



# Poll Everywhere

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**Which concept has given you the most difficulty so far in the context of Homework 3?**

- A. **Understanding the index file layout**
- B. **C++ Classes & Inheritance**
- C. **C++ STL**
- D. **Query Processor Algorithm**
- E. **Debugging/GDB**
- F. **Style considerations**
- G. **Prefer not to say**

# Server-side Programming

## CSE 333 Autumn 2021

**Instructor:** Chris Thachuk

**Teaching Assistants:**

Arpad (John) Depaszthory

Ian Hsiao

Logan Gnanapragasam

Mengqi (Frank) Chen

Angela Xu

Khang Vinh Phan

Maruchi Kim

Cosmo Wang

# Administrivia

- ❖ Exercise 14 due Monday (Nov. 22)
  - Client-side programming
- ❖ Exercise 15 released Monday
  - Server-side programming
- ❖ hw3 due Wednesday (Nov. 24)
- ❖ hw4 will be pushed & released over the weekend
  - Due last Thursday of quarter (Dec. 9)
- ❖ No lecture on Wednesday (Nov. 24)

# Socket API: Server TCP Connection

*Analogy: opening a coffee shop!*

- ❖ Pretty similar to clients, but with additional steps:
  - 1) Figure out the IP address and port on which to listen *Finding a good location*
  - 2) Create a socket *Building the store*
  - 3) **bind()** the socket to the address(es) and port *Advertising the store*
  - 4) Tell the socket to **listen()** for incoming clients *Open shop!*
  - 5) **accept()** a client connection *Next customer in line, Please!*
  - 6) **read()** and **write()** to that connection *Transaction occurs*
  - 7) **close()** the client socket *Customer leaves shop or refuse service*

# Servers

- ❖ Servers can have multiple IP addresses (“*multihoming*”)
  - Usually have at least one externally-visible IP address, as well as a local-only address (127.0.0.1)
- ❖ The goals of a server socket are different than a client socket
  - Want to bind the socket to a particular *port* of one or more IP addresses of the server
  - Want to allow multiple clients to connect to the same port
    - OS uses client IP address and port numbers to direct I/O to the correct server file descriptor

# Step 1: Figure out IP address(es) & Port

- ❖ Step 1: `getaddrinfo` () invocation may or may not be needed (but we'll use it)
  - Do you know your IP address(es) already?
    - Static vs. dynamic IP address allocation
    - Even if the machine has a static IP address, don't wire it into the code – either look it up dynamically or use a configuration file
  - Can request listen on all local IP addresses by passing `NULL` as `hostname` and setting `AI_PASSIVE` in `hints.ai_flags`
    - Effect is to use address `0.0.0.0` (IPv4) or `::` (IPv6)

*Common and hard to find bug  
is forgetting to set this 😞*

## Step 2: Create a Socket

- ❖ Step 2: **socket** () call is same as before
  - Can directly use constants or fields from result of **getaddrinfo** ()
  - Recall that this just returns a file descriptor – IP address and port are not associated with socket yet

## Step 3: Bind the socket

- ❖ 

```
int bind(int sockfd, const struct sockaddr* addr, socklen_t addrlen);
```

  - Looks nearly identical to **connect** () !
  - Returns **0** on success, **-1** on error
- ❖ Some specifics for `addr`: *We'll just pass in results from `getaddrinfo()` & `socket()`*
  - **Address family:** `AF_INET` or `AF_INET6`
    - What type of IP connections can we accept?
    - POSIX systems can handle IPv4 clients via IPv6 😊
  - **Port:** port in network byte order (**htons** () is handy)
  - **Address:** specify *particular* IP address or *any* IP address
    - “Wildcard address” – `INADDR_ANY` (IPv4), `in6addr_any` (IPv6)

# Step 4: Listen for Incoming Clients

- ❖ 

```
int listen(int sockfd, int backlog);
```
- Tells the OS that the socket is a listening socket that clients can connect to
- `backlog`: maximum length of connection queue
  - Gets truncated, if necessary, to defined constant `SOMAXCONN`
  - The OS will refuse new connections once queue is full until server `accept()` s them (removing them from the queue)
- Returns `0` on success, `-1` on error
- Clients can start connecting to the socket as soon as `listen()` returns
  - ✘ Server can't use a connection until you `accept()` it

# Pseudocode Time

- ❖ Assume we have set up `struct addrinfo` hints to get both IPv4 and IPv6 addresses
  - Write pseudocode to bind to and listen on the first socket that works
- ❖ Pieces you can use:
  - `Error()`; *// print msg and exit*
  - `retval = getaddrinfo(..., &res);`
  - `freeaddrinfo(res);`
  - `fd = socket(...);`
  - `retval = bind(fd, ...);`
  - `retval = listen(fd, SOMAXCONN);`
  - `close(fd);`

# Pseudocode example

```
retval = getaddrinfo(..., &res);  
if (retval != 0)  
    Error();  
  
for (result in res) { // res is Linked List of results  
    /*  
    bool success = setup_addr();  
    if (success) break;  
    else continue;  
    */  
}
```

# Pseudocode example

```
retval = getaddrinfo(..., &res);
if (retval != 0)
    Error();
bool success = false;
for (result in res) { // res is Linked List of results
    int fd = socket(...);
    if (fd == -1)
        continue;
    retval = bind(fd, ...);
    if (retval == -1) {
        close(fd);
        continue;
    }
    retval = listen(fd, SOMAXCONN);
    if (retval == -1) {
        close(fd);
        continue;
    }
    success = true;
    break;
}
freeaddrinfo(res);
if (!success) Error();
```

# Example #1

- ❖ See `server_bind_listen.cc`
  - Takes in a port number from the command line
  - Opens a server socket, prints info, then listens for connections for 20 seconds
    - Can connect to it using netcat (`nc`)

# Step 5: Accept a Client Connection

```
❖ int accept(int sockfd, struct sockaddr* addr, socklen_t* addrlen);
```

- Returns an active, ready-to-use socket file descriptor connected to a client (or `-1` on error)
  - `sockfd` must have been created, bound, *and* listening
  - Pulls a queued connection or waits for an incoming one
- `addr` and `addrlen` are output parameters
  - `*addrlen` should initially be set to `sizeof(*addr)`, gets overwritten with the size of the client address
  - Address information of client is written into `*addr`
    - Use `inet_ntop()` to get the client's printable IP address
    - Use `getnameinfo()` to do a *reverse DNS lookup* on the client

HINT FOR HW4 AND EX 15

# Example #2

- ❖ See `server_accept_rw_close.cc`
  - *Takes in a port number from the command line*
  - *Opens a server socket, prints info, then listens for connections*
    - *Can connect to it using netcat (`nc`)*
  - Accepts connections as they come
  - Echoes any data the client sends to it on `stdout` and also sends it back to the client

# Something to Note

- ❖ Our server code is not concurrent
  - Single thread of execution
  - The thread blocks while waiting for the next connection
  - The thread blocks waiting for the next message from the connection
  
- ❖ A crowd of clients is, by nature, concurrent
  - While our server is handling the next client, all other clients are stuck waiting for it 😞

# hw4 demo

## ❖ Multithreaded Web Server (333gle)

- Don't worry – multithreading has mostly been written for you
- `./http333d <port> <static files> <indices+>`
- Some security bugs to fix, too

# Extra Exercise #1

- ❖ Write a program that:
  - Creates a listening socket that 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 addresses associated with the DNS name
  - Closes the connection to the client