Operating Systems

4. The Abstraction: The Process

How to provide the illusion of many CPUs?

- CPU virtualizing
  - The OS can promote the illusion that many virtual CPUs exist.
  - **Time sharing**: Running one process, then stopping it and running another
    - The potential cost is performance.

A Process

A process is a running program.

- Comprising of a process:
  - Memory (address space)
    - Instructions
    - Data section
  - Registers
    - Program counter
    - Stack pointer

Process API

- These APIs are available on any modern OS.
  - **Create**
    - Create a new process to run a program
  - **Destroy**
    - Halt a runaway process
  - **Wait**
    - Wait for a process to stop running
  - **Miscellaneous Control**
    - Some kind of method to suspend a process and then resume it
  - **Status**
    - Get some status info about a process

Process Creation

1. **Load** a program code into memory, into the address space of the process.
   - Programs initially reside on disk in *executable format*.
   - OS perform the loading process lazily.
     - Loading pieces of code or data only as they are needed during program execution.

2. The program's run-time **stack** is allocated.
   - Use the stack for *local variables*, *function parameters*, and *return address*.
   - Initialize the stack with arguments → `argc` and the `argv` array of `main()` function

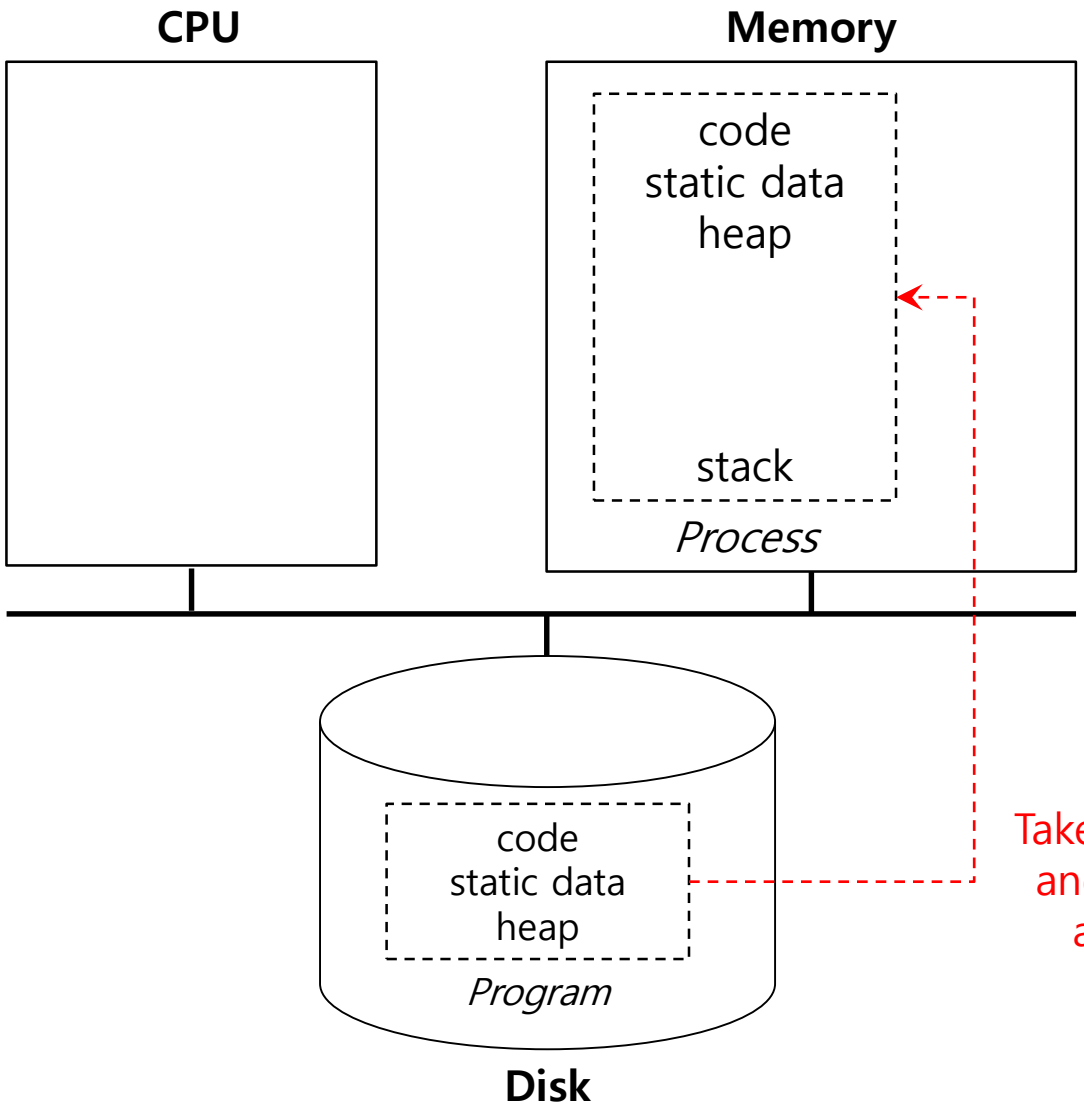
Process Creation (Cont.)

3. The program's **heap** is created.
   - Used for explicitly requested dynamically allocated data.
   - Program request such space by calling `malloc()` and free it by calling `free()`.

4. The OS do some other initialization tasks.
   - input/output (I/O) setup
     - Each process by default has three open file descriptors.
     - Standard input, output and error

5. **Start the program** running at the entry point, namely `main()`.
   - The OS *transfers control* of the CPU to the newly-created process.

Loading: From Program To Process

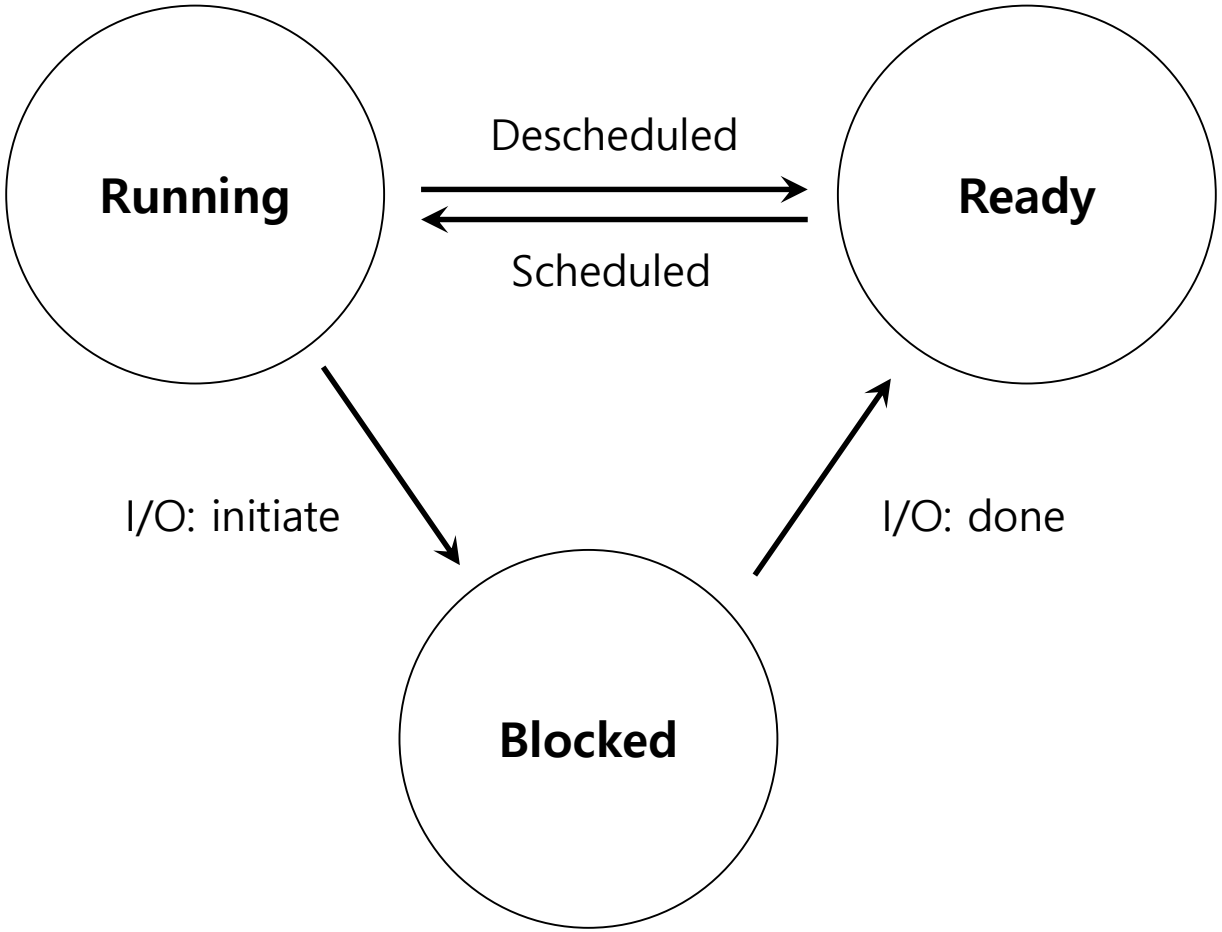


Loading:
Takes on-disk program and reads it into the address space of process

Process States

- A process can be one of three states.
  - **Running**
    - A process is running on a processor.
  - **Ready**
    - A process is ready to run but for some reason the OS has chosen not to run it at this given moment.
  - **Blocked**
    - A process has performed some kind of operation.
    - When a process initiates an I/O request to a disk, it becomes blocked and thus some other process can use the processor.

Process State Transition



Data structures

- PCB(Process Control Block)
  - A C-structure that contains information about each process.
  - **Register context:** a set of registers that define the state of a process

- **Process list**
  - Ready processes
  - Blocked processes
  - Current running processx

Example) thread structure in Pintos

```
struct thread{
    /* Owned by thread.c. */
    tid_t tid;                          /* Thread identifier. */
    enum thread_status status           /* Thread state. */
    char name[16];          /* Name (for debugging purposes). */
    uint8_t *stack;         /* Saved stack pointer. */
    int priority;           /* Priority. */
    struct list_elem allelem;           /* List element for
all threads list. */

    /* Shared between thread.c and synch.c. */
    struct list_elem elem;              /* List element. */

#ifdef USERPROG
    /* Owned by userprog/process.c. */
    uint32_t *pagedir;                  /* Page directory. */
#endif

    /* Owned by thread.c. */
    unsigned magic;         /* Detects stack overflow. */
  };
```

Example) The xv6 kernel Proc Structure (Cont.)

```
// 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
};
```

Example) Register Context 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 };
```