CS 370: Operating Systems [Processes]

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Frequently asked questions from the previous class survey

- Processors, CPU, and Core: Can we please disambiguate?
  - Cores: Too much of a good thing?
- Caches: L1 L2, L3 on the CPU?
  - Why are cache hits so high? Ans: Spatial/temporal locality [Working Sets].
  - Why not have only a gigantic cache and do away with Main Memory altogether?
- Is the Kernel in Main memory or Cache?
- What runs in main memory?
- Why do you need hardware timers or interrupt processing?
- How many processes does a modern processor 'run" at the same time?
- Quantum

Frequently asked questions from the previous class survey

- Non-aligned memory addresses? Does user code have to worry about it?
- Is kernel mode like root in Linux?
- How does the kernel know how much memory to give each application?
- Which is better? Replication or improving?
  - Horizontal scaling vs vertical scaling

Topics covered in this lecture

- Processes
- A process in memory
- Process Control Blocks
- Interrupts & Context switches
- Operations on processes
  - Creation

Processes

Process

- The oldest and most important abstraction that an operating system provides
- Supports the ability to have (*psuedo*) **concurrent** operation
  - Even if there is only 1 CPU

What is a process?

- A process is the **execution** of an application program with restricted rights
  - It is the abstraction for protected execution provided by the kernel

All modern computers do several things at a time

- Browsing while e-mail client is fetching data
- Printing files while burning a CD-ROM

Multiprogramming

- CPU **switches** from process-to-process quickly
- Runs each process for 10s-100s of milliseconds

Multiprogramming and parallelism

- At any instant of time, the CPU is running **only one** process
- In the course of 1 second, it is working on **several** of them
- Gives the **illusion** of parallelism
  - Psuedoparallelism

A process is the unit of work in most systems

- Arose out of a need to **compartmentalize** and control *concurrent* program executions
- A process is a program in execution
- Essentially an **activity** of some kind
  - Has a program, input, output and a state.

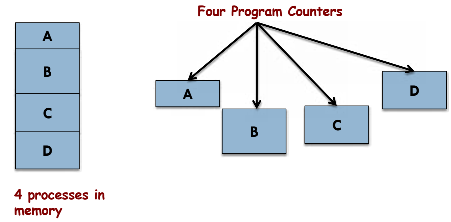
A process is just an instance of a program [1/2]

- In much the same way that an object is an instance of a class in object-oriented programming
- Each program can have zero, one or more processes executing it
- For each instance of a program, there is a process with its own copy of the program in memory.

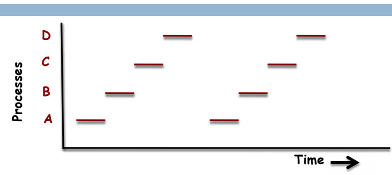
A process is just an instance of a program [2/2]

- Conceptually each process has its own **virtual CPU**
- In reality, the CPU switches back-and-forth from process to process
- Processes are <u>not affected</u> by the multiprogramming
  - Or *relative speeds* of different processes

An example scenario: 4 processes



Example scenario: 4 processes



- At any instant <u>only one</u> process executes
- *Viewed over a long time*, all processes have made **progress**

Programs and Processes

Programs and processes

- Programs are **passive**, processes are **active**
- The difference between a program and a process is subtle, but crucial

Analogy of a culinary-minded computer scientist baking cake for his daughter

Analogy	Mapping to real settings
Birthday cake recipe	Program (algorithm expressed in a suitable notation)
Well-stocked kitchen: flour, eggs, sugar, vanilla extract, etc	Input Data
Computer scientist	Processor (CPU)

- **Process is the <u>activity</u> of**
  1. Baker reading the recipe
  2. Fetching the ingredients
  3. Baking the cake

Scientist's son comes in screaming about a bee sting

- Scientist records *where he was* in the recipe
  - State of current process is saved
- Gets out a first aid book, follows directions in it

In our example, the scientist has switched to a higher priority process …

- From Baking
  - Program is the cake recipe
- To administering medical care
  - Program is the first-aid book
- When the bee sting is taken care of
  - Scientist **goes back to where he was** in the baking

Key concepts

- Process is an **activity** of some kind; it has a
  - Program
  - Input and Output
  - State
- Single processor may be shared among several processes
  - **Scheduling algorithm** decides when to stop work on one, and start work on another

How a program becomes a process

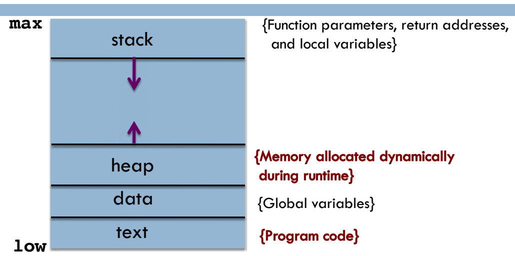
The journey from code to a becoming a process [1/2]

- Programmer types code in some high-level language
- A compiler converts that code into a sequence of machine instructions and stores those instructions in a file
  - Called the program's **executable image**
  - Compiler also defines any static data the program needs, along with its initial values, and includes them in the executable image

The journey from code to a becoming a process [2/2]

- To run the program, the kernel copies the instructions and data from the executable image into physical memory
- The kernel sets asides memory regions
  - The execution **stack**, to hold local variables during procedure calls
  - The **heap**, for any dynamically allocated data structures the program might need
- Of course, to copy the program into memory, the kernel itself must already be in memory, with its own stack and heap

A process in memory



Memory conservation

- Most operating systems reuse memory wherever possible
- The OS stores only a single copy of a program's instructions
  - Even when multiple copies of the program are executed at the same time
- Even so, a **separate copy** of the program's data, heap, and stack are needed.

How a program becomes a process

- Allocation of memory is *not enough* to make a program into a process
- Must have a process ID
- OS tracks IDs and process **state**s to orchestrate system resources

Program in memory [1/2]

- Program image <u>*appears*</u> to occupy **contiguous** blocks of memory
- OS **maps** programs into non-contiguous blocks

Program in memory [2/2]

- Mapping divides the program into equal-sized pieces: **pages**
- OS loads pages into memory
- When processor references memory on page
  - OS looks up page in table, and loads into memory

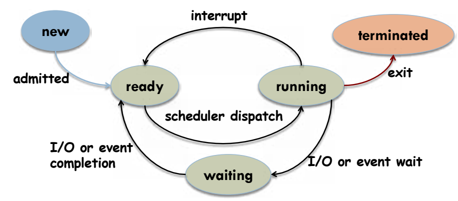
Advantages of the mapping process

- Allows **large** logical address space for stack and heap
  - **No physical memory used** <u>unless</u> actually needed
- OS hides the mapping process
  - Programmer views program image as **logically contiguous**
  - Some pages may not reside in memory

Finite State Machine

- An initial **state**
- A set of possible **input** events
- A <u>finite</u> number of states
- **Transitions** between these states
- Actions

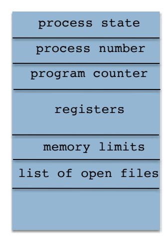
Process state transition diagram: When a process executes it changes state



How does the OS track processes?

- Via a data structure called the **process control block**, or **PCB**
- The PCB stores all the information the OS needs about a particular process
  - Where it is stored in memory, where its executable image resides on disk, which user asked it to execute, what privileges it has, etc.
- The set of the PCBs defines the current state of the OS

Each process is represented by a process control block (PCB)

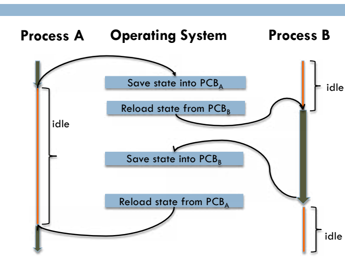


PCB is a **repository** for *any* information that *varies* from process to process.

Where is the PCB stored?

- Since PCB contains the critical information for the process
  - It must be kept in an area of memory protected from normal user access
- Maintained in kernel memory

An example of CPU switching between processes



THERE'S AN APP FOR THAT!

What can be at the user level, should be.

- Allow user programs to create and manage their own processes
- If creating a process is something a process can do, then anyone can build a new version of any of these applications
  - **Without recompiling the kernel** or forcing anyone else to use it
- Instead of a single program that does everything, we can create specialized programs for each task, and mix-and-match what we need
  - There's an app for that!

INTERRUPTS & CONTEXTS

Interrupts and Contexts

- Interrupt causes the OS to **change** CPU from its current task to run a kernel routine
- Save current context so that ***suspend*** and ***resume*** are possible
- Context is represented in the **PCB**
  - Value of CPU registers
  - Process state
  - Memory management information

Context switch refers to switching from one process to another

① **Save** state of current process

② **Restore** state of a different process

- Context switch time is pure **overhead**
  - No useful work done while switching

Factors that impact the speed of the context switch

- Memory speed
- Number of registers to copy
- Special instructions for loading/storing registers
- Memory management: Preservation of address space

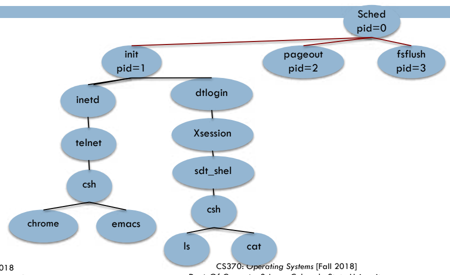
Processes execute concurrently
Can be created and deleted dynamically.

OPERATIONS ON PROCESSES

Process Creation: A process may create new processes during its execution

- **Parent** process: The creating process
- **Child** process: New process that was created
  - May itself create processes: **Process tree**
- All processes have ***unique*** identifiers

Example: Process tree in Solaris



Processes in UNIX

- `init` : Root parent process for all user processes
- Get a listing of processes with **ps** command
  - `ps`: List of all processes associated with user
  - `ps –a` : List of all processes associated with terminals
  - `ps –A` : List of all active processes

Resource sharing between a process and its subprocess

- Child process may obtain resources **directly from OS**
- Child may be **constrained** to a subset of parent's resources
  - Prevents any process from overloading system
- Parent process also passes along initialization data to the child
  - Physical and logical resources

Parent/Child processes: Execution possibilities

- Parent executes **concurrently** with children
- Parent **wait**s until some or all of its children terminate

Parent/Child processes: Address space possibilities

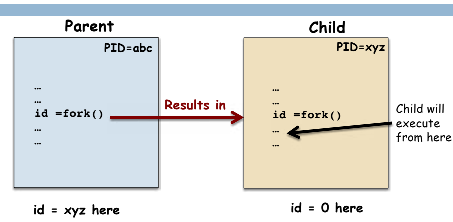
- Child is a **duplicate** of the parent
  - Same program and data as parent
- Child has a **new program** loaded into it

Process Creation

Process creation in UNIX

- Process created using **`fork()`**
  - `fork()` copies parent's memory image
  - Includes copy of parent's address space
- Parent and child continue execution **at instruction after** `fork()`
  - Child: Return code for `fork()` is **0**
  - Parent: Return code for `fork()` is the non-ZERO *process-ID* of new child

`fork()` results in the creation of 2 distinct processes



Simple example:

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

int main(void) {
    int x;
    x=0;
    fork();
    x=1;
     …
}
```

Both parent and child execute this *after* returning from fork()

Another example

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

int main () {
    printf("Hello World\n");
    fork();
    printf("Hello World\n");
 }
```

Hello World
Hello World
Hello World

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

int main () {
    printf("Hello World\n");
    if (fork()==0) {
       printf("Hello World\n");
    }
}
```

Hello World
Hello World

What happens when `fork()` fails?

- No child is created
- `fork()` returns **-1** and sets `errno`
  - `errno` is a global variable in `errno.h`

The contents of this slide-set are based on the following references

- *Andrew S Tanenbaum and Herbert Bos. Modern Operating Systems. 4th Edition, 2014. Prentice Hall. ISBN: 013359162X/ 978-0133591620.* [Chapter 2].
- *Thomas Anderson and Michael Dahlin. Operating Systems: Principles and Practice, 2nd Edition. Recursive Books. ISBN: 0985673524/978-0985673529. [Chapters 1-2]*
- *Avi Silberschatz, Peter Galvin, Greg Gagne. Operating Systems Concepts, 9th edition. John Wiley & Sons, Inc. ISBN-13: 978-1118063330.* [Chapter 3]
- *Kay Robbins & Steve Robbins. Unix Systems Programming, 2nd edition, Prentice Hall ISBN-13: 978-0-13-042411-2.* [Chapter 2, 3]
- *CS 451: Operating Systems (Colorado State University)* Help Session 2B: *Forking in C by Rink Dewri. Feb 1, 2010. Spring 2010: Professor: Shrideep Pallickara, GTA: Rinku Dewri*