CS3.301 Operating Systems and Networks

Virtualization - Process

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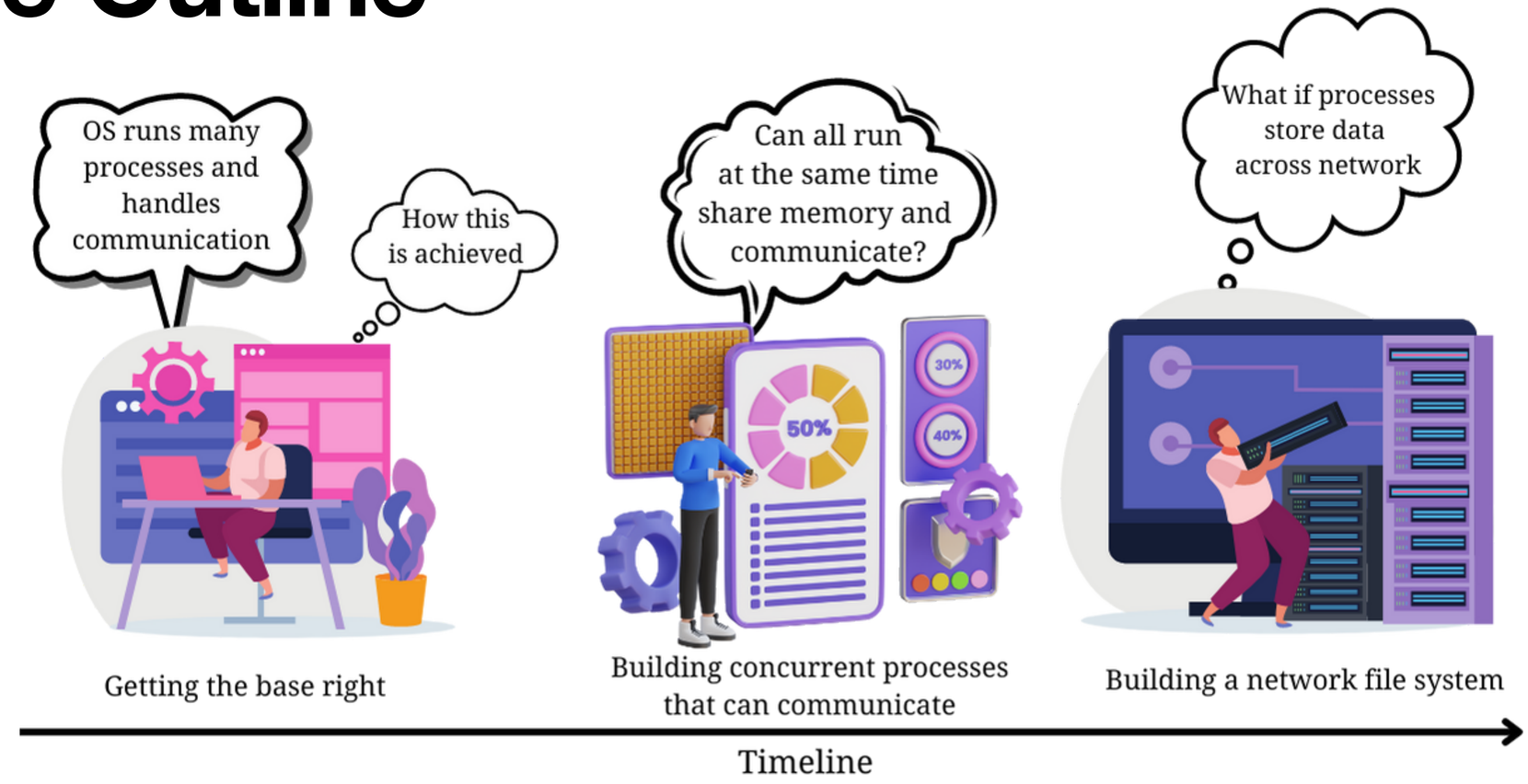
Acknowledgement

The materials used in this presentation have been gathered/adapted/generate from various sources as well as based on my own experiences and knowledge -- Karthik Vaidhyanathan

Sources:

- OSTEP Educator Materials, Remzi et al.
- OSTEP Book by Renzi et al.
- Modern Operating Systems, Tanenbaum et al.

Course Outline

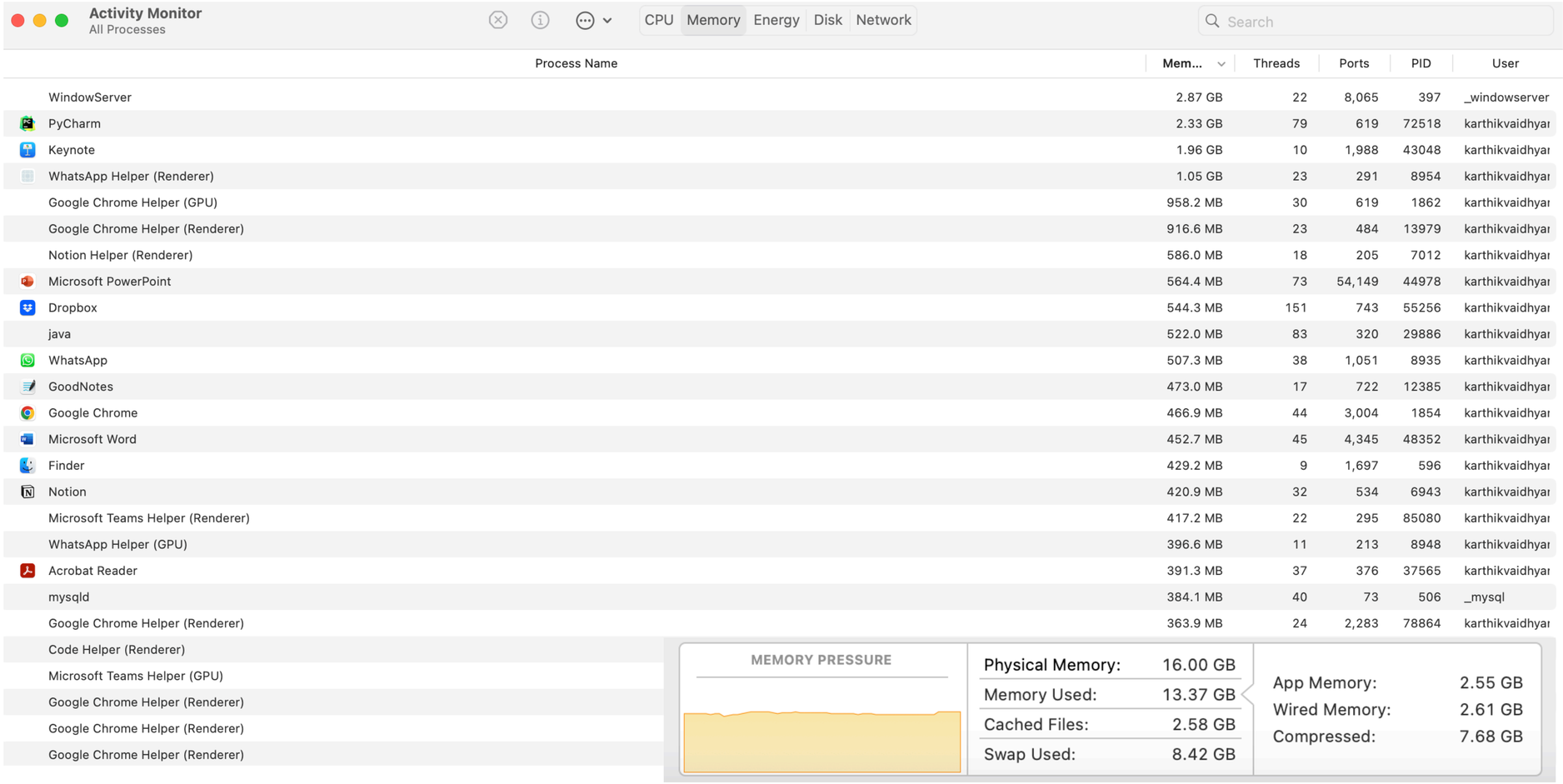


This Course

Process and Memory Virtualization	Concurrency	Persistence
Networking intro	Addressing and Routing	Network file Systems

Many processes run at the same time!

- How many processes are currently running in your machine?



What is a Process?

- A Program is nothing but code
- Processes are **running program**
- There can be more than one process that are created per program

Process Virtualization

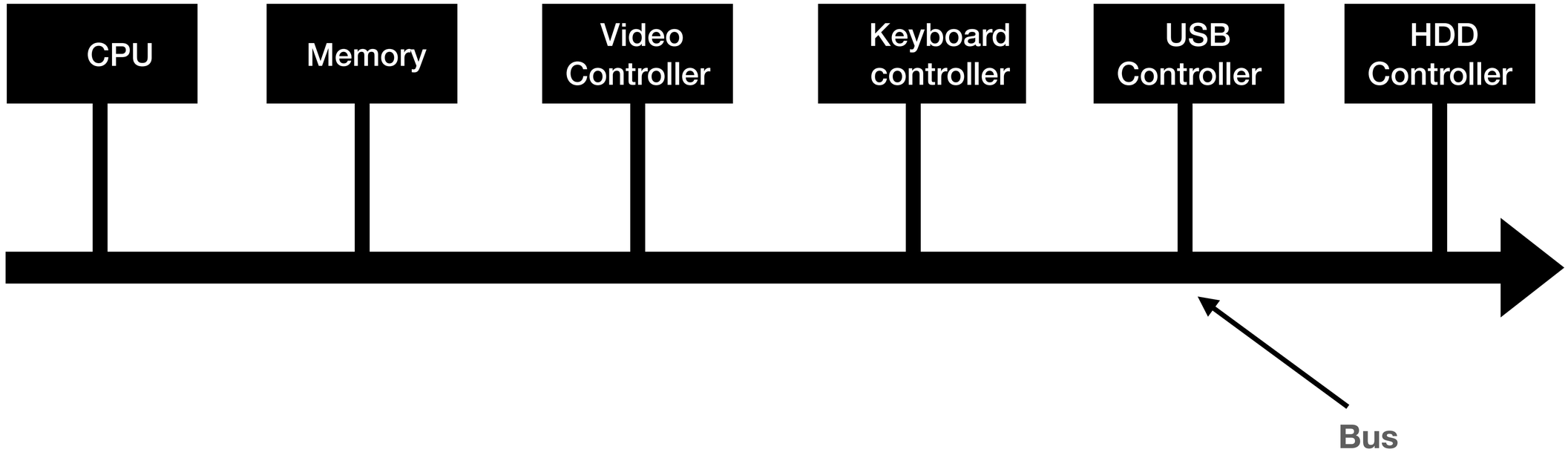
- Each process feels that it has its own CPU
- Even in Single core machines - There can be multiple process that run at the same time
- How is CPU handling this?

With limited CPU can we create an illusion that Endless CPU's are available?

OS achieves this using Virtualization of the CPU

Question: Can you of think of how such thing can be done?

Some Prerequisite



As we go more away from CPU, the more time it takes

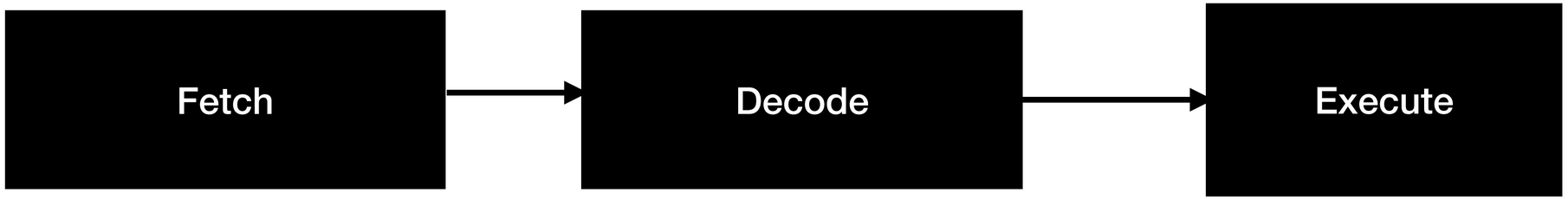
Some Prerequisite - Computer Hardware

- CPU contains some registers
  - Temporary registers
  - Program Counter (PC), Stack pointer (SP), Data register, address register,..
- Some key registers
  - Program counter - Points to the next instruction
  - Stack pointer - Points to top of the stack in the memory
  - Program Status word - Status of current state of CPU and program (condition bits)

Some Prerequisites

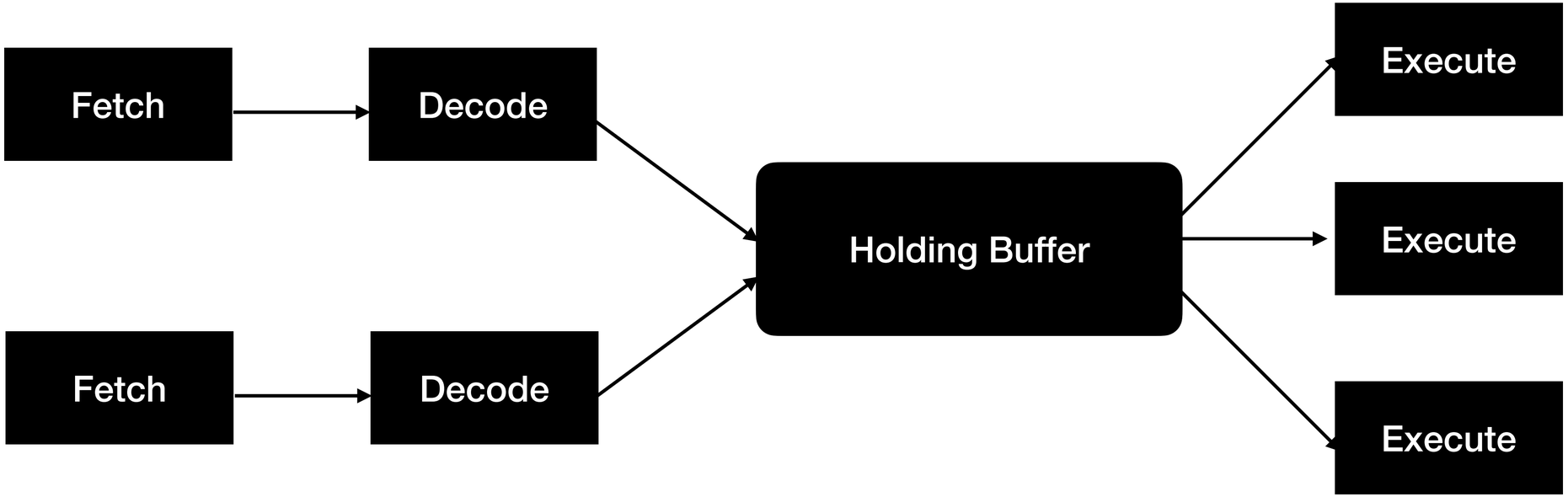
How does CPU execute a program?

- Three stage pipeline



Question: Do you believe that the current hardware structure is similar to this?

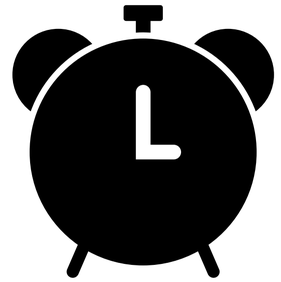
Some Prerequisite - Computer Hardware

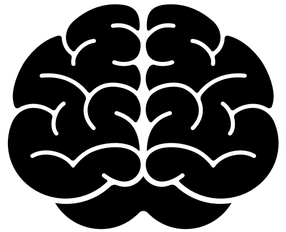


Superscalar CPU

How to make it at software level?

- We do need support from the hardware
  - Some mechanism to switch
  - Eg: Each process runs for a particular time and then we switch
  - Low-level mechanism (Context Switch)
- We also need some intelligence in the software
  - Some algorithm that can intelligently decide
  - Policies for switching
- Basically we need - **low level mechanisms** and **policies** (CPU Scheduler)



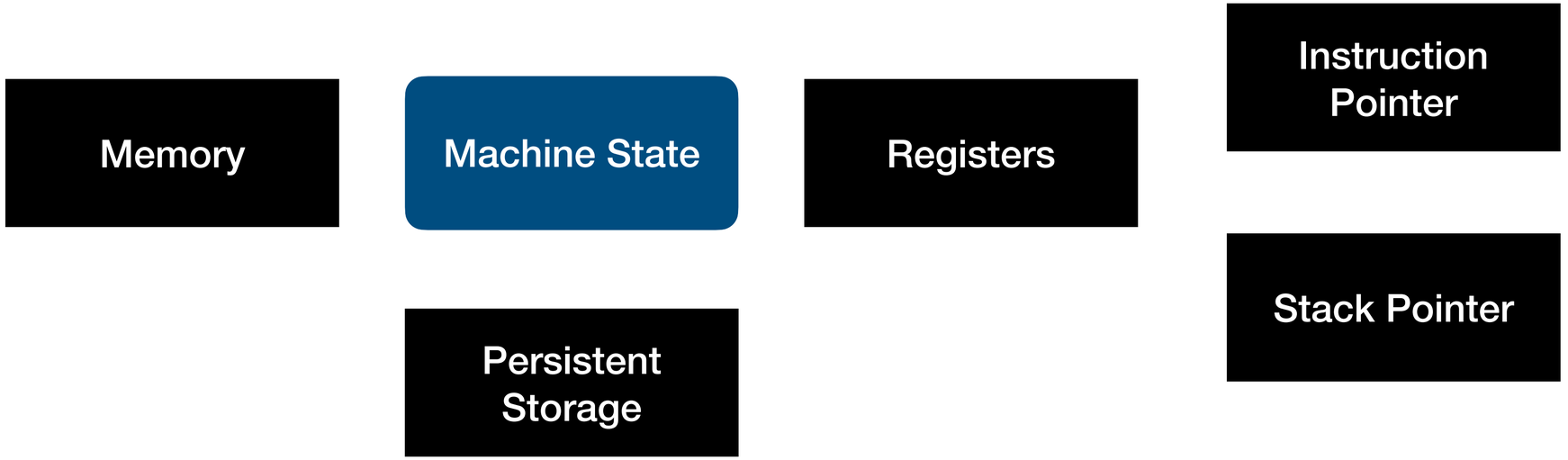


What Constitutes a Process?

Lets make it clear - Process is nothing but running program!!

- The Characteristics that make up a process (State)
  - What parts of the machine are important for execution?
- The most obvious component - Memory! Why?
  - Instructions lie in the memory, data (reads and writes) is in the memory
  - **Address space** is part of the process
- What else does a running program need?

What Constitutes a Process?



- Memory - address space (Memory that the process can address)
- Instruction pointer or program counter - which instruction is executed
- Stack pointer- local variables, functions and return addresses
- Peristent storage - I/O information

What Constitutes a Process?

- Unique Identifier (Process ID)
- Memory Image
  - Code and data (static)
  - Stack and Heap (Dynamic)
- CPU Context: Registers
  - Program Counter
  - Current Operands
  - Stack Pointer
- File Descriptors
  - Pointers to open files and devices

Creation of a Process by OS

- Load program into memory
  - Initially program resides on the disk
  - OS does **lazy loading**
- Allocate runtime stack
  - Use for local variables
  - Function parameters and return arguments

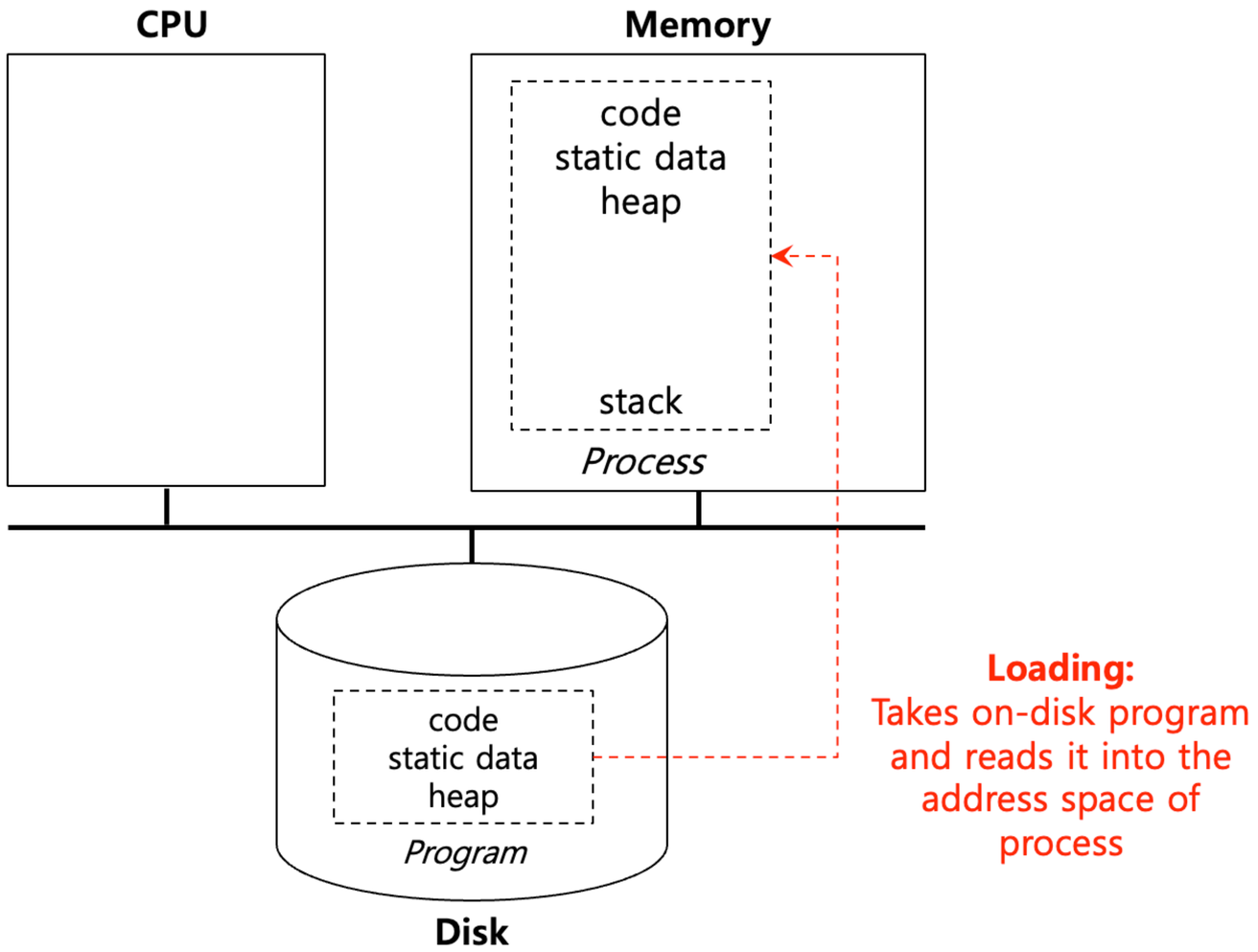


Image from OS lecture by Youjip Won

Creation of a Process by OS

- Creation of Program heap
  - Used for dynamically allocated data
  - malloc() and free()
- Basic file setup
  - STDIN, OUT, ERR
- Initialise CPU registers
  - PC to the first instruction
- Start the program

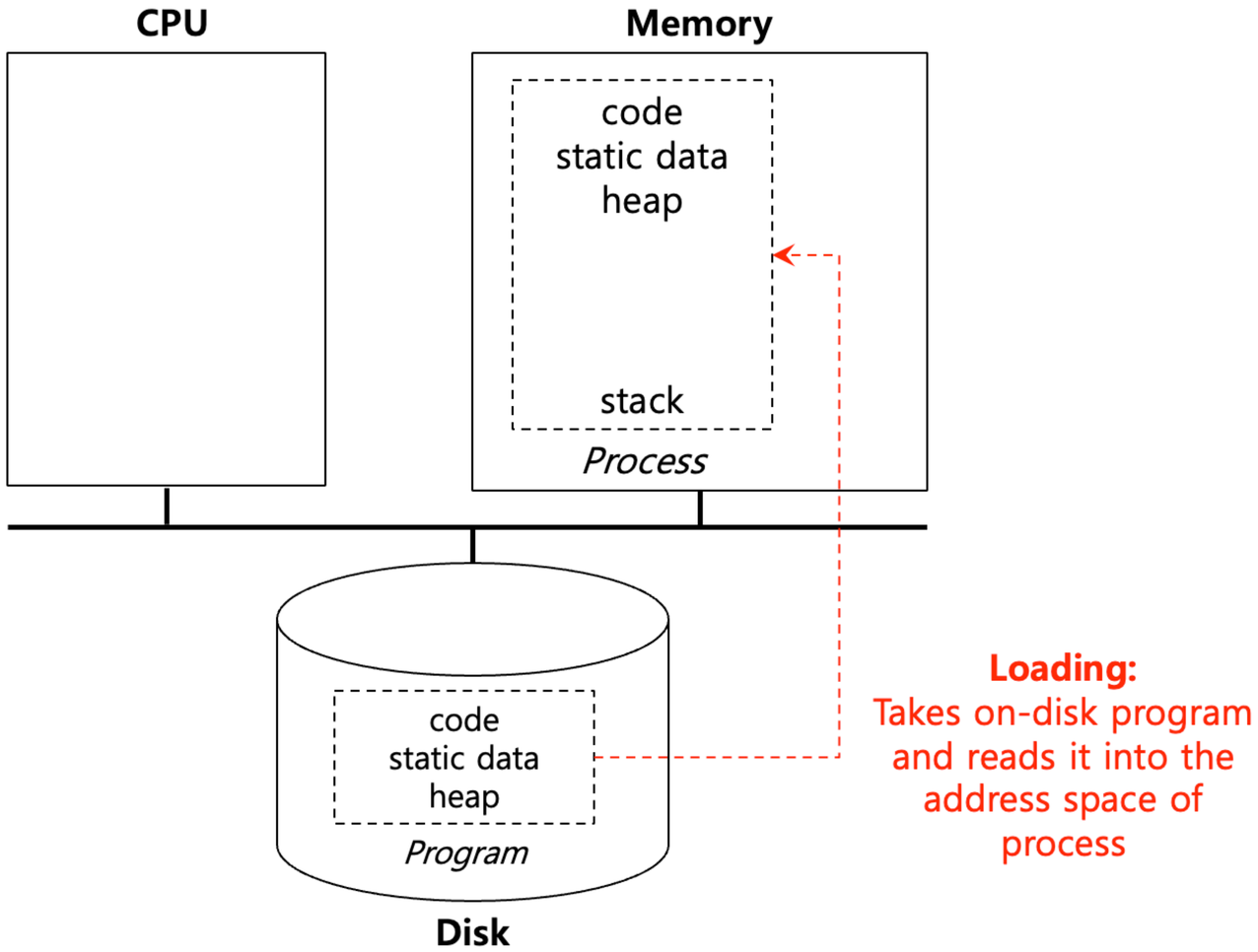


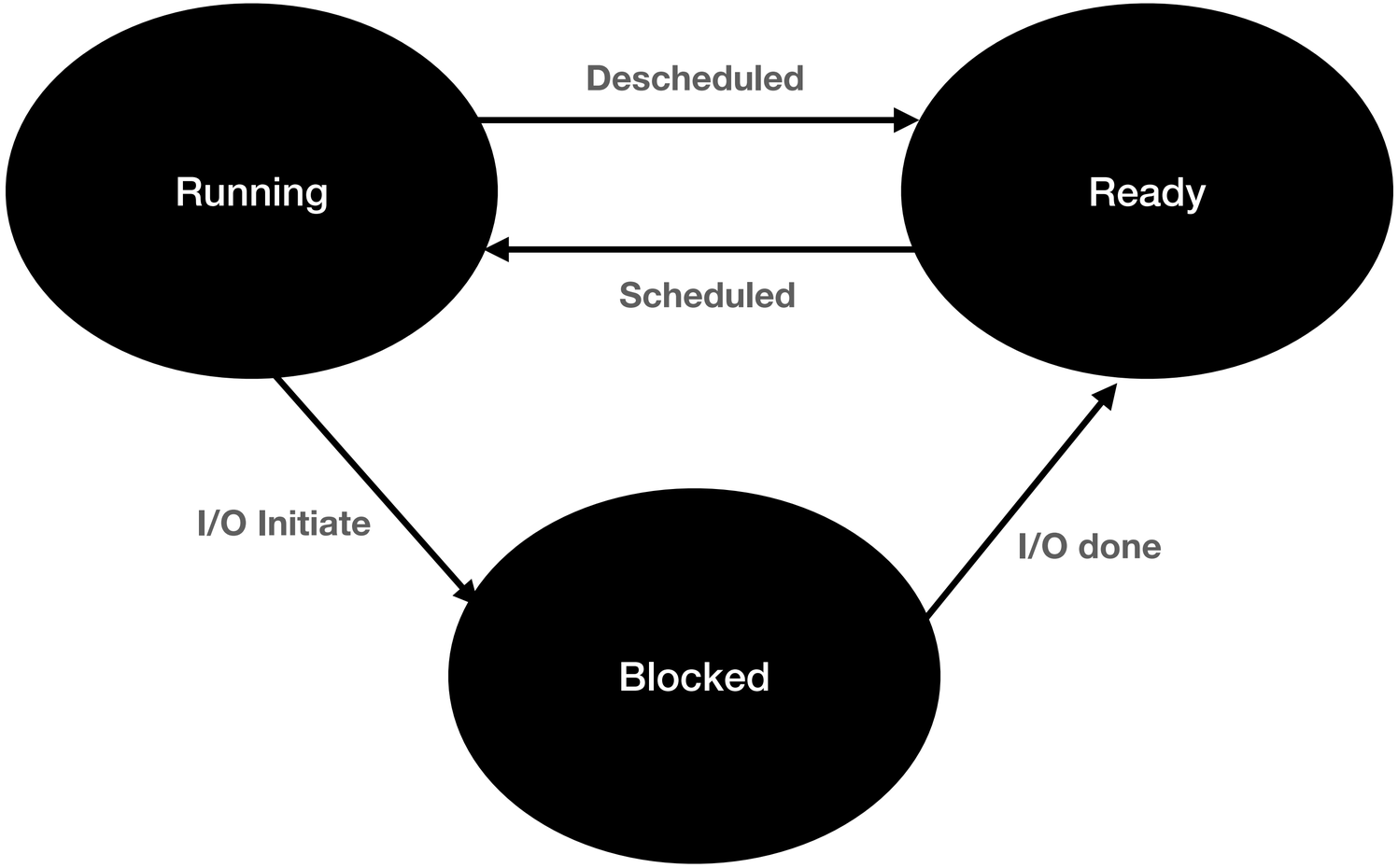
Image from OS lecture by Youjip Won

States of the Process

- At any point process can be in one of the following states
  - Running - Its running on the processor
  - Ready - Ready to run
  - Blocked - Not ready to run, something else is running
    - Any reason that you can think of?
  - Think of I/O call - Wait what does that mean?

States of the Process

Process State Transitions



Lets look at an Example

Time	Process 0	Process 1	What's happening
1	Running	Ready	
2	Running	Ready	
3	Running	Ready	Process 0 initiates I/O
4	Blocked	Running	Process 0 is blocked, 1 runs
5	Blocked	Running	
6	Blocked	Running	I/O of process 0 is done
7	Ready	Running	Process 1 is done
8	Running	-	Process 0 is done

How to store Metadata? - Use data structures

- Need for some mechanism to store the state of the process
- **Remember:** OS is a software
  - It leverages data structures to store the information
  - OS makes use of data structure called, **process list**
  - What to store inside each? - Process Control Block (PCB)
    - Process id? - Identification of the process
    - State of the process - ready, running or blocked
    - Address space of the process - the registers

Process List

Xv6 Operating System

Teaching OS developed by MIT - Replicate basic Unix

https://pdos.csail.mit.edu/6.828/2012/xv6.html

Process Structure in Xv6

```
// the information xv6 tracks about each process
// including its register context and state
struct proc {
    char *mem;                  // Start of process memory
    uint sz;                    // Size of process memory
    char *kstack;               // Bottom of kernel stack
                                // for this process
    enum proc_state state;      // Process state
    int pid;                    // Process ID
    struct proc *parent;        // Parent process
    void *chan;                 // If non-zero, sleeping on chan
    int killed;                 // If non-zero, have been killed
    struct file *ofile[NOFILE]; // Open files
    struct inode *cwd;          // Current directory
    struct context context;     // Switch here to run process
    struct trapframe *tf;       // Trap frame for the
                                // current interrupt
};
```

Process Structure in Xv6

```
// the registers xv6 will save and restore
// to stop and subsequently restart a process
struct context {
    int eip;    // Index pointer register
    int esp;    // Stack pointer register
    int ebx;    // Called the base register
    int ecx;    // Called the counter register
    int edx;    // Called the data register
    int esi;    // Source index register
    int edi;    // Destination index register
    int ebp;    // Stack base pointer register
};

// the different states a process can be in
enum proc_state { UNUSED, EMBRYO, SLEEPING,
                  RUNNABLE, RUNNING, ZOMBIE };
```

What features should the OS Provide?

Consider that we should be able to run multiple processes!

- **Create a process**
  - Double click and something just runs
- **Destroy a process**
  - Force quit, task manager -> end process
- **Wait**
  - Wait before running
- **Suspend**
  - Keep the process in pause and resume (eg: Downloading from websites!)
- **Status**
  - Can we get some status of the process (task manager, system monitor, top)

How to make it happen? - Heard of APIs?

- Application Programming Interface - What's that?
  - How does a travel website get information about different flights and allows booking?
  - What about payment services?
- API allows different programs/applications to communicate with each other
- Provides a software interface for accomplishment
- Comes with detailed documentation

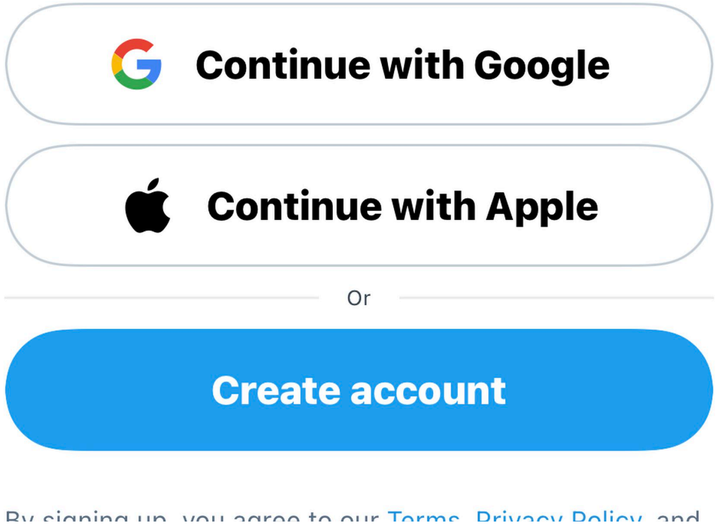
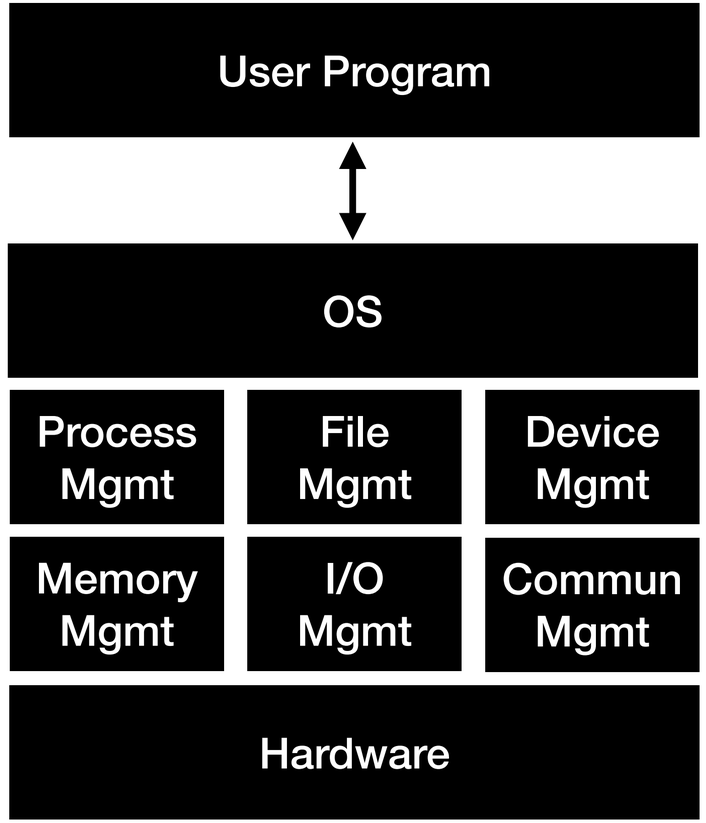


Image source: verge

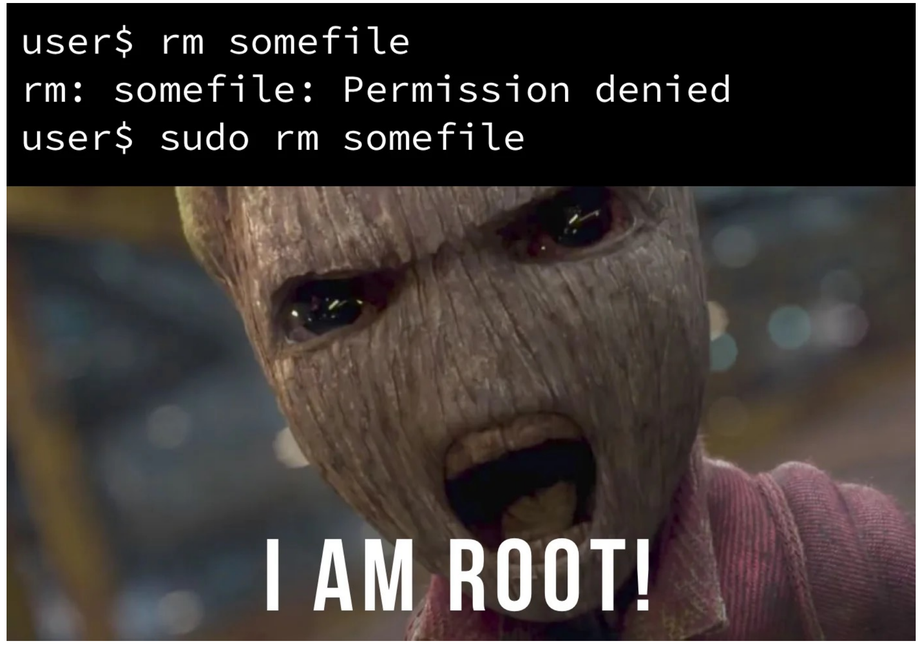
Does OS Provide API? - System Calls!

- Way for user program to interact with the OS
- OS provides some functions that can be leveraged by user programs
- Available in the form of “System calls”
  - Function call into OS code that runs at a higher privilege level
  - Think about access to hardware
- What if user wants to execute a process?



But you need Privileges!

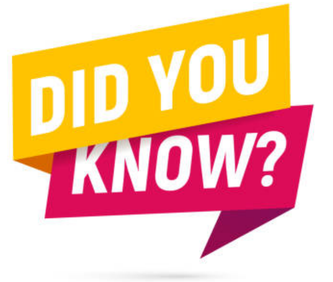
- What if a user gives a instruction to delete all files?
  - Should all the instructions be considered with equal priority?
  - When does the role of OS come in to the main picture?
    - Think about reading a file or writing a file - How to achieve it in C?
    - What if you just wanted to multiply two numbers?
    - What about the command to get list of available directories?
- Two modes of execution - **User mode** and **Kernel mode**

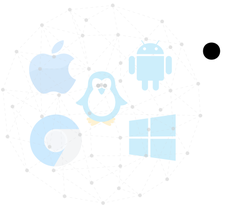


Source: reddit

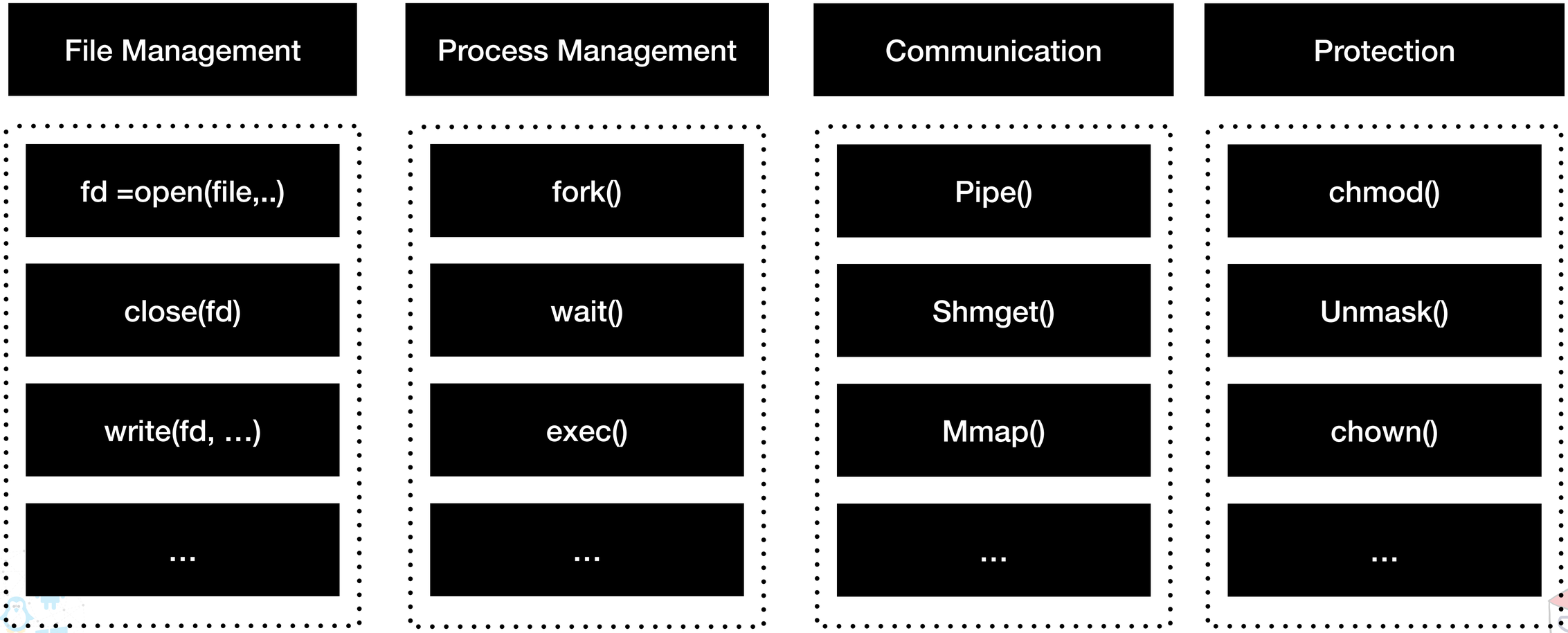
For Each OS = Rewrite Programs?

- POSIX API (Portable Operating Systems Interface)
  - Standard set of System calls that an OS must implement
  - Most modern OS's are POSIX compliant
  - Ensures portability
- Programming language libraries abstract systems calls
  - printf() in C internally invokes write system call
  - User programs usually do not worry about system calls





Some System Calls



System Calls for Process (Unix)

System Call	Supports
fork()	Creates a new child process
exec()	Makes a process execute (runs an executable)
wait()	Causes a parent to block until child terminates
exit()	Terminates a process

- Many variants of the above calls exist
- **init** process is the ancestor of all processes

The Fork System Call

- A new process is created
  - Parents image copy is made
- The new process is added to the list of processes and scheduled
- Parent and child start execution just after fork (with different return values)
- Parent and child execute and modify memory independently

The Wait API

- ***Wait()*** call blocks in parent until child terminates (options like ***waitpid()*** exists)
- Wait() also collects exit status of the terminated child process
  - Provides some visibility to the parent process
- Without wait, if process terminates - **Zombie process**
  - Exit status not collected by the parent
- Wait allows OS to reclaim the resources of the child - Prevent zombies
- What if Parent terminates before the child? - **Think!**

Remember: Init process, adopts orphans and reaps them

The Exec API

- When we perform a fork(), the parent and child execute the same code
  - Do you see some problem there?

- exec() comes to the rescue
  - Load a different executable to the memory
  - **Essence:** Child can run a different program from parent
- In some variants of exec(), command lines to the executables can be passed!

Thank you

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