Lecture 22: Processes in xv6

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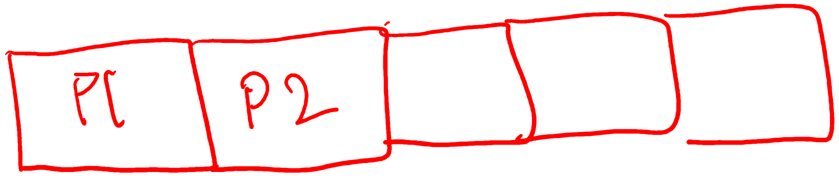
The process abstraction

- The OS is responsible for concurrently running multiple processes (on one or more CPU cores/processors)
  - Create, run, terminate a process
  - Context switch from one process to another
  - Handle any events (e.g., system calls from process)
- OS maintains all information about an active process in a process control block (PCB)
  - Set of PCBs of all active processes is a critical kernel data structure
  - Maintained as part of kernel memory (part of RAM that stores kernel code and data, more on this later)
- PCB is known by different names in different OS
  - struct proc in xv6
  - task_struct in Linux



PCB in xv6: struct proc

- Page 23, process structure and process states

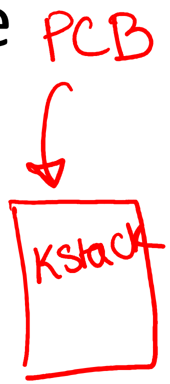
```
enum procstate { UNUSED, EMBRYO, SLEEPING, RUNNABLE, RUNNING, ZOMBIE };

// Per-process state
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)
};
```

struct proc: kernel stack

```
char *kstack;                    // Bottom of kernel stack for this process
```

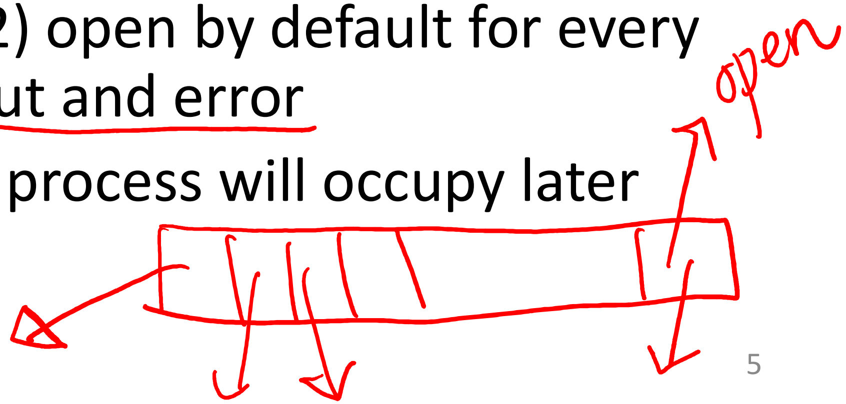
- Recall: register state (CPU context) saved on user stack during function calls, to restore/resume later
- Likewise, CPU context stored on kernel stack when process jumps into OS to run kernel code
  - Why separate stack? OS does not trust user stack
  - Separate area of memory per process within the kernel, not accessible by regular user code
  - Linked from struct proc of a process



struct proc: list of open files

```
struct file *ofile[NOFILE];  // Open files
```

- Array of pointers to open files (struct file has information about the open file, more on this later)
  - When user opens a file, a new entry is created in this array, and the index of that entry is passed as a file descriptor to user
  - Subsequent read/write calls on a file use this file descriptor to refer to the file
  - First 3 files (array indices 0,1,2) open by default for every process: standard input, output and error
  - Subsequent files opened by a process will occupy later entries in the array



struct proc: page table

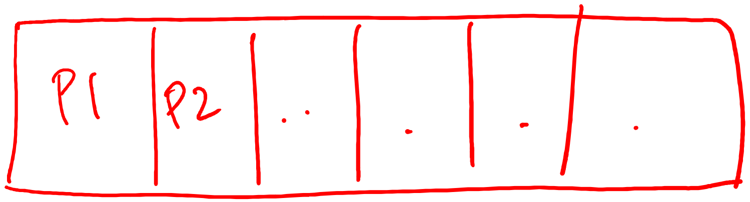
```
2339    pde_t* pgdir;                    // Page table
```

- Every instruction or data item in the memory image of process (code/data, stack, heap, etc.) has an address
  - Virtual addresses, starting from 0
  - Actual physical addresses in memory can be different (all processes cannot store their first instruction at address 0)
- Page table of a process maintains a mapping between the virtual addresses and physical addresses (more on this later)

Process table (ptable) in xv6

lock

```
struct {
  struct spinlock lock;
  struct proc proc[NPROC];
} ptable;
```



- ptable: Fixed-size array of all processes
  - Real kernels have dynamic-sized data structures
- CPU scheduler in the OS loops over all runnable processes, picks one, and sets it running on the CPU

```
    // Loop over process table looking for process to run.
    acquire(&ptable.lock);
    for(p = ptable.proc; p < &ptable.proc[NPROC]; p++){
      if(p->state != RUNNABLE)
        continue;

      // Switch to chosen process.  It is the process's job
      // to release ptable.lock and then reacquire it
      // before jumping back to us.
      c->proc = p;
      switchuvm(p);
      p->state = RUNNING;
```

Process state transition examples

- A process that needs to sleep (e.g., for disk I/O) will set its state to SLEEPING and invoke scheduler
- A process that has run for its fair share will set itself to RUNNABLE (from RUNNING) and invoke scheduler
- Scheduler will once again find another RUNNABLE process and set it to RUNNING

```
// Give up the CPU for one scheduling round.
void
yield(void)
{
  acquire(&ptable.lock);
  myproc()->state = RUNNABLE;
  sched();
  release(&ptable.lock);
```

```
void
sleep(void *chan, struct spinlock *lk)
{
  struct proc *p = myproc();

  if(p == 0)
    panic("sleep");

  if(lk == 0)
    panic("sleep without lk");

  // Must acquire ptable.lock in order to
  // change p->state and then call sched.
  // Once we hold ptable.lock, we can be
  // guaranteed that we won't miss any wakeup
  // (wakeup runs with ptable.lock locked),
  // so it's okay to release lk.
  if(lk != &ptable.lock){
    acquire(&ptable.lock);
    release(lk);
  }
  // Go to sleep.
  p->chan = chan;
  p->state = SLEEPING;

  sched();
```

Summary of xv6 processes

- We have seen basics of PCB structure (struct proc), list of processes (ptable), scheduler code, state transitions
- We will keep revisiting this xv6 code multiple times to understand it better
  - Each concept will deepen understanding further