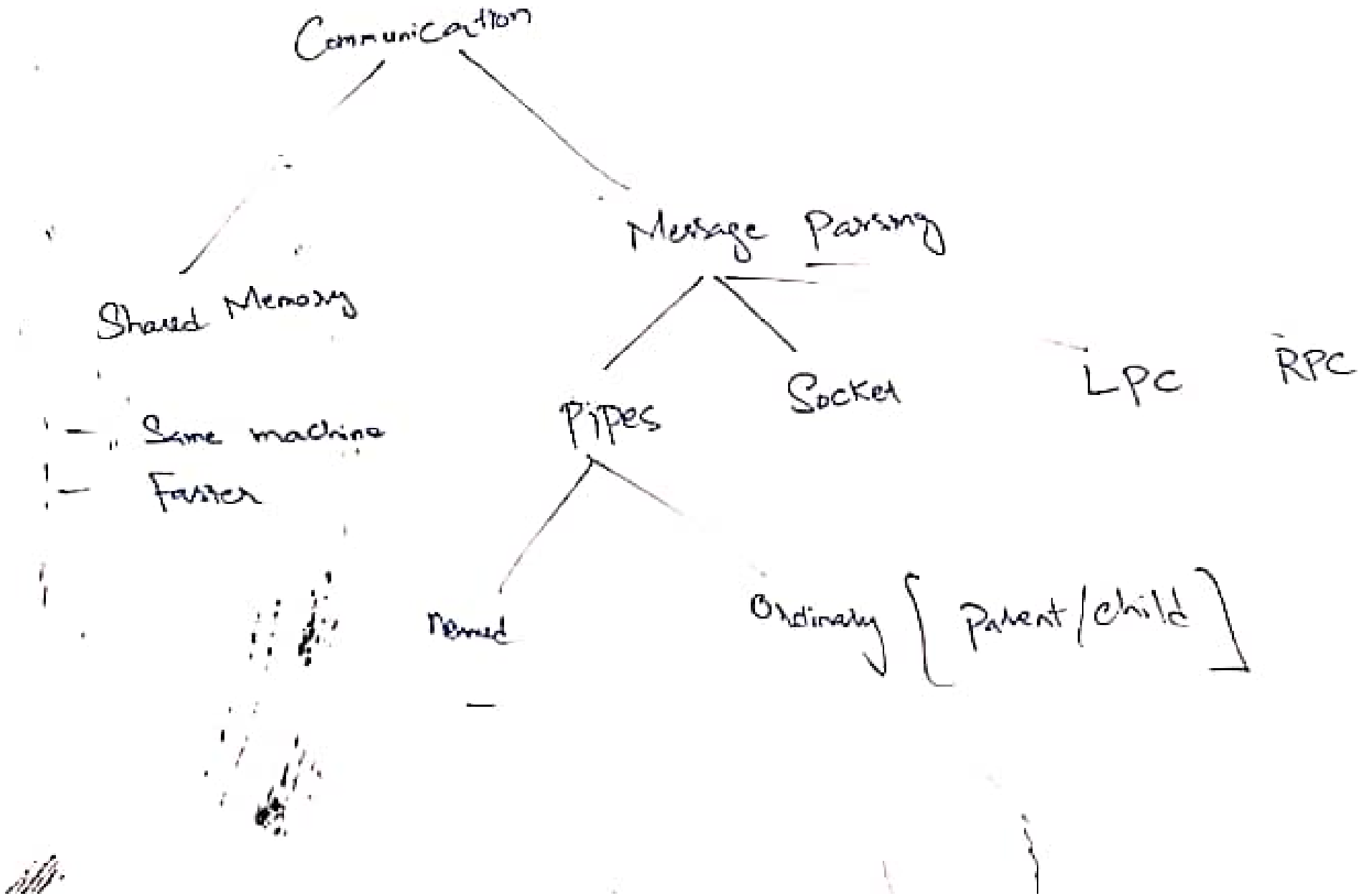

Communication
Shared Memory
Same machine
Faster
Message Passing
Pipes
Named
Ordinary { Parent/child }
Socket
LPC
RPC

Examples of IPC Systems - POSIX

- POSIX Shared Memory
  - Process first creates shared memory segment

```
shm_fd = shm_open(name, O_CREAT | O_RDWR, 0666);
```

  - Also used to open an existing segment to share it
  - Set the size of the object

```
ftruncate(shm_fd, 4096);
```

  - Now the process could write to the shared memory

```
sprintf(shared memory, "Writing to shared memory");
```

IPC POSIX Producer

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <sys/shm.h>
#include <sys/stat.h>

int main()
{
/* the size (in bytes) of shared memory object */
const int SIZE = 4096;
/* name of the shared memory object */
const char *name = "OS";
/* strings written to shared memory */
const char *message_0 = "Hello";
const char *message_1 = "World!";

/* shared memory file descriptor */
int shm_fd;
/* pointer to shared memory obect */
void *ptr;

    /* create the shared memory object */
    shm_fd = shm_open(name, O_CREAT | O_RDWR, 0666);

    /* configure the size of the shared memory object */
    ftruncate(shm_fd, SIZE);

    /* memory map the shared memory object */
    ptr = mmap(0, SIZE, PROT_WRITE, MAP_SHARED, shm_fd, 0);

    /* write to the shared memory object */
    sprintf(ptr,"%s",message_0);
    ptr += strlen(message_0);
    sprintf(ptr,"%s",message_1);
    ptr += strlen(message_1);

    return 0;
}
```

Comm

IPC POSIX Consumer

```
#include <stdio.h>
#include <stdlib.h>
#include <fcntl.h>
#include <sys/shm.h>
#include <sys/stat.h>

int main()
{
/* the size (in bytes) of shared memory object */
const int SIZE = 4096;
/* name of the shared memory object */
const char *name = "OS";
/* shared memory file descriptor */
int shm_fd;
/* pointer to shared memory obect */
void *ptr;

   /* open the shared memory object */
   shm_fd = shm_open(name, O_RDONLY, 0666);

   /* memory map the shared memory object */
   ptr = mmap(0, SIZE, PROT_READ, MAP_SHARED, shm_fd, 0);

   /* read from the shared memory object */
   [illegible]

   /* remove the shared memory object */
   shm_unlink(name);

   return 0;
}
```

Communications in Client-Server Systems

- Sockets
- Remote Procedure Calls
- Pipes
- Remote Method Invocation (Java)

Pipes

- Acts as a conduit allowing two processes to communicate
- Issues:
  - Is communication unidirectional or bidirectional?
  - In the case of two-way communication, is it half or full-duplex?
  - Must there exist a relationship (i.e., *parent-child*) between the communicating processes?
  - Can the pipes be used over a network?
- Ordinary pipes – cannot be accessed from outside the process that created it. Typically, a parent process creates a pipe and uses it to communicate with a child process that it created.
- Named pipes – can be accessed without a parent-child relationship.

Ordinary Pipes

- Ordinary Pipes allow communication in standard producer-consumer style
- Producer writes to one end (the **write-end** of the pipe)
- Consumer reads from the other end (the **read-end** of the pipe)
- Ordinary pipes are therefore unidirectional
- Require parent-child relationship between communicating processes

- Windows calls these anonymous pipes
- See Unix and Windows code samples in textbook

```c
#include <unistd.h>
#include <stdio.h>
#include <string.h>

int main()
{
    int fd[2];
    char buffer[100];
    pid_t pid;

    if (pipe(fd) == -1) {
        perror("pipe");
        return 1;
    }

    pid = fork();
    if (pid == -1) {
        perror("fork");
        return 1;
    }
    if (pid == 0) {
        // Child process
        close(fd[0]);
        strcpy(buffer, "Hello from the child process");
        write(fd[1], buffer, strlen(buffer));
    } else {
        // Parent process
        close(fd[1]);
        read(fd[0], buffer, sizeof(buffer));
        printf("Received message: %s\n", buffer);
    }

    return 0;
}
```

Named Pipes

- Named Pipes are more powerful than ordinary pipes
- Communication is bidirectional
- No parent-child relationship is necessary between the communicating processes
- Several processes can use the named pipe for communication
- Provided on both UNIX and Windows systems

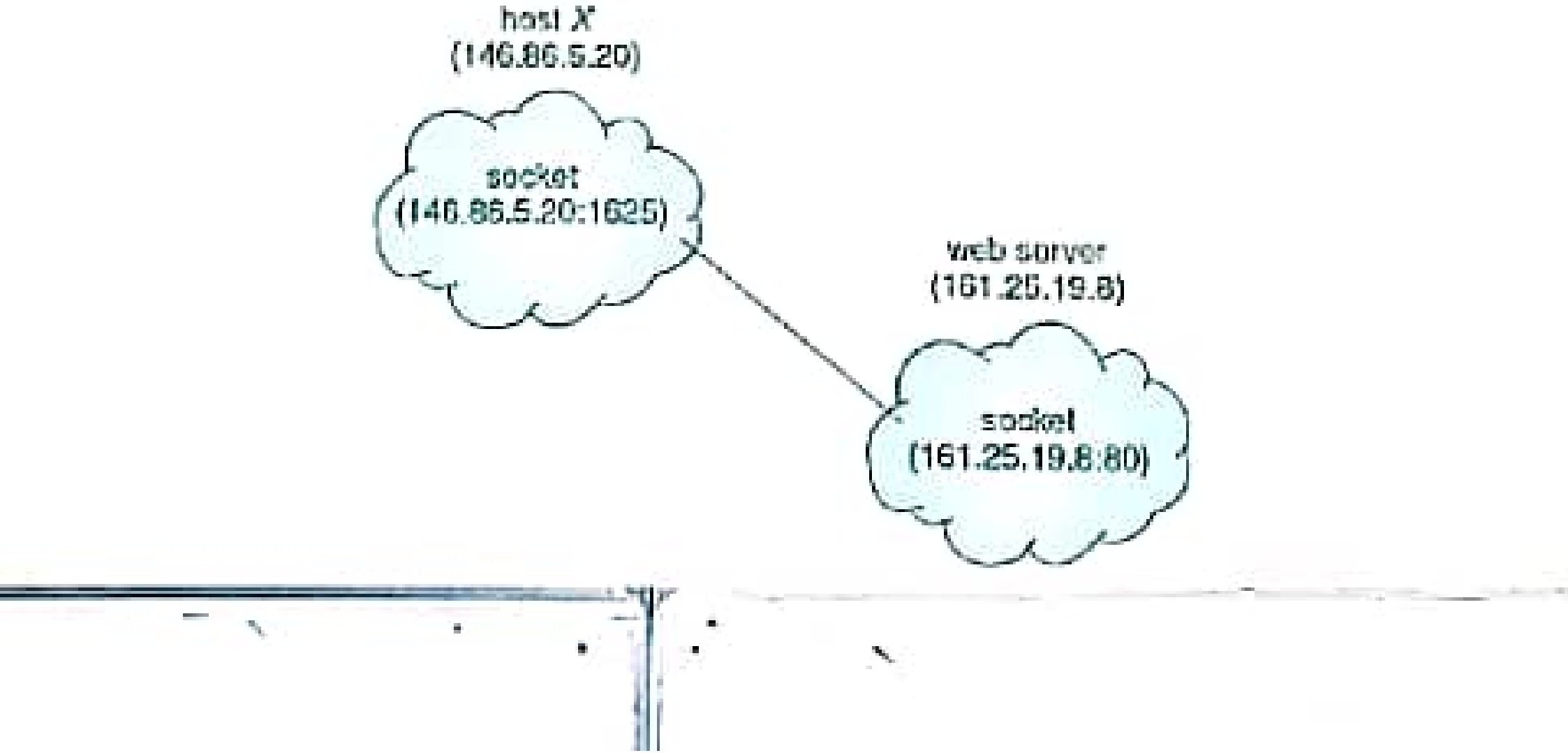
```
int main()
{
    int pipe_fd;
    char buf[100];

    /* Create the named pipe */
    if (mkfifo(FIFO_NAME, 0666) == -1) {
        perror("mkfifo");
        exit(EXIT_FAILURE);
    }
```

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <unistd.h>
#define FIFO_NAME "my_fifo"
int main()
{
    int pipe_fd;
    char buf[100];

    /* Create the named pipe */
    if (mkfifo(FIFO_NAME, 0666) == -1) {
        perror("mkfifo");
        exit(EXIT_FAILURE);
    }

    /* Open the named pipe */
    pipe_fd = open(FIFO_NAME, O_RDONLY);
    if (pipe_fd == -1) {
        perror("open");
        exit(EXIT_FAILURE);
    }

    /* Read data from the pipe */
    read(pipe_fd, buf, 100);
    printf("Received message: %s\n", buf);

    /* Close the pipe */
    close(pipe_fd);

    return 0;
```

Sockets

- A **socket** is defined as an endpoint for communication
- Concatenation of IP address and **port** – a number included at start of message packet to differentiate network services on a host
- The socket **161.25.19.8:1625** refers to port **1625** on host **161.25.19.8**
- Communication consists between a pair of sockets
- All ports below 1024 are ***well known***, used for standard services
- Special IP address 127.0.0.1 (**loopback**) to refer to system on which process is running

Socket Communication



Sockets in Java

Three types of sockets

- **Connection-oriented (TCP)**
- **Connectionless (UDP)**
- `MulticastSocket` class– data can be sent to multiple recipients

Consider this "Date" server:

```
import java.net.*;
import java.io.*;

public class DateServer
{
   public static void main(String[] args) {
      try {
         ServerSocket sock = new ServerSocket(6013);

         /* now listen for connections */
         while (true) {
            Socket client = sock.accept();

            PrintWriter pout = new
             PrintWriter(client.getOutputStream(), true);

            /* write the Date to the socket */
            pout.println(new java.util.Date().toString());

            /* close the socket and resume */
            /* listening for connections */
            client.close();
         }
      }
      catch (IOException ioe) {
         System.err.println(ioe);
      }
   }
}
```

Remote Procedure Calls

- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems
  - Again uses ports for service differentiation
- **Stubs** – client-side proxy for the actual procedure on the server
- The client-side stub locates the server and **marshalls** the parameters
- The server-side stub receives this message, unpacks the marshalled parameters, and performs the procedure on the server
- On Windows, stub code compile from specification written in **Microsoft Interface Definition Language** (**MIDL**)

Remote Procedure Calls (Cont.)

- Data representation handled via **External Data Representation** (**XDL**) format to account for different architectures
  - **Big-endian** and **little-endian**
- Remote communication has more failure scenarios than local
  - Messages can be delivered ***exactly once*** rather than ***at most once***
- OS typically provides a rendezvous (or **matchmaker**) service to connect client and server

Execution of RPC