Client-side Networking

CSE 333 Spring 2019

Instructor: Justin Hsia

Teaching Assistants:

Aaron Johnston	Andrew Hu	Daniel Snitkovskiy
Forrest Timour	Kevin Bi	Kory Watson
Pat Kosakanchit	Renshu Gu	Tarkan Al-Kazily
Travis McGaha		

Administrivia

- hw3 is due Thursday (5/23)
  - Usual reminders: don’t forget to tag, clone elsewhere, and recompile
- hw4 out on Friday (5/24)
- Exercise 15 will be released on Thursday
  - Client-side TCP connection
  - Related to section this week

Resolving DNS Names

- The POSIX way is to use **`getaddrinfo()`**
  - A complicated system call found in `#include <netdb.h>`

  -
    ```
    int getaddrinfo(const char* hostname,
                    const char* service,
                    const struct addrinfo* hints,
                    struct addrinfo** res);
    ```
    - Tell **`getaddrinfo()`** which host and port you want resolved
      - String representation for host: DNS name or IP address
    - Set up a "`hints`" structure with constraints you want respected
    - **`getaddrinfo()`** gives you a list of results packed into an "`addrinfo`" structure/linked list
      - Returns 0 on success; returns *negative number* on failure
    - Free the `struct addrinfo` later using **`freeaddrinfo()`**

recursively frees res linked list

getaddrinfo

○ "don't care" options

- `getaddrinfo()` arguments:
  - `hostname` – domain name or IP address string
  - `service` – port # (*e.g.* `"80"`) or service name (*e.g.* `"www"`) or `NULL`/`nullptr`

  -
    ```
    struct addrinfo {
      int        ai_flags;          // additional flags
      int        ai_family;         // AF_INET, AF_INET6, AF_UNSPEC
      int        ai_socktype;       // SOCK_STREAM, SOCK_DGRAM, 0
      int        ai_protocol;       // IPPROTO_TCP, IPPROTO_UDP, 0
      size_t     ai_addrlen;        // length of socket addr in bytes
    ☆ struct sockaddr* ai_addr;     // pointer to socket addr
      char*      ai_canonname;      // canonical name
      struct addrinfo* ai_next;     // can form a linked list
    };
    ```

DNS Lookup Procedure

```
struct addrinfo {
  int       ai_flags;          // additional flags
  int       ai_family;         // AF_INET, AF_INET6, AF_UNSPEC
  int       ai_socktype;       // SOCK_STREAM, SOCK_DGRAM, 0
  int       ai_protocol;       // IPPROTO_TCP, IPPROTO_UDP, 0
  size_t    ai_addrlen;        // length of socket addr in bytes
  struct sockaddr* ai_addr;    // pointer to socket addr
  char*     ai_canonname;      // canonical name
  struct addrinfo* ai_next;    // can form a linked list
};
```

1) Create a `struct addrinfo hints`
2) Zero out `hints` for “defaults”
3) Set specific fields of `hints` as desired
4) Call **`getaddrinfo`**`()` using `&hints`
5) Resulting linked list `res` will have all fields appropriately set

- See dnsresolve.cc

Socket API: Client TCP Connection

- There are five steps:
  1) Figure out the IP address and port to connect to
  2) Create a socket
  3) Connect the socket to the remote server
  4) `read()` and `write()` data using the socket
  5) Close the socket

Step 2: Creating a Socket

- `int socket(int domain, int type, int protocol);`
  - Creating a socket doesn't bind it to a local address or port yet
  - Returns file descriptor or -1 on error

socket.cc

```
#include <arpa/inet.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <iostream>

int main(int argc, char** argv) {
  int socket_fd = socket(AF_INET, SOCK_STREAM, 0);
  if (socket_fd == -1) {    // check for error
     std::cerr << strerror(errno) << std::endl;
     return EXIT_FAILURE;
  }
  close(socket_fd);    // close when done
  return EXIT_SUCCESS;
}
```

Step 3: Connect to the Server

- The `connect()` system call establishes a connection to a remote host

  usually: struct sockaddr_storage ss;

  (sockaddr *)(&ss)

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

  - `sockfd`: Socket file description from Step 2 — socket()
  - `addr` and `addrlen`: Usually from one of the address structures returned by `getaddrinfo` in Step 1 (DNS lookup) — getaddrinfo() struct addrinfo
  - Returns **0** on success and **-1** on error

- `connect()` may take some time to return
  - It is a *blocking* call by default — waits on an event before returning
  - The network stack within the OS will communicate with the remote host to establish a TCP connection to it
    - This involves ~2 *round trips* across the network

Connect Example

- See connect.cc

```
// Get an appropriate sockaddr structure.
struct sockaddr_storage addr;
size_t addrlen;
LookupName(argv[1], port, &addr, &addrlen);    // does the getaddrinfo() call

// Create the socket.
int socket_fd = socket(addr.ss_family, SOCK_STREAM, 0);
if (socket_fd == -1) {
  cerr << "socket() failed: " << strerror(errno) << endl;
  return EXIT_FAILURE;
}

// Connect the socket to the remote host.
int res = connect(socket_fd,
                  reinterpret_cast<sockaddr*>(&addr),
                  addrlen);
if (res == -1) {
  cerr << "connect() failed: " << strerror(errno) << endl;
}
```

Review Question

return # of bytes read/written

- How do we *error* check `read()` and `write()`?
  - Vote at http://PollEv.com/justinh

A. `ferror()` for fread()/fwrite()

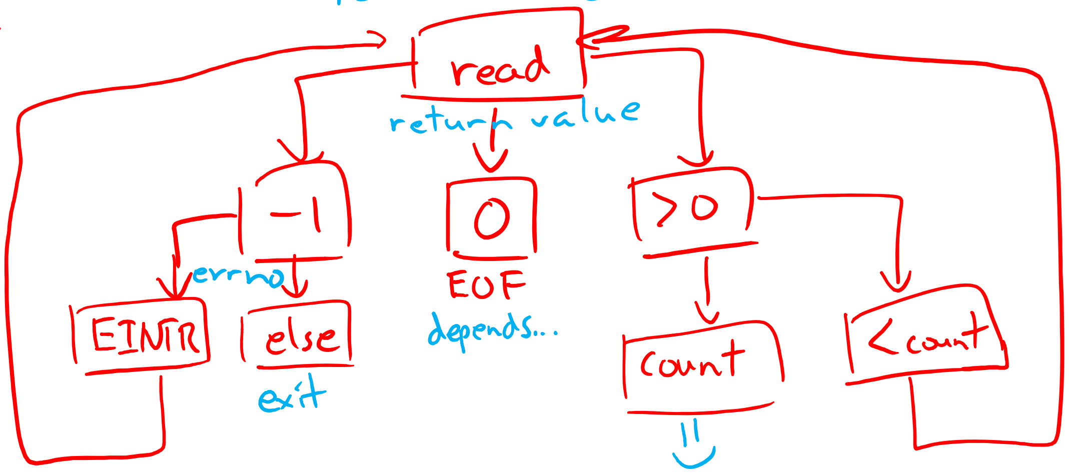
B. Return value less than expected happens, but not on error

C. Return value of 0 or NULL valid return value (means EOF for read())

[✓ D. Return value of -1]

E. We're lost…

for File I/O:

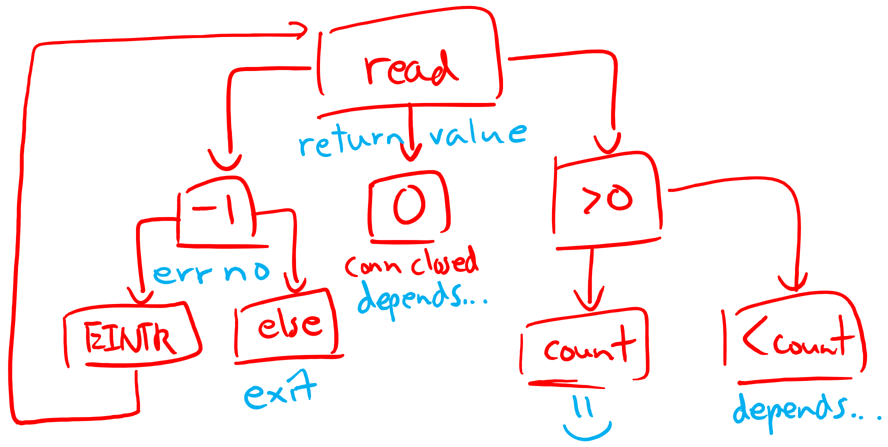


Step 4: `read()`

- If there is data that has already been received by the network stack, then read will return immediately with it
  - `read()` might return with *less* data than you asked for

- If there is no data waiting for you, by default `read()` will *block* until something arrives
  - How might this cause *deadlock*? server & client have no data to read but both call read()
  - Can `read()` return 0?
    ↳ Yes, if connection is closed

for Network I/O:



Step 4: `read()`

- Assume we have:
  - `int socket_fd;       // fd of connected socket`
  - `char readbuf[BUF]; // read buffer`
  - `int res;             // to store read result`
- Write *C++* code to read in `BUF` characters from `socket_fd`
  - If error occurs, send error message to user and **`exit()`**

```
while (1) {
    res = read(socket_fd, readbuf, BUF);
    if (res == -1) {
        if (errno == EINTR)
            continue;
        std::cerr << "read error: " << strerror(errno) << std::endl;
        close(socket_fd);
        exit(EXIT_FAILURE);
    }
    ...
```

See sendreceive.cc for complete code

Step 4: `write()`

- `write()` queues your data in a send buffer in the OS and then returns
  - The OS transmits the data over the network in the background
  - When `write()` returns, the receiver probably has not yet received the data!

- If there is no more space left in the send buffer, by default `write()` will *block*

Read/Write Example

- See sendreceive.cc

```
while (1) {
  int wres = write(socket_fd, readbuf, res);
  if (wres == 0) {
    cerr << "socket closed prematurely" << endl;
    close(socket_fd);
    return EXIT_FAILURE;
  }
  if (wres == -1) {
    if (errno == EINTR)
      continue;
    cerr << "socket write failure: " << strerror(errno) << endl;
    close(socket_fd);
    return EXIT_FAILURE;
  }
  break;
}
```

Step 5: `close()`

-
  ```c
  int close(int fd);
  ```
  - Nothing special here – it's the same function as with file I/O
  - Shuts down the socket and frees resources and file descriptors associated with it on both ends of the connection

Extra Exercise #1

- Write a 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