbers and addresses are in *network order*.

// A mostly-protocol-independent address structure.
struct sockaddr {
    short int   sa_family;   // Address family; AF_INET, AF_INET6
    char        sa_data[14]; // 14 bytes of protocol address
};

// An IPv4 specific address structure.
struct sockaddr_in {
    short int          sin_family;   // Address family, AF_INET == IPv4
    unsigned short int sin_port;     // Port number
    struct in_addr     sin_addr;     // Internet address
    unsigned char      sin_zero[8];  // Same size as struct sockaddr
};

struct in_addr {
    uint32_t s_addr; // IPv4 address
};
```

# IPv6 address structures

```
// A structure big enough to hold either IPv4 or IPv6 structures.
struct sockaddr_storage {
    sa_family_t ss_family;   // address family
    // a bunch of padding; safe to ignore it.
    char       __ss_pad1[_SS_PAD1SIZE];
    int64_t    __ss_align;
    char       __ss_pad2[_SS_PAD2SIZE];
};
// An IPv6 specific address structure.
struct sockaddr_in6 {
    u_int16_t        sin6_family;     // address family, AF_INET6
    u_int16_t        sin6_port;       // Port number
    u_int32_t        sin6_flowinfo;   // IPv6 flow information
    struct in6_addr  sin6_addr;       // IPv6 address
    u_int32_t        sin6_scope_id;   // Scope ID
};
struct in6_addr {
    unsigned char s6_addr[16];        // IPv6 address
};
```

# Generating these structures

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

int main(int argc, char **argv) {
  struct sockaddr_in sa;   // IPv4
  struct sockaddr_in6 sa6; // IPv6

  // IPv4 string to sockaddr_in.
  inet_pton(AF_INET, "192.0.2.1", &(sa.sin_addr));

  // IPv6 string to sockaddr_in6.
  inet_pton(AF_INET6, "2001:db8:63b3:1::3490", &(sa6.sin6_addr));
  return EXIT_SUCCESS;
}
```

# Generating these structures

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

int main(int argc, char **argv) {
  struct sockaddr_in6 sa6;        // IPv6
  char astring[INET6_ADDRSTRLEN]; // IPv6

  // IPv6 string to sockaddr_in6.
  inet_pton(AF_INET6, "2001:db8:63b3:1::3490", &(sa6.sin6_addr));

  // sockaddr_in6 to IPv6 string.
  inet_ntop(AF_INET6, &(sa6.sin6_addr), astring, INET6_ADDRSTRLEN);
  printf("%s\n", astring);
  return EXIT_SUCCESS;
}
```

# DNS – Domain Name System/Service

- A hierarchical distributed naming system any resource connected to the Internet or a private network.
- Resolves queries for names into IP addresses.
- The sockets API lets you convert between the two.
- Is on the application layer on the Internet protocol suite.

# Resolving DNS names

- The POSIX way is to use **getaddrinfo( ).**
- Set up a “hints” structure with constraints, e.g. IPv6, IPv4, or either.
- Tell getaddrinfo( ) which host and port you want resolved.
- Host - a string representation: DNS name or IP address
- getaddrinfo() gives you a list of results in an “addrinfo” struct.

# getaddrinfo() and structures

```
int getaddrinfo(const char *hostname,         // hostname to look up
                const char *servname,         // service name
                const struct addrinfo *hints, //desired output type
                struct addrinfo **res);       //result structure

// Hints and results take the same form. Hints are optional.
struct addrinfo {
    int              ai_flags;      // Indicate options to the function
    int              ai_family;     // AF_INET, AF_INET6, or AF_UNSPEC
    int              ai_socktype;   // Socket type, (use SOCK_STREAM)
    int              ai_protocol;   // Protocol type
    size_t           ai_addrlen;    // INET_ADDRSTRLEN, INET6_ADDRSTRLEN
    char             *ai_canonname; // canonical name for the host
    struct sockaddr *ai_addr;       // Address (input to inet_ntop)
    struct addrinfo *ai_next;       // Next element (It’s a linked list)
};

// Converts an address from network format to presentation format
const char *inet_ntop(int af,                          // family (see above)
                      const void * restrict src,       // sockaddr
                      char * restrict dest,            // return buffer
                      socklen_t size);                 // length of buffer
```

# dig program – a DNS lookup utility

- Demo simple dig command usage

*dnsresolve.cc*

# nc - Netcat utility

- Demo simple nc usage.

sendreceive.cc

# Section exercise 1

- Write a client program that:
  - reads DNS names, one per line, from stdin
  - translates each name to one or more IP addresses
  - prints out each IP address to stdout, one per line

# Section exercise 2

- Write a program that:
  - creates a listening socket, accepts connections from clients
  - reads a line of text from the client
  - parses the line of text as a DNS name
  - does a DNS lookup on the name
  - writes back to the client the list of IP addrsses associated with the DNS name
  - closes the connection to the client