Network Programming Basics

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Socket programming *with TCP*

client must contact server

- server process must first be running
- server must have created socket (door) that welcomes client's contact

client contacts server by:

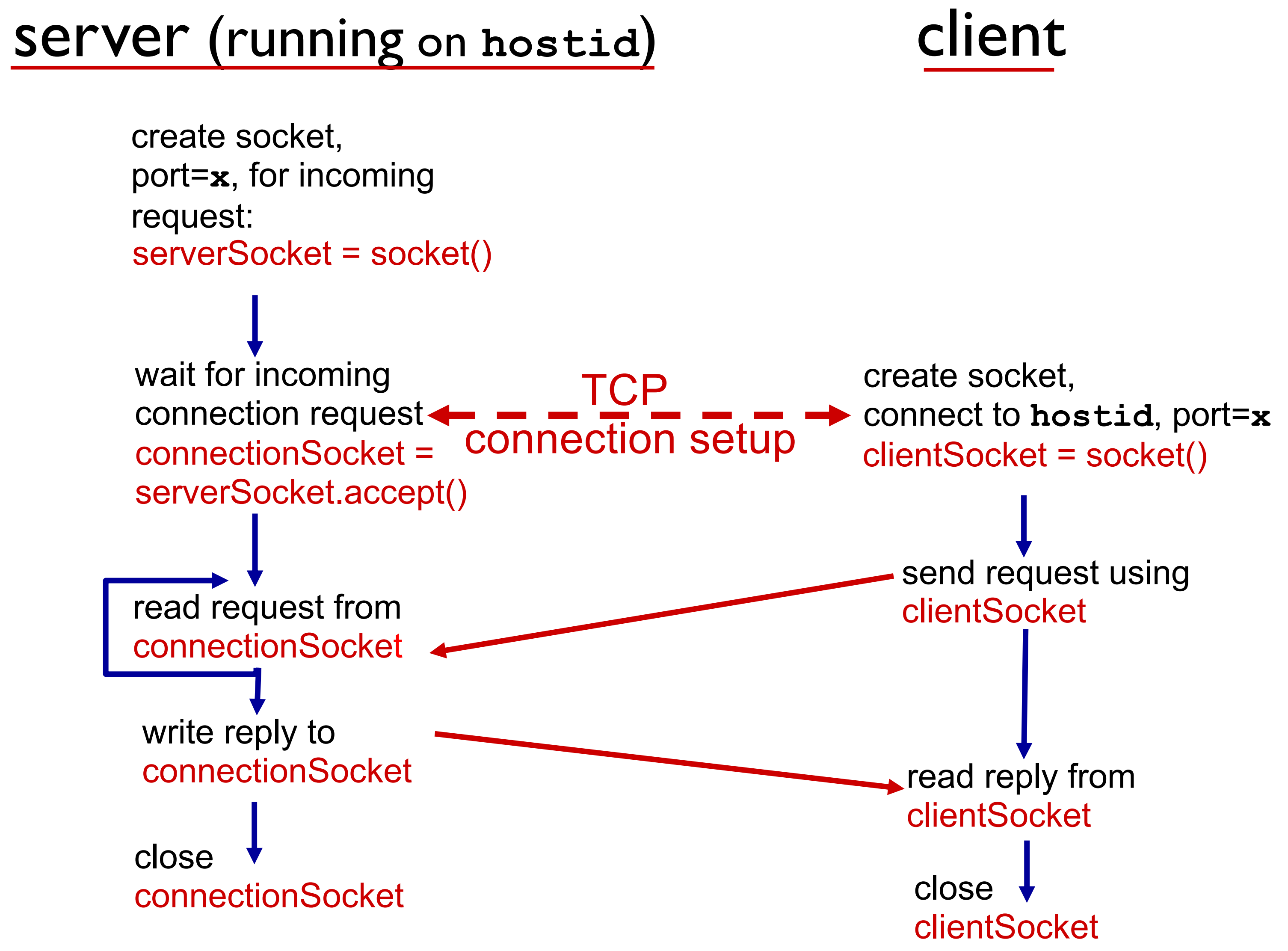
- Creating TCP socket, specifying IP address, port number of server process
- *when client creates socket:* client TCP establishes connection to server TCP

- when contacted by client, *server TCP creates new socket* for server process to communicate with that particular client
  - allows server to talk with multiple clients
  - source port numbers used to distinguish clients (more in Chap 3)

application viewpoint:

TCP provides reliable, in-order byte-stream transfer ("pipe") between client and server

Client/server socket interaction: TCP


server (running on hostid)
client
create socket, port=x, for incoming request:
serverSocket = socket()
wait for incoming connection request
connectionSocket = serverSocket.accept()
TCP connection setup
create socket, connect to hostid, port=x
clientSocket = socket()
send request using clientSocket
read request from connectionSocket
write reply to connectionSocket
read reply from clientSocket
close connectionSocket
close clientSocket

Echo Client with only one action

1.	Program starts with Server IP Address, Message and Server Port	main()
2.	Create socket	socket()
3.	Set server parameters to socket	
4.	Connect to server	connect()
5.	Send message	send()
6.	Receive message	recv()
7.	Show message echoed by server	printf()
8.	Destroy socket and die	close()

Let’s get started.

socket() System Call (1/2)

- Cerates socket
- int socket(int family, int type, int proto)
  - Protocol Familiy

AF_LOCAL / PF_LOCAL	Host-internal protocols
AF_INET / PF_INET	Internet version 4 protocols
AF_ROUTE / PF_ROUTE	Internal Routing protocol
AF_INET6 / PF_INET6	Internet version 6 protocols
etc	

  - Socket Type
    - SOCK_STREAM
    - SOCK_DGRAM
    - SOCK_RAW
  - Protocol
    - Normally “0” except the case of RAW

socket() System Call (2/2)

- Return value
  - Success: socket descriptor
  - Failure: -1

- Example

```
int sd;
sd = socket(AF_INET, SOCK_STREAM, 0);
if (sd < 0) {
     something bad happened…
}
```

struct sockaddr_in

- Specification of a local or remote endpoint

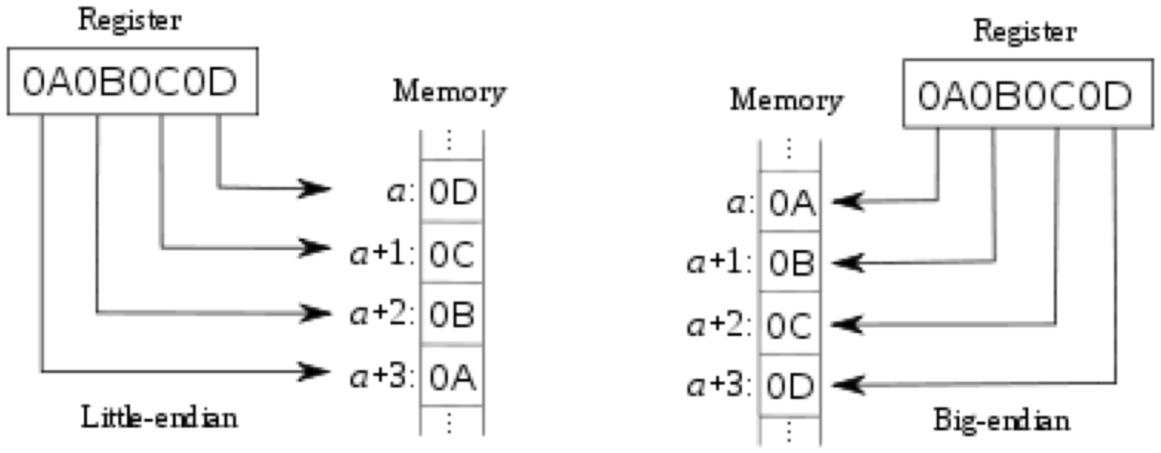
```
#include <sys/socket.h>
#include <netinet/in.h>
#include <netinet/ip.h> /* superset of previous */

struct sockaddr_in {
        sa_family_t         sin_family;    /* address family: AF_INET */
        in_port_t           sin_port;      /* port in network byte order */
        struct in_addr      sin_addr;      /* internet address */
};

/* Internet address. */
struct in_addr {
        uint32_t            s_addr;        /* address in network byte order */
};
```

inet_pton() Function

- Returns IP address in text format to that in binary format
  - Endianness
  - Network byte order (Big-endian)



connect() System Call

- Initiate TCP connection on a socket

- Set the server address

```
struct sockaddr_in servAddr;
memset(&servAddr, 0, sizeof(servAddr));
servAddr.sin_family = AF_INET;
int err = inet_pton(AF_INET, servIP, &servAddr.sin_addr.s_addr);
if (err <= 0) {
        perror("inet_pton() failed");
        exit(-1);
}
servAddr.sin_port = htons(servPort);
```

- Connect to server

```
if (connect(sockfd, (struct sockaddr *) &servAddr, sizeof(servAddr)) < 0) {
        perror("connect() failed");
        exit(-1);
}
```

Echo Server

1. Program starts with Server Port	main()
2. Create socket	socket()
3. Set server parameters to socket	bind()
4. Wait for client	listen()
5. Establish TCP connection	accept()
6. Receive message	recv()
7. Send back message (ECHO)	send()
8. Repeat 5 to 7	

bind() System Call

- Called on the server
- Bind a socket with a specific endpoint (me!!)

- int bind(int sockfd,struct sockaddr *addr,int addrlen);
- Example

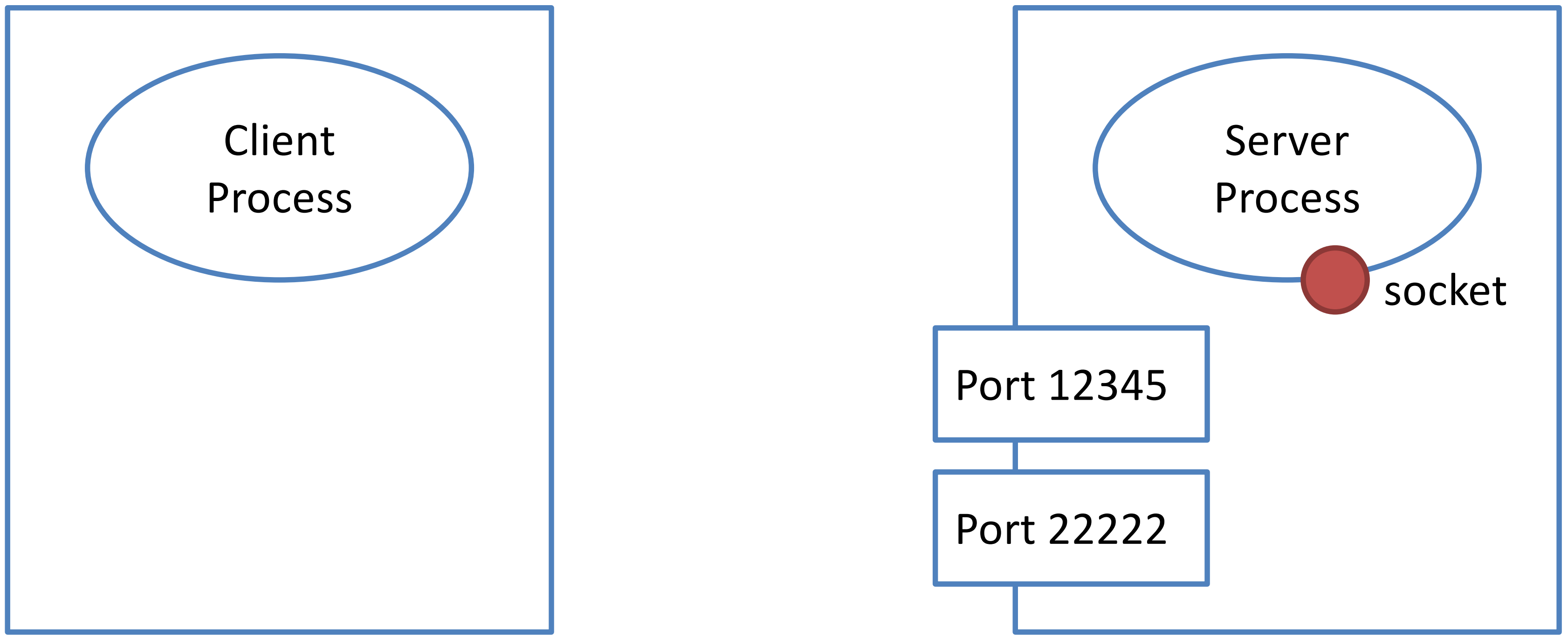
```
struct sockaddr_in server;

memset((void *)&server, 0, sizeof(server));
server.sin_family = AF_INET;
server.sin_port = htons(12345);
server.sin_addr.s_addr = INADDR_ANY;

bind(sd,(struct sockaddr *)&server, sizeof(server));
```

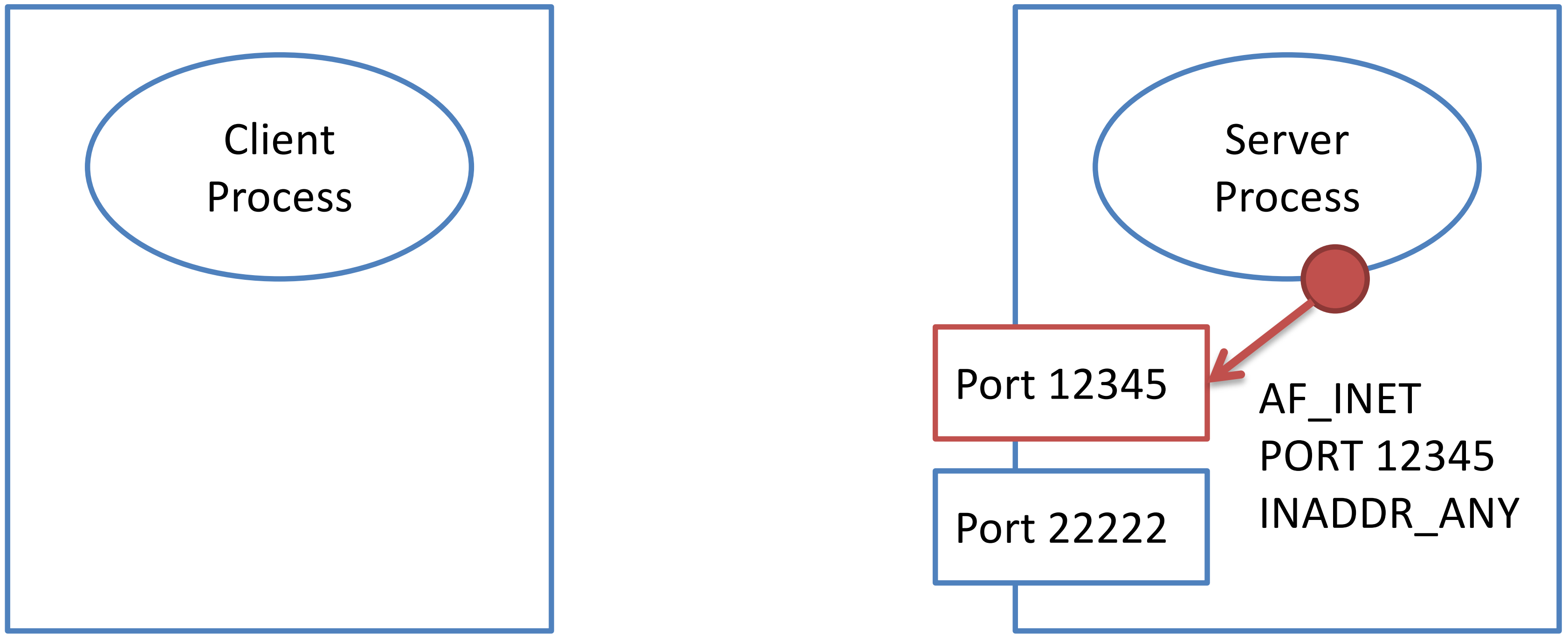
Creating Socket and Binding on Sever

- socket() is called



Creating Socket and Binding on Sever

- Bind to listening port on server



```
[sfc-cpu:7:29] netstat -an
Active Internet connections (including servers)
Proto      Recv-Q   Send-Q   Local Address  Foreign Address     (state)
udp4       0      0       *.12345          *.*
```

listen() System Call

- int
  listen(int socket, int backlog);

- Listen on a socket and wait for a connection

accept() System Call

- int
  accept(int socket, struct sockaddr *restrict address, socklen_t *restrict address_len);

- Accept a connection on a socket
- “address” contains the address of connecting host (i.e. client)

send() and recv() System Call

- ssize_t
  send(int socket, const void *buffer, size_t length, int flags);

- ssize_t
  recv(int socket, void *buffer, size_t length, int flags);

- send() and recv() do not have an argument to store address information because they will be called after establishing connection (from and to are both known)

Echo Client with Loop Action with BYE

- Extend the simple echo client

- You can repeat to type message
- You can stop your client by command “BYE”

- Program starts with Server IP Address and Server Port

Echo Server with Multiple Clients

- Server serves for multiple clients
- Non blocking
  - Do not wait for the interrupt from a specific input
  - Use select()

DNS?

GetAddrInfo.c

addrinfo

- Used to store the result of DNS lookup from resolver

```
struct addrinfo {
      int                    ai_flags;
      int                    ai_family;
      int                    ai_socktype;
      int                    ai_protocol;
      size_t                 ai_addrlen;
      struct sockaddr        *ai_addr;
      char                   *ai_canonname;
      struct addrinfo        *ai_next;
};
```

getaddrinfo() (1/2)

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netdb.h>

struct addrinfo hints;                      // Give initial hints to resolver
struct addrinfo *result, *rp;               // Result will be stored here

// Prepare the hints for resolver
memset(&hints, 0, sizeof(struct addrinfo));
hints.ai_family = AF_UNSPEC;                // IPv4 or v6 (You can specify either)
hints.ai_socktype = SOCK_STREAM;            // Hardcoded TCP as dummy
hints.ai_protocol = IPPROTO_TCP;            // Hardcoded TCP as dummy
hints.ai_flags = AI_CANONNAME;              // I want canonical name!!
```

getaddrinfo() (2/2)

```
int s = getaddrinfo(hostName, NULL, &hints, &result);

for (rp = result; rp != NULL; rp = rp->ai_next) {
    SHOW CORRESPONDING IPv4/v6 ADDRESS;
    or
    ATTEMPT connect() to IPv4/v6 ADDRESS;
}
```

- getaddrinfo() takes hostname/address and/or port number as the 1st and 2nd arguments.

Knowing the address family from rp

```
struct sockaddr_in *saIn4;
struct sockaddr_in6 *saIn6;
char addrString[INET6_ADDRSTRLEN];
memset(addrString, 0, sizeof(addrString));

switch (rp->ai_family) {
case AF_INET:
        saIn4 = (struct sockaddr_in *) rp->ai_addr;
        inet_ntop(rp->ai_family, &saIn4->sin_addr.s_addr, addrString, sizeof(addrString));
        break;

case AF_INET6:
        saIn6 = (struct sockaddr_in6 *) rp->ai_addr;
        inet_ntop(rp->ai_family, &saIn6->sin6_addr.s6_addr, addrString, sizeof(addrString));
        break;

…
```

Assignment

Compulsory Assignment: Extending echo client/server functions

Q-1. Integrate getaddrinfo() as part of your client software so that the hostname of the server can be given as the command line option. This feature must be demonstrated by showing 1) the screenshot of successful execution of your client software with hostname, and 2) the screenshot of wireshark/tcpdump to prove that your client software sends a DNS query and receives a response.

Q-2. Add at least two features to Echo Client /Server, and demonstrate them. In the report, you must describe the new features with their benefit. Significance of the features will impact the marks given.

Example Marks

1	Adding or recording a timestamp of a message exchange
5	Supporting IPv6 (with proper network configuration)
10	Supporting IPv6 and multicast (with extra clients)
10	Supporting SSL (with proper certificate configuration)

Implementation Guidance

- Individual Assignment
- You may choose any programing language (C, JAVA, Python, Perl and etc.)
- The software must be based on Socket Programming.
- Wrappers of API must not be used (messaging etc). Use send/recv or read/write using TCP socket.
- Keep the record of **Reference. Which web site, documents, or textbook did you refer?**

Submission Guidance

- Deadlines
  - Demo to TAs: December 12th and 13th
  - Submission of Report to Google Classroom: December 14th
- Requirement of Report
  - The core idea of your answer to each question. Better visibility like screenshot of application will be appreciated.
  - **Reference (web sites, books, etc.) which corresponds to each answer.** That's why, the reference is important. **Answers without appropriate reference may not get mark.**
  - Human readable source code as separate files
  - README as a separate file so that TAs and instructor can compile source code and execute the binary anytime
  - Submit all files as one tar ball or zip ball.

Project: Networked Software

- Developing an application (routing protocol / server-client / P2P / Blockchain, etc.)

- Where did that idea come from?
  - Papers, blogs, your own finding as inspirations?
  - Does anybody else attempt to develop a similar application?

- Group Project
  - 4 to 8 members per group
  - Big or small or a group is not considered as evaluation criteria.
  - Individual contribution is not considered. Same marks will be offered to all members in the group.

- You MUST NOT re-use a project which has been or is going to be conducted as part of any other course.

Leftover Contents

IPv6 Address

```
#include <sys/socket.h>
#include <netinet/in.h>

struct sockaddr_in6 {
      sa_family_t        sin6_family;      /* AF_INET6 */
      in_port_t          sin6_port;        /* port number */
      uint32_t           sin6_flowinfo;    /* IPv6 flow information */
      struct in6_addr    sin6_addr;        /* IPv6 address */
      uint32_t           sin6_scope_id;    /* Scope ID (new in 2.4) */
};

struct in6_addr {
      unsigned char      s6_addr[16];      /* IPv6 address */
};
```

Compulsory Assignment #2: Making echo client/server “protocol independent”

Q-3. Revise echo client and server to be protocol independent (support both IPv4 and IPv6).

- Hint 1: sockaddr is too small for sockaddr_in6. sockaddr_storage has enough size to support both sockaddr_in and sockaddr_in6. (You will see this in server side program.)
- Hint 2: integrate getaddrinfo to avoid typing IPv6 address on your CLI
- Hint 3: you may use hostname (IPv4: “localhost”, IPv6: “ip6-localhost” address to develop / demonstrate the software on Ubuntu. They’re written in “/etc/hosts”.