Network Programming

Preliminaries

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Advanced Computing & Microelectronics Unit
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October 9, 2023

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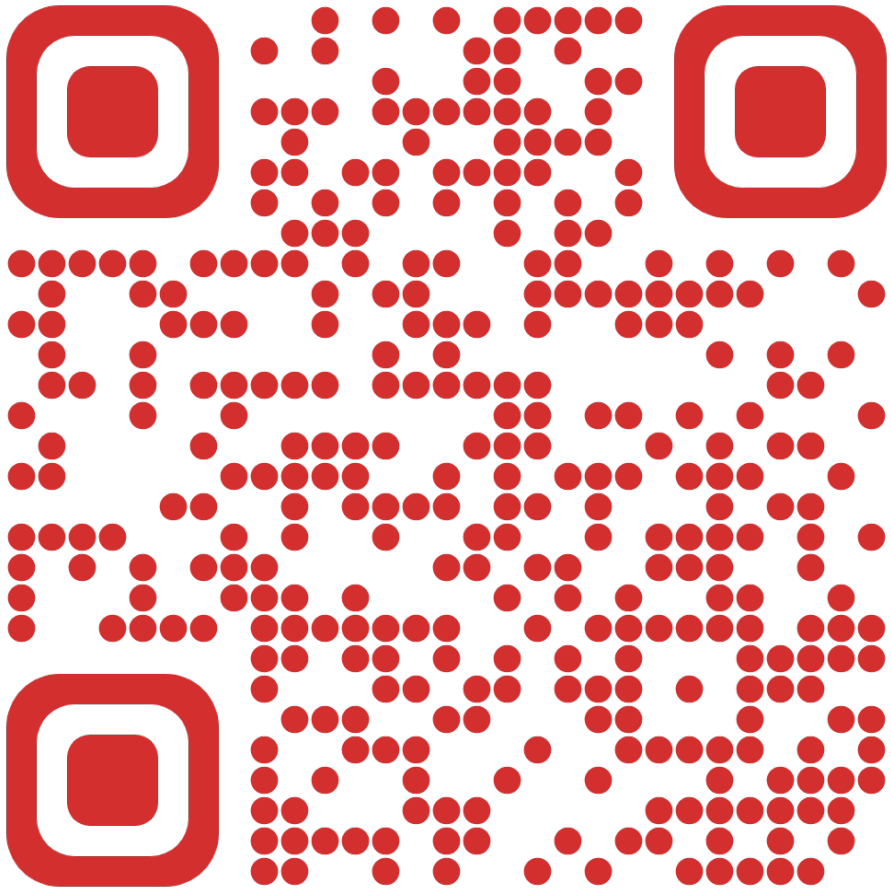

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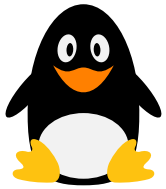
Communication via Protocol Stack



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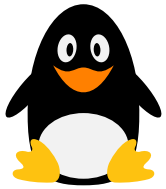

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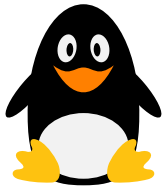

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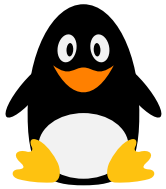

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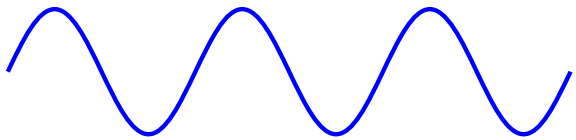

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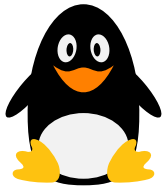

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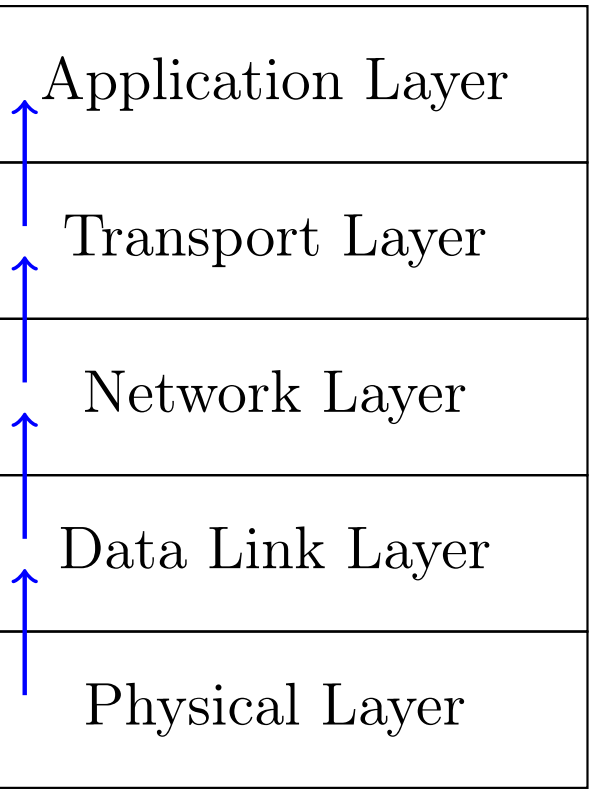

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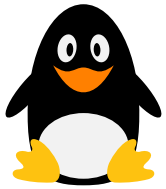

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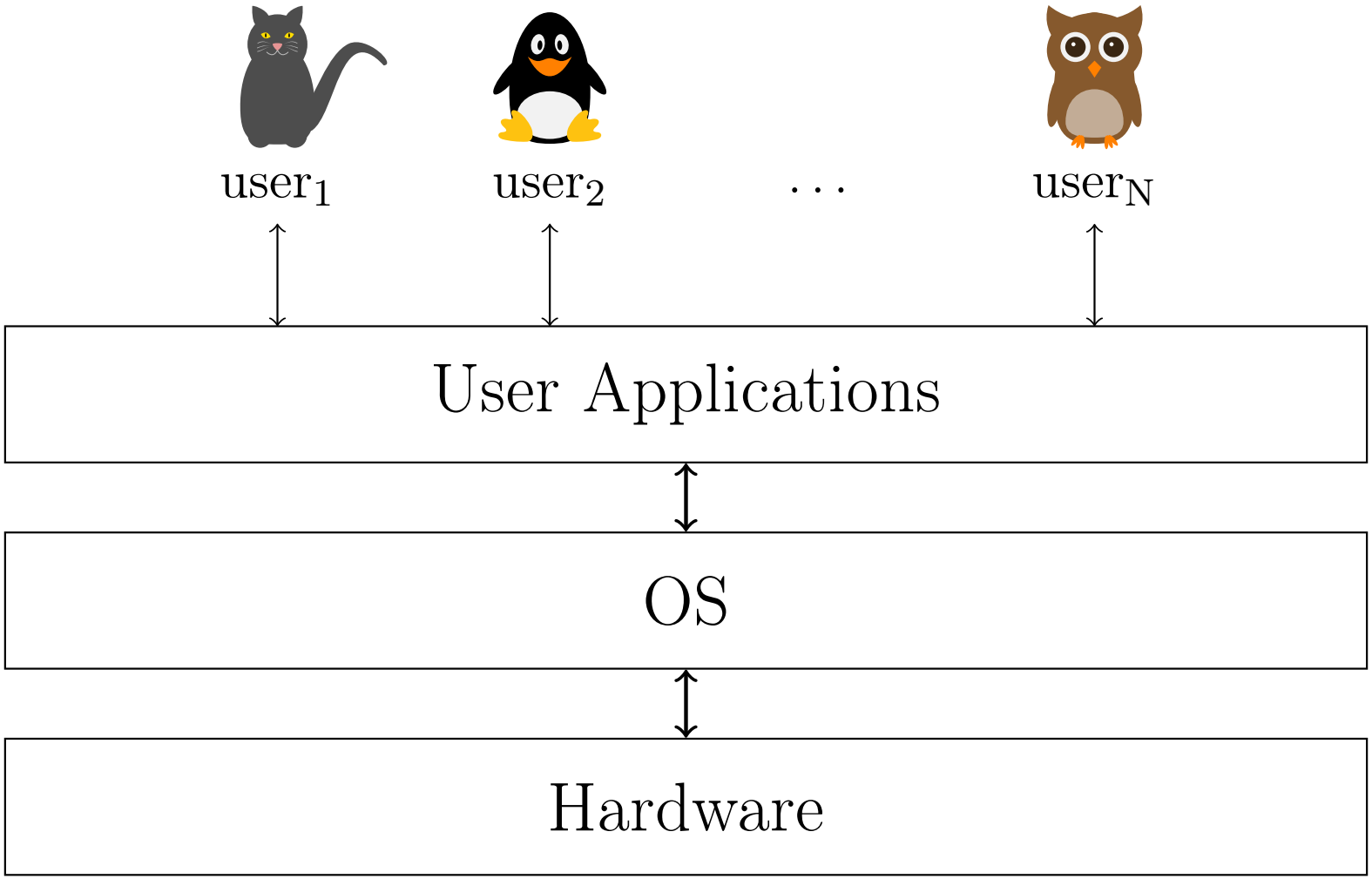
Role of Operating System

The Operating System (OS) acts as an interface between the user application software and the underlying hardware



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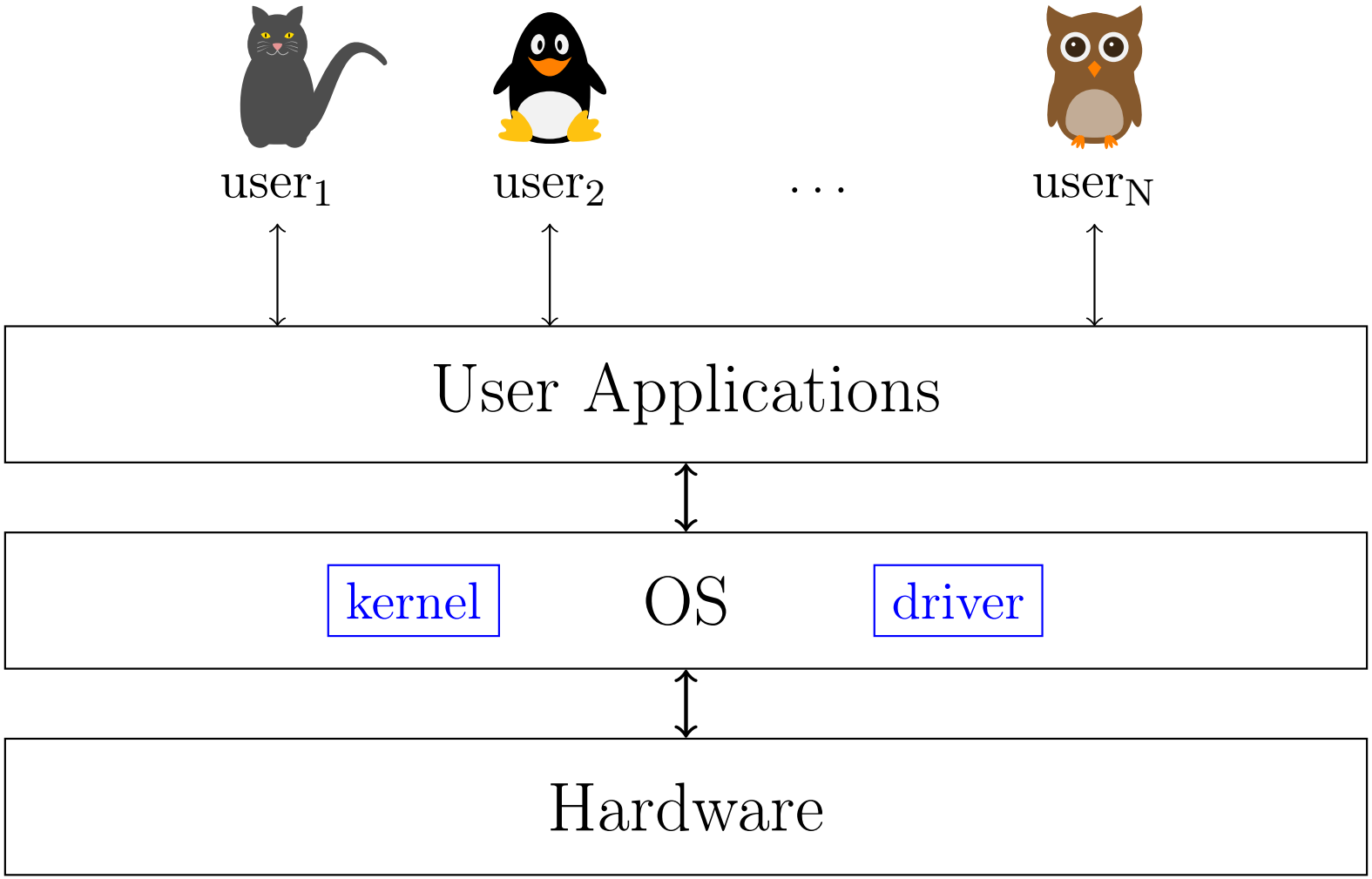

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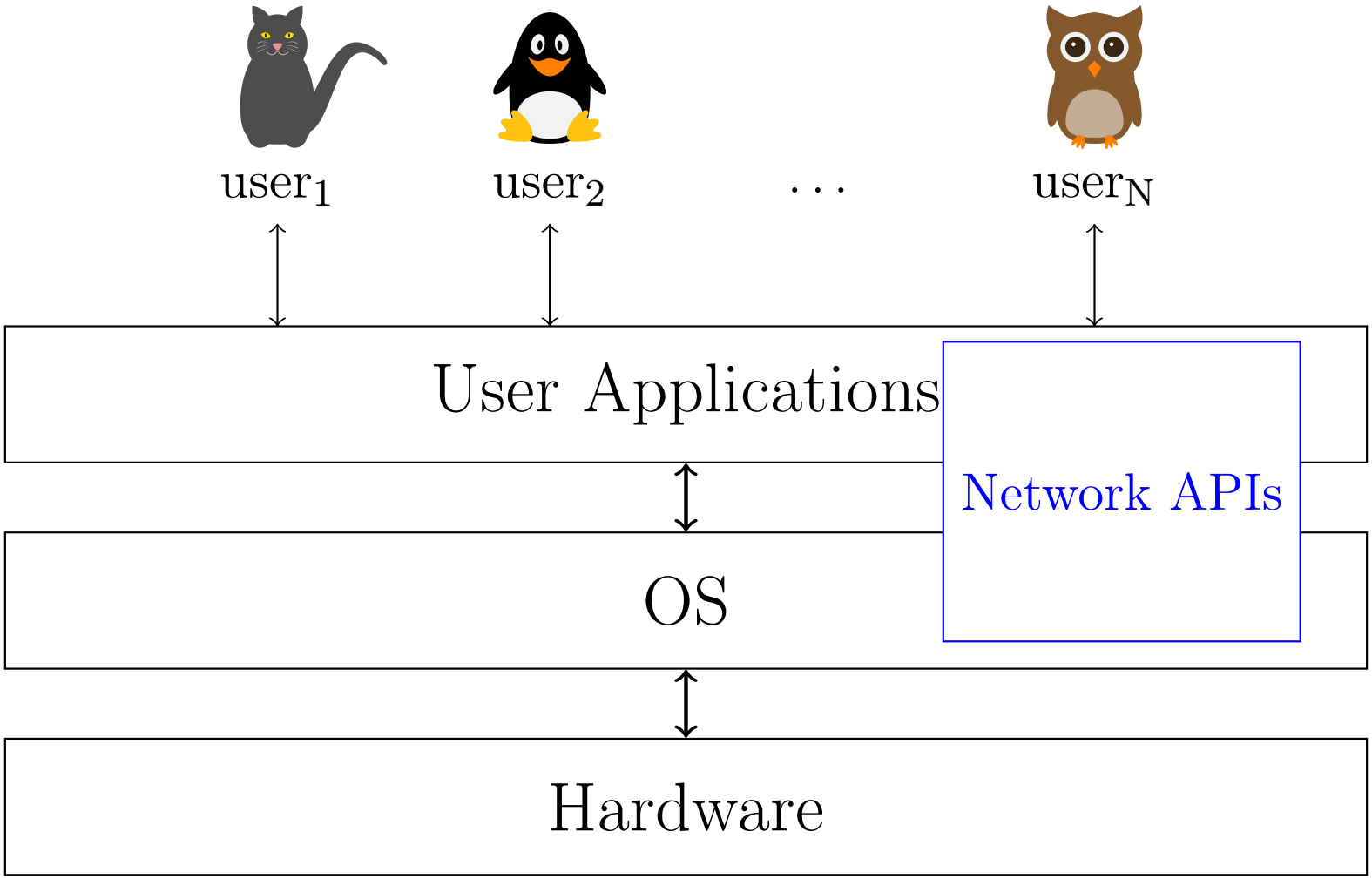

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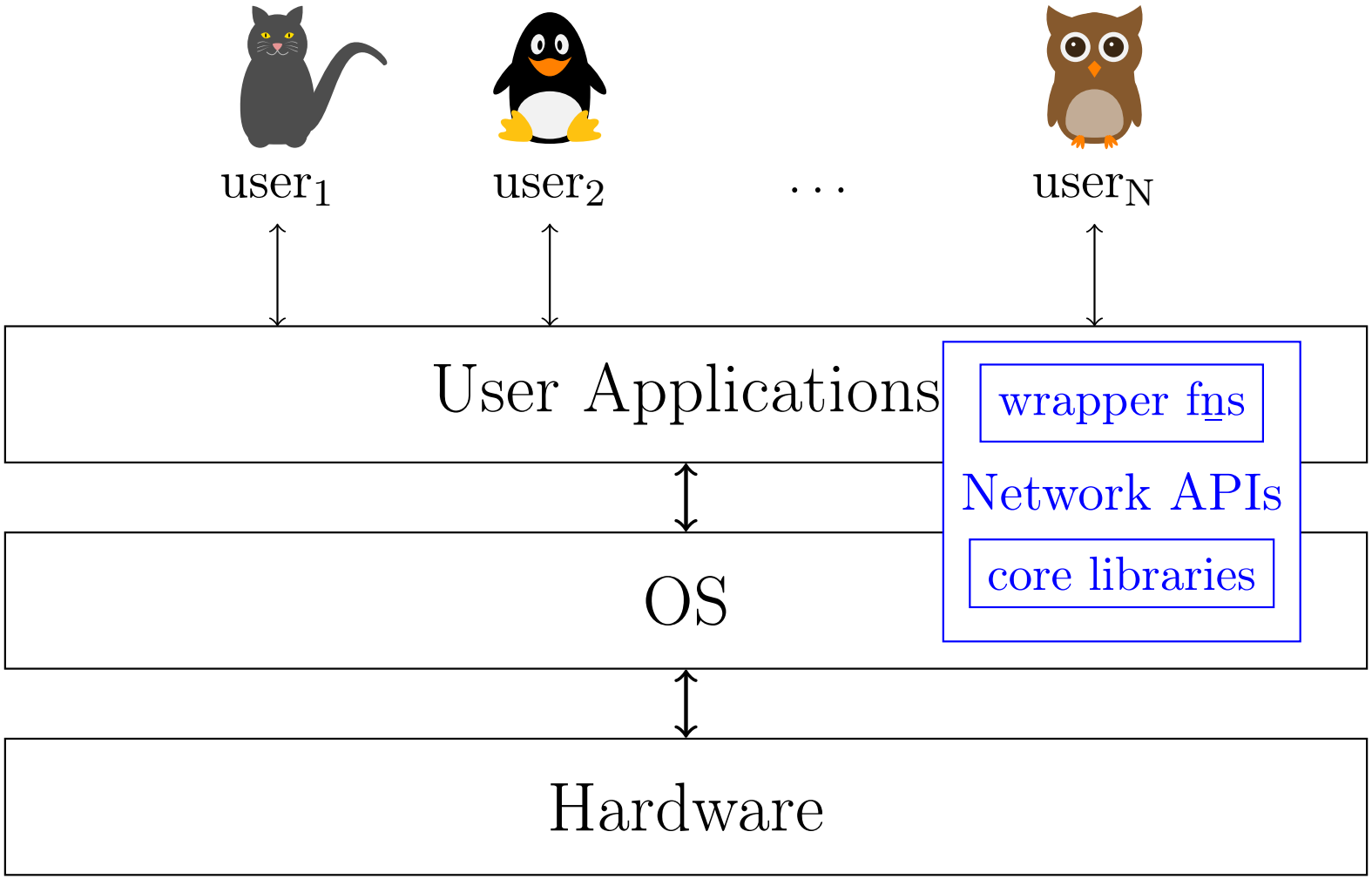

Agenda

- Using Sockets for the communications
- Using Remote Procedure Calls

What is a Socket?

- "A network **socket** is a software structure within a network node of a computer network that serves as an endpoint for sending and receiving data across the network . . . Sockets are created only during the lifetime of a process of an application running in the node" – WIKI[1]

- "A **socket** is a communications connection point (endpoint) that you can name and address in a network. Socket programming shows how to use socket APIs to establish communication links between remote and local processes" – IBM[2]

- "A **socket** is one endpoint of a two-way communication link between two programs running on the network" – ORACLE[3]

[1] https://en.wikipedia.org/wiki/Network_socket

[2] https://www.ibm.com/docs/en/i/7.5?topic=communications-socket-programming

[3] https://docs.oracle.com/javase/tutorial/networking/sockets/definition.html

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- ports 0 through 1023 are well-known ports (aka system ports)
- ports 1024 through 49151 are registered ports[4]
- ports from 49152 through 65535 are dynamic or private ports; commonly known as ephemeral ports[5]

[4] IANA maintains the official list https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

[5] ephemeral (adj.): lasting for a very short time or having a very short life cycle

Why another address?

TCP/IP Layer

Application
Transport
Network
Data-Link Physical

[3] session control, a process(browser) may have multiple active session(tabs) to same client(google search), uses application specific URIs

[2] process-to-process, a node can run multiple processes each talking via different protocol

[1] better management, efficient routing

Why another address?

TCP/IP Layer	Common Protocols
Application	TELNET, HTTP, DHCP, PING, FTP, ...
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Network	IP, ARP, TCMP, ...
Data-Link Physical	Ethernet, WiFi, ...

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TCP/IP Layer	Common Protocols	Data Packet
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Socket Programming Using C

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- We also need a little understanding of command-line arguments

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- Other fds can be created with `open()` system call

The `read()` API

```
#include <unistd.h>
ssize_t read(int fd, void *buf, size_t count);
```

Attempts to read (up to `count` bytes) from file descriptor `fd` into the buffer starting at `buf`

Return value: On success, the number of bytes read is returned (zero indicates end of file), and the file position is advanced by this number. On error, -1 is returned

Parameters:
`fd`: a file descriptor to read from
`buf`: pointer to a buffer area (array) to read into
`count`: maximum number of bytes to read

[1] See man page for `read` system call: https://man7.org/linux/man-pages/man2/read.2.html

[2] See for `size_t` and `ssize_t`: https://man7.org/linux/man-pages/man3/size_t.3type.html

The `write()` API

```
#include <unistd.h>
ssize_t write(int fd, void *buf, size_t count);
```

Writes (up to `count` bytes) from buffer starting at `buf` into the file descriptor `fd`

Return value: On success, the number of bytes written is returned. On error, -1 is returned

Parameters:
`fd`: a file descriptor to write into
`buf`: pointer to a buffer area (array) to write from
`count`: maximum number of bytes to write

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Using `read()`/`write()` for I/O

See: system_call_io.c

The open() API

```
#include <fcntl.h>
int open(char *pathname, int flags[, mode_t mode]);
```

Attempts to opens the file specified by `pathname`

Return value: On success, the new file descriptor (a nonnegative integer) is returned. On error, -1 is returned

Parameters:
`pathname`: a file path to open
`flags`: specifies the open mode flag

flag	description
O_RDONLY	open in read only mode
O_WRONLY	open in write only mode
O_RDWR	open in read-write mode
O_CREAT	creates the file if it does not exist
O_TRUNC	truncates if the file exists
O_APPEND	opens in append mode

`mode`: (optional) access mode, useful for creating new files

[1] See man page for `open` system call: https://man7.org/linux/man-pages/man2/open.2.html

[2] See for `mode_t`: https://man7.org/linux/man-pages/man3/mode_t.3type.html

The open() API

```
#include <unistd.h>
int close(int fd);
```

Closes a file descriptor specified by `fd`, so that it no longer refers to any file and may be reused

Return value: returns zero on success. On error, -1 is returned

Parameters:
`fd`: a file descriptor to close

[1] See man page for `close` system call: https://man7.org/linux/man-pages/man2/close.2.html

Using `read()`/`write()` for File I/O

See: file_copy.c

Some Useful Tools

- `ip`

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- `ip address show`

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- `ip address show`
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- Also see `netstat`, `ifconfig`, `nmap`, `nslookup`, `dig` etc.

Using Telnet

Download server1.c
Compile and run the server1 in one terminal; and leave it be

```
gcc server1.c -o server1 && ./server1
```

[1] Telnet is an application protocol used on the Internet or local area network to provide a bidirectional interactive text-oriented communication facility - WIKI

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`gcc server1.c -o server1 && ./server1`

Open another terminal and run a `telnet`[1] client in that
`telnet <server ip> <server port>`
`telnet localhost 54321`

Write anything in telnet
Type "quit" (or send `ctrl+]`) to close the connection

Use `netstat -nlp | grep 54321` to check if the port 54321 is blocked
Then maybe use `kill <pid>` to kill it

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Practice Exercises

- Write a program that accepts a file name as a command-line argument and outputs the number of vowels and consonants in the file on the standard output. You may use `fopen()` and other file I/O library functions, or you may stick to bare `open()` and other system calls for I/O.

- Repeat the above task and use only `read()` and `write()` for all I/O operations (including console outputs).

- Run the Echo Server program (`server1.c`) on your computer. Find the IP address of another computer connected on the same local network as yours. Run `telnet` on that computer and try to connect to the Echo Server running on your computer.