The Process

CS 450: Operating Systems
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Agenda

- The Process: what is it and what’s in it?
- Forms of Multitasking
- Tracking processes in the OS
- Context switches and Scheduling
- Process API
a **process** is a *program in execution*

- its behavior is largely defined by the program being executed
- but a process is much more than just a program!
Multitasking

- Modern general-purpose OSes typically run dozens to hundreds of processes simultaneously
- May collectively exceed capacity of hardware
- Recall: *virtualization* allows each process to ignore physical hardware limitations and let OS take care of details
CPU/Memory Virtualization

- *Time-slicing* of CPU(s) is performed to simulate concurrency

- Memory is partitioned and shared amongst processes
  - But per-process view is of a *uniform address space*
  - *Lazy/On-demand loading* of processes lowers total burden
Logical execution

Physical execution

time

P0  P1

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vs. “Batch” processing

- Without multitasking, each program is run from start to finish without interruption from other processes
- Including any I/O operations (which may be lengthy!)
- Ensures minimal overhead (but at what cost?)
- Is virtualization still necessary?
Pros/Cons of Multitasking

- Pro: may improve resource utilization if we can run some processes while others are blocking
- Pro: makes process interaction possible
- Con: virtualization introduces overhead (examples?)
- Con: possibly reduced overall throughput
Forms of Multitasking

- *Cooperative* multitasking: processes voluntarily cede control
- *Preemptive* multitasking: OS polices transitions (how?)
- *Real-time* systems: hard, fixed time constraints (late is wrong!)
What’s in a process?

- Program ("text") and data
  - Static/Stack/Heap memory contents
- Registers (e.g., PC, SP, FP)
- Open files and devices (e.g., network)
- What else?
Data vs. Metadata

- User-maintained data vs. Kernel-maintained data
- Metadata examples:
  - PID, GID, UID
  - Allotted CPU time
  - Virtual → Physical memory mapping
  - Pending I/O operations
OS Data Structures

- Critical function of OS is to maintain data structures for keeping track of and managing all current processes

- Layout of many structures are dictated by hardware
  - e.g., VM structures, interrupt stack frame
PCB

- Aggregate per-process data entry is referred to as the *Process Control Block* (PCB)
- Implementation likely consists of many disparate structures
// xv6 PCB components (not comprehensive!)

```c
struct context {
    uint edi;
    uint esi;
    uint ebx;
    uint ebp;
    uint eip;
};

enum procstate { UNUSED, EMBRYO, SLEEPING, RUNNABLE, RUNNING, ZOMBIE };;

struct proc {
    uint sz; // Size of process memory (bytes)
    pde_t* pgdir; // Page table
    char *kstack; // Bottom of kernel stack for this process
    enum procstate state; // Process state
    int pid; // Process ID
    struct proc *parent; // Parent process
    struct trapframe *tf; // Trap frame for current syscall
    struct context *context; // swtch() here to run 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
    char name[16]; // Process name (debugging)
};
```
Context Switches

- Multitasking via virtualization relies on seamlessly *switching contexts* between processes on hardware
- Requires frequently saving/loading state to/from PCB
- At any point may have multiple processes *ready* to run
- How to pick the incoming process?
Scheduler

- Combination of *policies* & *mechanisms* used to select which process is allocated resources
- Can express operations in a state transition diagram
READY/Runnable

"ZOMBIE"/TERMINATED

"ready queue ()

"start"

loaded

scheduled

preempted

I/O complete

I/O request

reaped
OS code

Po

1/0 request

v

save Po state,

restore Pi state

(Po 1/0 request complete)

save Pi,

restore Po

Pi

“quantum”

clock interrupt!

ready

running

blocked

ready

running

running
Policy vs. Mechanism

- Recurring theme in OS (and general software) implementation
- Ideally: keep policy separate from mechanism (why?)
  - Cross-cutting issues may be difficult to isolate, resulting in a high degree of coupling between modules
- API vs. Implementation is an example of policy vs. mechanism
Unix Process API

- Set of flexible, *orthogonal* process APIs that enable:
  - Creation & Program execution
  - Management (e.g., suspension, destruction, synchronization)
  - Metadata access (e.g., status, termination conditions)
  - Interoperation
Unix Process API (partial)

- Creation: fork
- Program execution: exec
- Synchronization: wait
- Termination: exit
/* Simple forking example */

if (fork() == 0) {
    /* in child */
    printf("Hello from child!\n");
} else {
    /* in parent */
    printf("Hello from parent!\n");
}
/* Primitive Unix shell: OS "interface" */

/* Read-Eval Loop */
while (1) {
    printf("$ "); /* print prompt */

    /* read command and build argv */
    fgets(buf, MAXLINE, stdin);

    /* fork child process */
    if (fork() == 0) {
        /* parse command line into arguments */
        parsecmd(buf, argv);

        /* execute argument program in child */
        if (execvp(argv[0], argv) < 0) {
            printf("Command not found\n");
            exit(0); // terminate
        }
    }

    /* wait for child completion in parent */
    wait(&status);
}
API vs. Kernel Implementation

- Unix API has stood the test of time — large parts unchanged from earliest versions
- “Those who don’t understand Unix are condemned to reinvent it, poorly.” (Henry Spencer)
- But this doesn’t mean we can’t re-engineered things under the hood!