CS341 Spring 2018
Programming Assignment #1

Socket Programming

KAIST

Advanced Networking Laboratory

Notice

- Due: 9am, Wed, March 21st, 2018
- This is not a team project. Do it by yourself.

Overview

- In this assignment, you will learn to do socket programming on Linux via implementing a simple HTTP server and a client.

- Client:
  - Implement only GET and POST requests of HTTP 1.0.

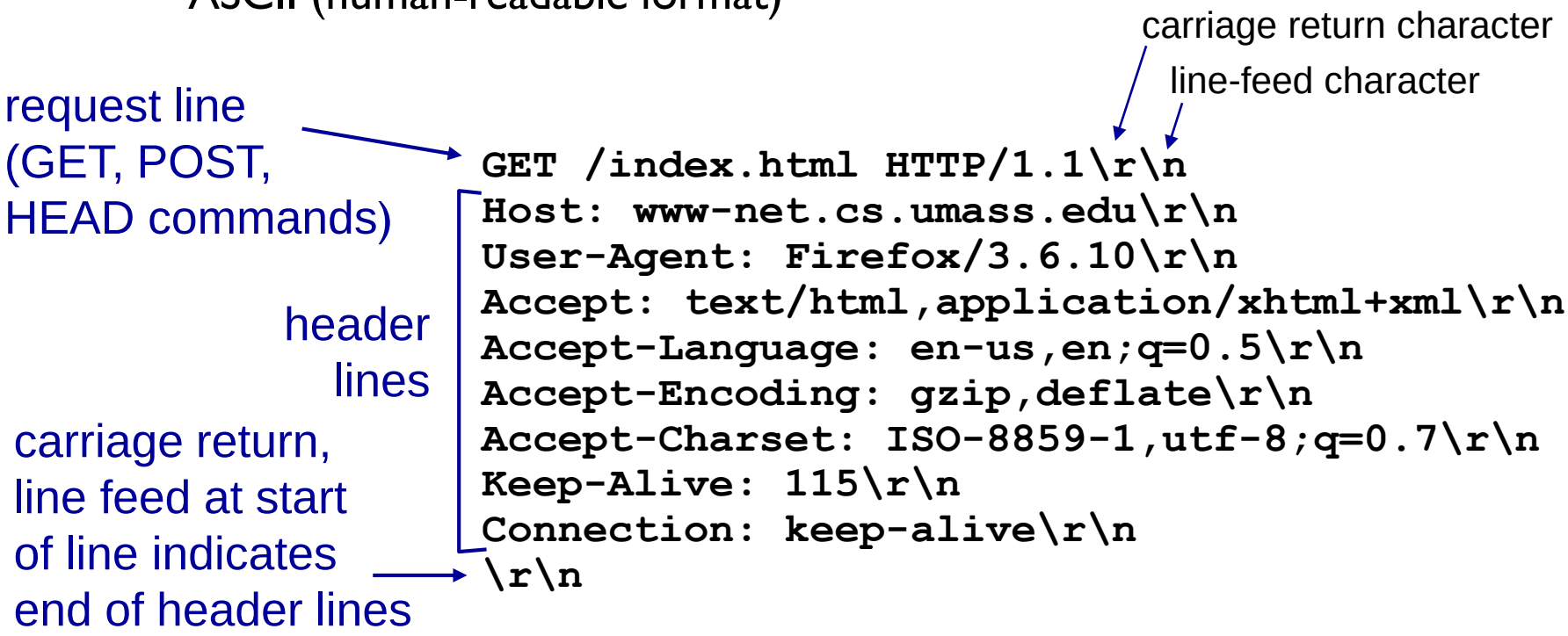
- Server:
  - Implement only the following RESPONSE status codes.
  - 200 OK / 400 Bad Request / 404 Not Found

Basic Socket API

- Server:
  - `socket()`
  - `bind()`
  - `listen()`
  - `select()`
  - `accept()`
  - `read()/write()`
  - `close()`
- Client:
  - `socket()`
  - `connect()`
  - `read()/write()`
  - `close()`

HTTP request message

- two types of HTTP messages: *request, response*
- HTTP request message:
  - ASCII (human-readable format)



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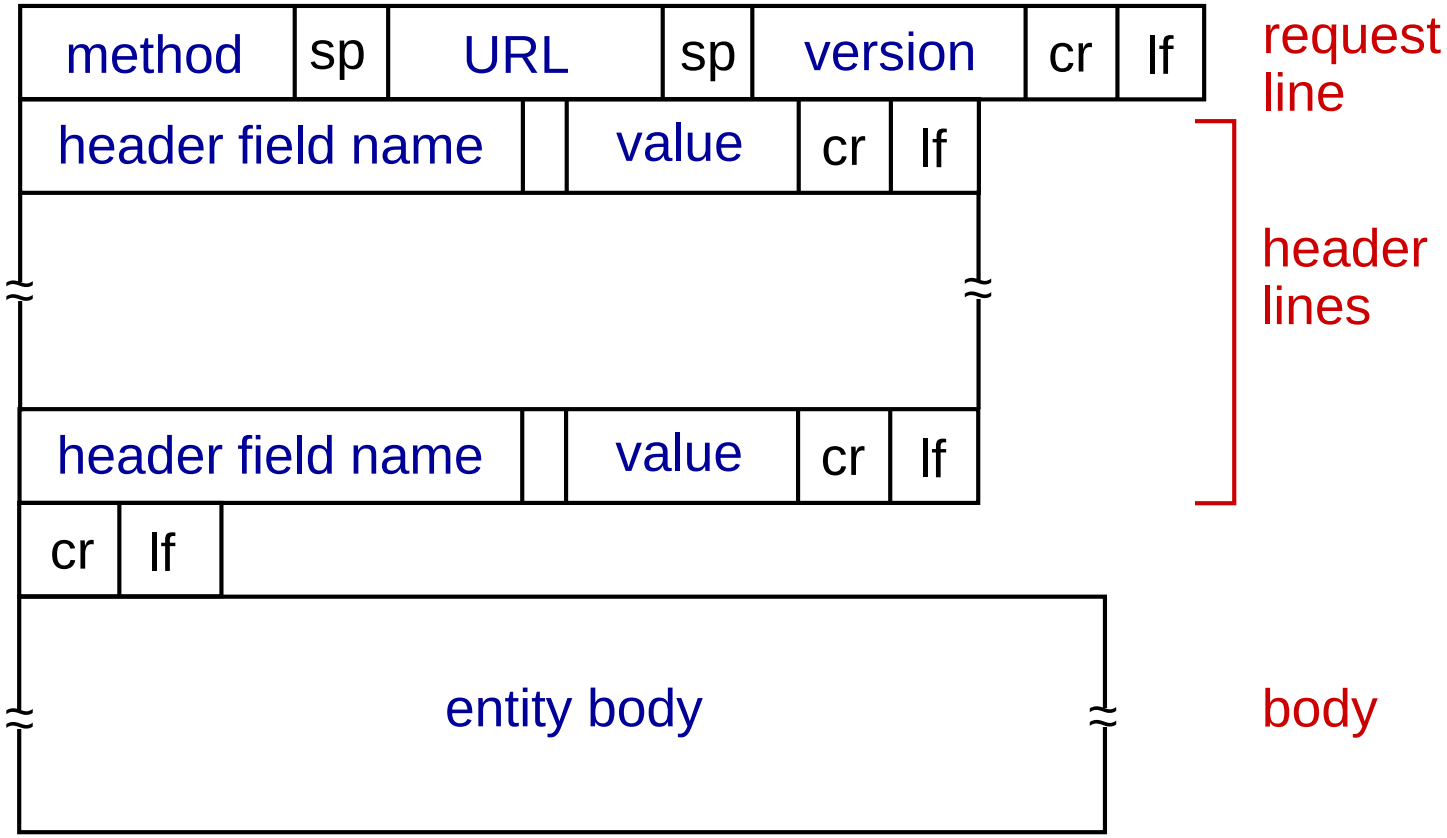
HTTP request message



slide borrowed from Kurose's Lecture slide

HTTP response message

status line (protocol status code status phrase)

header lines

data, e.g., requested HTML file

```
HTTP/1.1 200 OK\r\n
Date: Sun, 26 Sep 2010 20:09:20 GMT\r\n
Server: Apache/2.0.52 (CentOS)\r\n
Last-Modified: Tue, 30 Oct 2007 17:00:02
   GMT\r\n
ETag: "17dc6-a5c-bf716880"\r\n
Accept-Ranges: bytes\r\n
Content-Length: 2652\r\n
Keep-Alive: timeout=10, max=100\r\n
Connection: Keep-Alive\r\n
Content-Type: text/html; charset=ISO-8859-
   1\r\n
\r\n
data data data data data ...
```

slide borrowed from Kurose's Lecture slide

Client

- Your client must be able to send GET and POST requests to the server.
- Write a program `client` such that it
  - Fetches payload by sending a GET request with a URL
    - ./client –G URL
  - Uploads payload by sending a POST request with a URL
    - ./client –P URL

Client

- Examples
  - ./client –G URL
    - This should print out the content of URL via standard output.
  - ./client –P URL
    - This should read standard input until the EOF appears.
    - Then, this should send out the data received from the standard input.
    - Hint 1: Don't forget "Content-Length:" in the header!
    - Hint 2: use redirection for easy test!
      - e.g.) ./client –P URL < aqours.jpg

URL

- http://www.kaist.ac.kr:8080/test.html
  - www.kaist.ac.kr must be replaced with your server IP address
  - 8080 must be replaced with your server port number
- In a "GET" request, the client should fetch "test.html" from the server.
- In a "POST" request, the body of the request the client sends should be stored in "test.html" on the server.

Port Numbers

- 0 to 1023: well-known ports
  - 20/21 FTP, 22 SSH, 25 SMTP, 80 HTTP, …
- 1024 to 49151: registered ports w/o superuser privileges
- 49152 to 65535: typically assigned sequentially thru connect()
- Pick a port number larger than 1024 and wish for no collision!

Server

- Your server must be able to handle a simple GET/POST HTTP requests.
- Write a program `server` such that
  - Returns corresponding payload to the given URL when a valid GET request arrives.
  - Stores the given payload to the file when a valid POST request arrives.
  - Handles error when an invalid request arrives
    - 400(Bad Request): A HTTP Request is not well-formatted
    - 404(Not found): There's nothing to serve for the given URL
- Your server must be executable with this command.
  - ./server –p [port_number]

Server

- Examples:
  - GET /xxx HTTP/1.0
    Host: [server_ip]:[server_port]
    - 404 Not Found
  - POST /xxx HTTP/1.0
    Host: [server_ip]:[server_port]

    wow
    - 200 OK
    - Stores file “xxx”, with content “wow”
  - GET /xxx HTTP/1.0
    Host: [server_ip]:[server_port]
    - 200 OK “wow”

Evaluation

- Server:
  - When a client requests the HTML file, the server must send the correctly formatted response.
  - When a client requests anything else, the server must send one of the remaining two response status codes: 400 or 404.
  - The server must use select() and be able to serve more than one client at any time.
  - We will use both a valid client and an invalid client when we test your server program.
- Client:
  - Your client will be tested with our valid server.
  - Note that only valid request will be accepted to our server.

Submission

- Submit a zip file that contains
  - Your code
  - A Makefile file that builds your code
  - readme.txt
- The name of the zip file must follow the format below.
  - [student_id]_[student_name]_PJ1.zip
  - e.g.) 20169997_SeokjuHong_PJ1.zip
- Submit the zip file to the link below.
  - https://www.dropbox.com/request/IDBoS3u4JBawck13Lsnz

Common Requirements for the Assignments

- Only in C programming language & Linux environment
- Use C standard libraries & Linux system calls only
  - No other 3rd party libraries!
- Implementation with blocking I/O will be given half credit.
  - To get full credit, implement non-blocking I/O with select().
- Data over the network must follow the network byte ordering (= Big-endian)
  - Refer to the functions such as htons(), htonl(), ntohs(), ntohl()
- **Provide a Makefile (make all) and follow the argument format** (Automated scripts will grade your program)

Recommended Links

- MDN Web docs
  - Before you begin the project, read the request and response format carefully.
  - Don't forget to include headers.
  - Content-Length header
    - https://developer.mozilla.org/en-US/docs/Web/HTTP/Headers/Content-Length
  - Host header
    - https://developer.mozilla.org/en-US/docs/Web/HTTP/Headers/Host

Recommended Links

- These links contain useful info and example codes
  - Beej's Guide to Network Programming
    - http://beej.us/guide/bgnet/html/single/bgnet.html
  - Implementation of simple server with select()
    - https://en.wikipedia.org/wiki/Select_(Unix)
- VirtualBox
  - We recommend you to use VirtualBox to establish a virtualized Linux environment on Windows
  - https://www.virtualbox.org/

Supplement slides for socket APIs

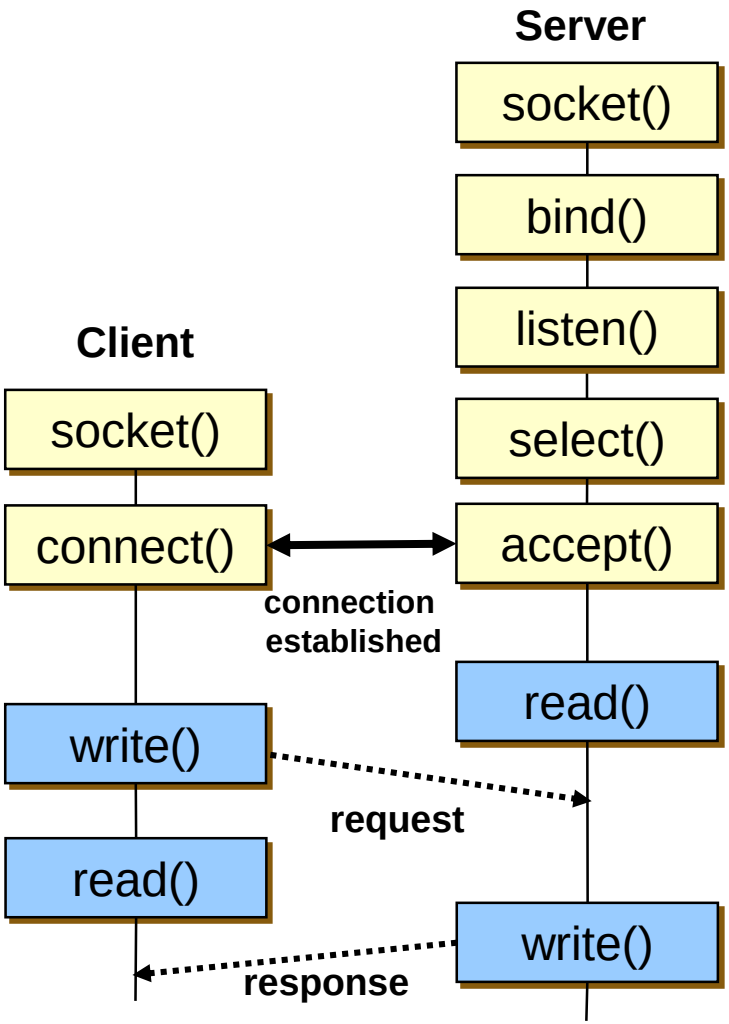
Socket

- An interface between application and network
- Unique identification to or from which information is transmitted in the network

- Clients and servers communicate with each other by reading from and writing to socket

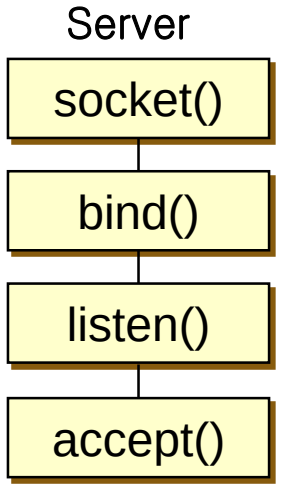
- In UNIX-like systems, a socket descriptor is just another file descriptor

How socket API calls proceed



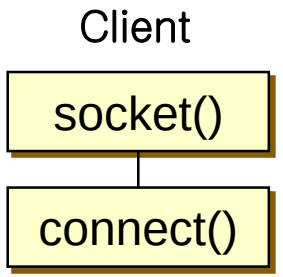
Server-side Basic Socket API

- socket()
  - Creates a new socket and returns its socket descriptor
- bind()
  - Associates a socket with a local port number and IP address
- listen()
  - Prepares a socket for incoming connections
- accept()
  - Accepts a received incoming attempt from client
  - Creates a new socket associated with a new TCP connection



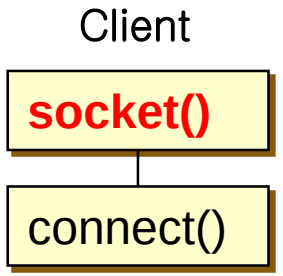
Client-side Basic Socket API

- socket()
  - Creates a new socket and returns its socket descriptor
- connect()
  - Binds a destination to a socket or set a connection



Socket API: socket()

- int socket (int family,
  int type,
  int protocol)
  - socket() creates a socket descriptor.
  - family specifies the protocol family.
    - AF_UNIX: Local Unix domain protocols
    - AF_INET: IPv4 Internet protocols
  - type specifies the communication semantics.
    - SOCK_STREAM: provides sequenced, reliable, two-way, connection-based byte streams
    - SOCK_DGRAM: supports datagrams (connectionless, unreliable messages of a fixed maximum length)
    - SOCK_RAW: provides raw network protocol access
  - protocol specifies a particular protocol to be used with the socket.

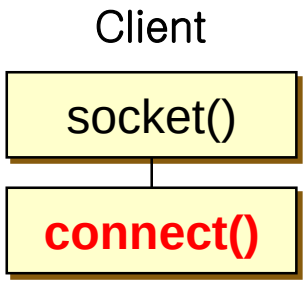


Socket API: connect()

- int connect (int sockfd,

  const struct sockaddr *servaddr,

  socklen_t addrlen)
  - TCP client uses to establish a connection with a TCP server.
  - servaddr contains *{IP address, port number}* of the server.
  - The client does not have to call bind() before calling connect().
    - The kernel will choose both an ephemeral port and the source IP address if necessary.
  - Client process suspends (blocks) until the connection is created.

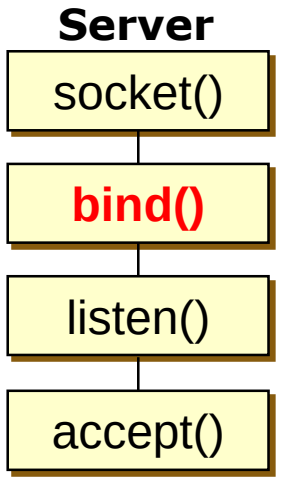


Socket API: bind()

- int bind (int sockfd,

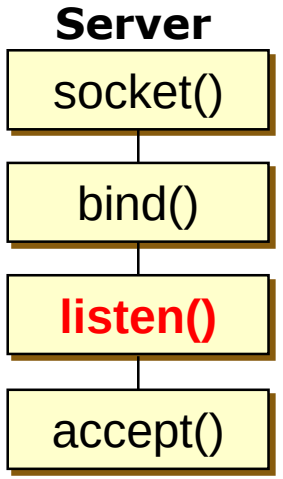
  struct sockaddr *myaddr,

  socklen_t addrlen)
  - bind() gives the socket sockfd the local address myaddr.
  - myaddr is addrlen bytes long.
  - Servers bind their well-known port when they start.
  - If a TCP server binds a specific IP address to its socket, this restricts the socket to receive incoming client connections destined only to that IP address.
  - Normally, a TCP client let the kernel choose an ephemeral port and a client IP address.

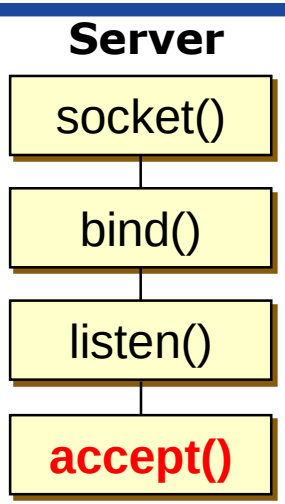


Socket API: listen()

- int listen (int sockfd,
  int backlog)
  - listen() converts an unconnected socket into a *passive socket*, indicating that the kernel should accept incoming connection requests.
    - When a socket is created, it is assumed to be an *active socket*, that is, a client socket that will issue a connect().
  - backlog specifies the maximum number of connections that the kernel should queue for this socket.
  - Historically, a backlog of 5 was used, as that was the maximum value supported by 4.2BSD.
    - Busy HTTP servers must specify a much larger backlog, and newer kernels must support larger values.

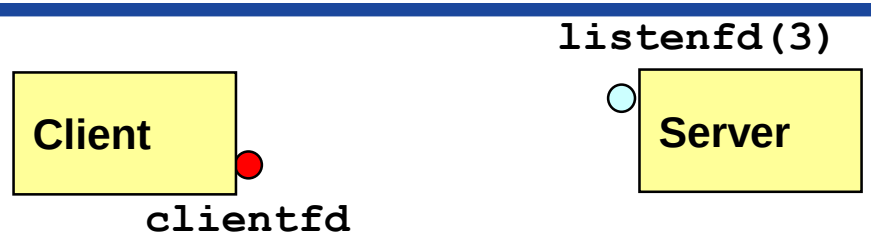


Socket API: accept()

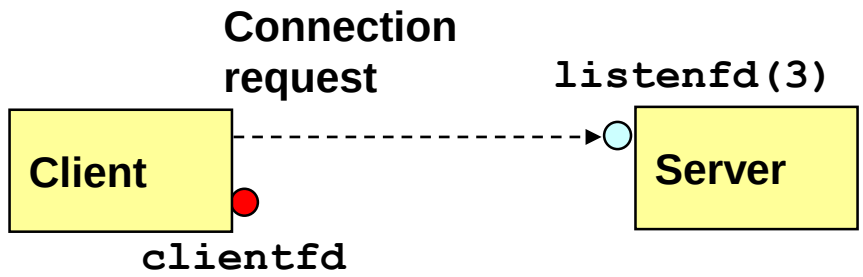


- int accept (int sockfd,
  struct sockaddr *cliaddr,
  socklen_t *addrlen)
  - accept() blocks waiting for a connection request.
  - accept() returns a connected descriptor with the same properties as the listening descriptor.
    - The kernel creates one connected socket for each client connection that is accepted.
    - Returns when the connection between client and server is created and ready for I/O transfers.
    - All I/O with the client will be done via the connected socket.
  - The cliaddr and addrlen arguments are used to return the address of the connected peer process (the client)

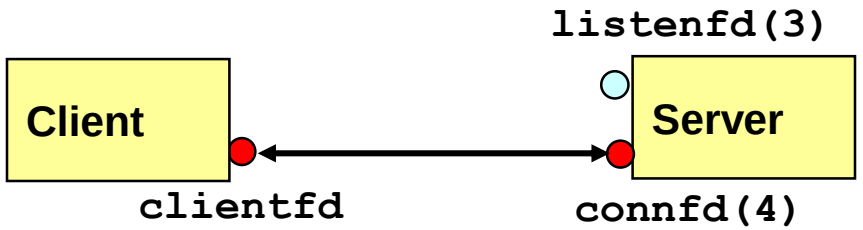
Socket API: accept()



1. Server blocks in `accept`, waiting for connection request on listening descriptor `listenfd`.



2. Client makes connection request by calling and blocking in `connect`.



3. Server returns `connfd` from `accept`. Client returns from `connect`. Connection is now established between `clientfd` and `connfd`.

Socket API: accept()

- Listening descriptor
  - End point for client connection requests
  - Created once and exists for lifetime of the server
- Connected descriptor
  - End point of the connection between client and server
  - A new descriptor is created each time the server accepts a connection request from a client.
  - Exists only as long as it takes to provide services for client.
- Why the distinction?
  - Allows for concurrent servers that can communicate over many client connections simultaneously.