Scheduling & Threads

CIS 4480/5480 Fall 2025

Overview

Threads

Background

pthreads

Concurrency

Scheduling

Background

FCFS

Algorithms

Processes vs. Threads

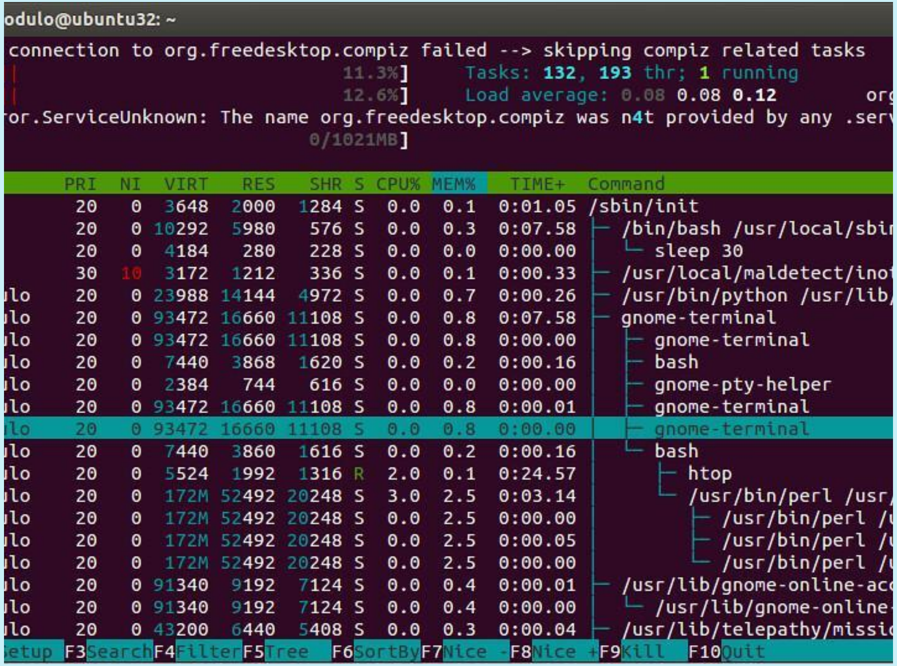
- Threads are sequential execution streams within a process
- Processes have:
  - Address space
  - OS resources (file descriptors)
- Threads have unique:
  - Stack
  - Stack Pointer
  - Program Counter
  - Registers
- Threads share:
  - Address spaces
  - Heap
  - Globals

Why Threads?

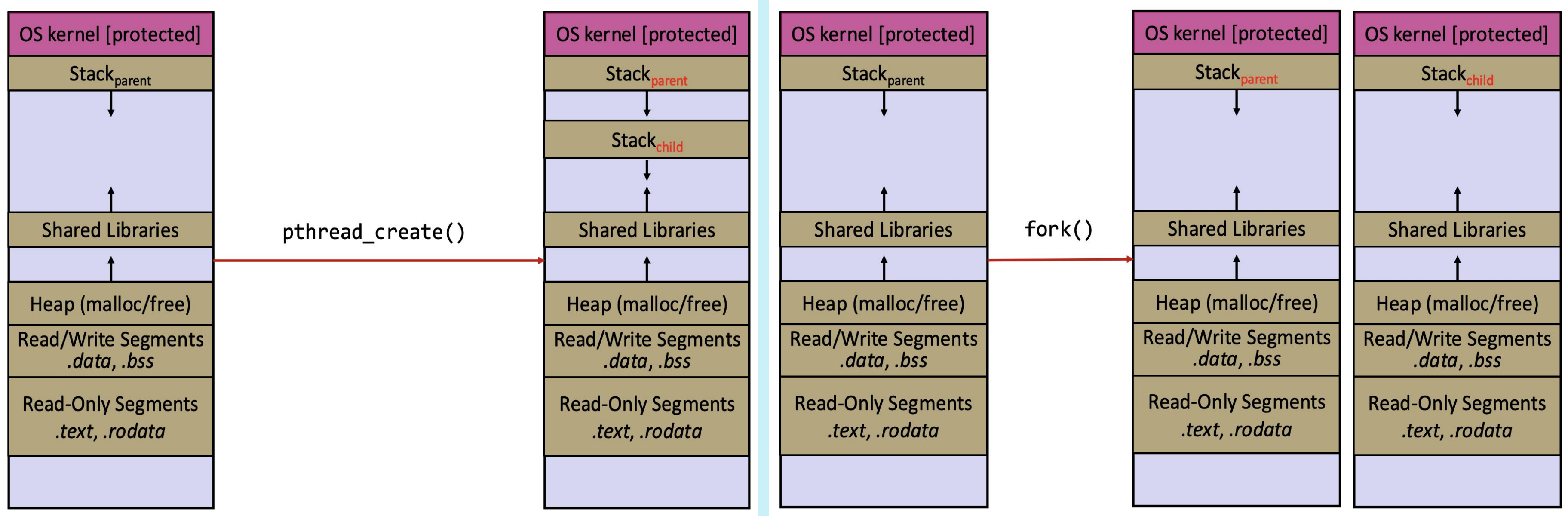
- Summary: lower overhead
- Smaller memory footprint than subprocesses
- Faster to create and destroy
- Can share memory with other threads
- Faster context switching
- Simpler synchronization primitives available

Why Processes?

- Portability (Language Support): Just call fork()
- Lack of shared memory means it's harder to run into concurrent modification issues
- One process crashing doesn't bring the others down so easily



pthread_create() vs fork()



Pthreads

Overview

- POSIX API for dealing with threads
- #include <pthread.h>

pthread_create()

- Creates a new thread and runs a given start function
- Returns 0 on success, error num on error

pthread_join()

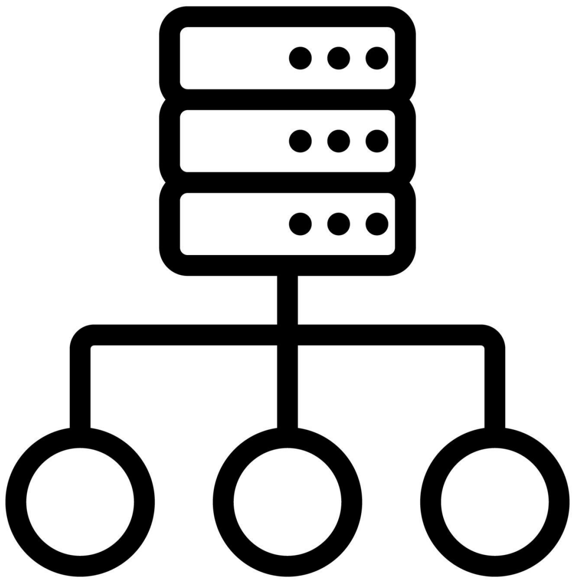
- Calling thread waits for a specified thread to terminate
- Joins execution streams together

```
int pthread_create(
        pthread_t* thread,
        const pthread_attr_t* attr,
        void* (*start)(void*),
        void* arg);
```

```
int pthread_join(pthread_t thread, void** retval);
```

Concurrency Intro

- Doing multiple tasks in the same time window
- Different from parallelism (see lecture)
  - Parallelism can help us achieve concurrency well
- Could require working together
  - May need synchronization (upcoming)
  - Mutexes, semaphores, etc.



Scheduling

- In operating systems, scheduling assigns tasks to CPUs
- OS-specific policies/algorithms decide which tasks to schedule next
  - Each have different strengths/weaknesses
- Linux has used a few schedulers
  - Completely Fair Scheduler
  - Earliest Eligible Virtual Deadline First (latest)

Scheduling (cont.)

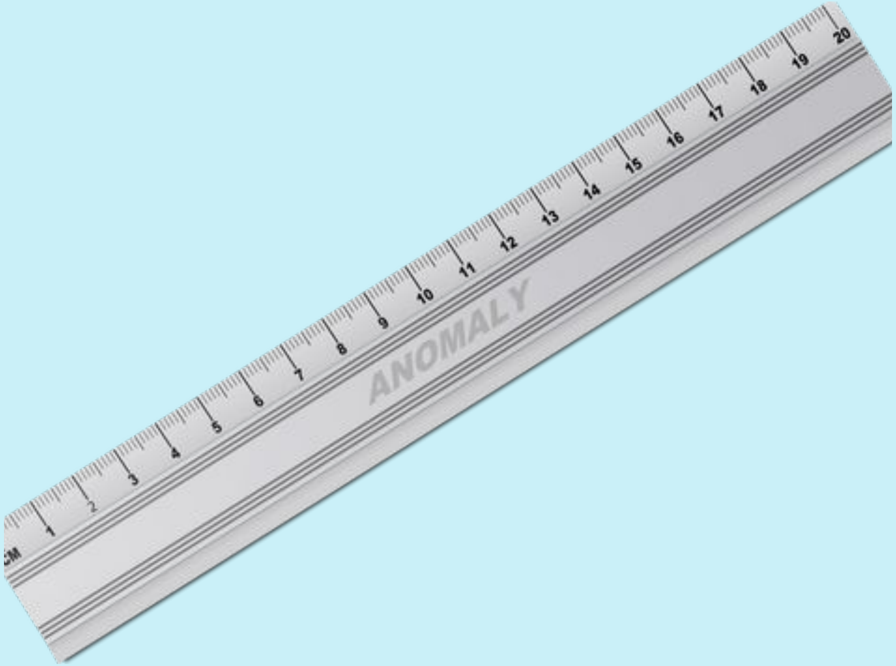
- We consider tasks to be threads
  - To Linux, threads are just a special process
- We care about
  - Fairness
  - Wait Time
  - Latency
  - Overhead
  - Throughput
  - In real OSes, priorities

First Come First Serve (FCFS)

- Schedule whichever job is ready first, and run it to completion/blocking
- Queue for ready tasks
  - Add task when created or unblocked
- Drawbacks:
  - Not so interactive
  - May be very unfair
    - Long CPU-bound task
  - No priority

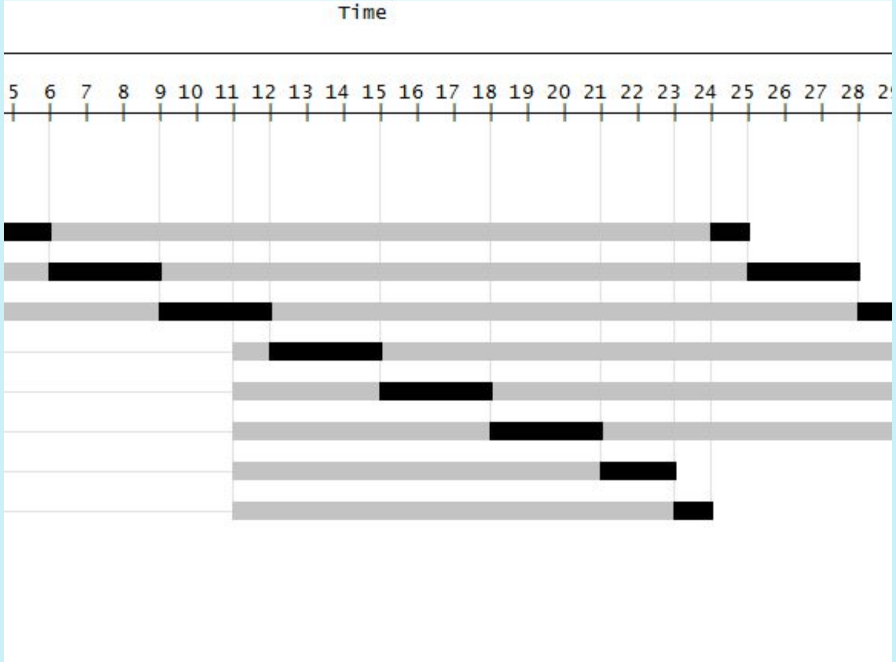
Shortest Job First (SJF)

- The next job is the shortest one in our current pool
- Queue for ready tasks
- Disadvantages:
  - Hard to estimate true job length
  - We may starve longer tasks



Round Robin (RR)

- Each job gets to run for at most a time quantum, then the next job in the ready queue is scheduled
- Preemptive: will stop a running process
- Disadvantages:
  - May be unfair to tasks that yield the CPU
  - No priorities
  - Context switching



Priority Round Robin (PRR)

- Round robin but tasks have priority now
- Runs lower priority tasks if the higher priority queues are empty
- In PennOS, you're asked to implement a PRR variant with 3 priority levels
  - We can schedule lower priority jobs even if there are higher priority jobs
  - We wait until the time quantum is complete before checking the thread status again

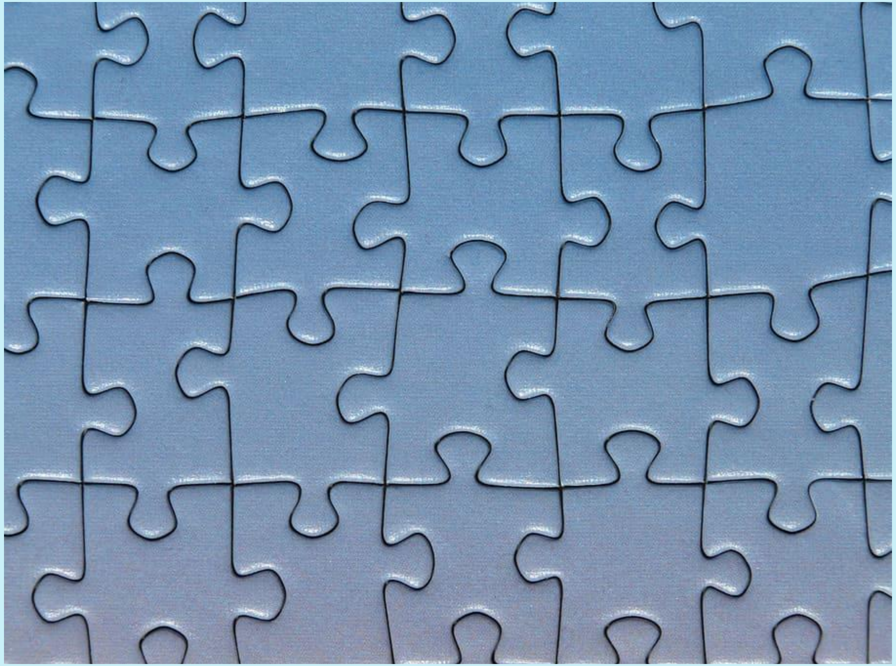
Multi-Level Feedback (MLF)

- Priority levels each have queues and associated time quanta
- Threads enter at highest priority level
- If a thread voluntarily gives up CPU, it gets moved to the end of its queue
- If it's pre-empted by the scheduler (forced to give up CPU), it's moved to lower-level queue
- Higher queues must be empty for any given queue to get scheduled

CFS

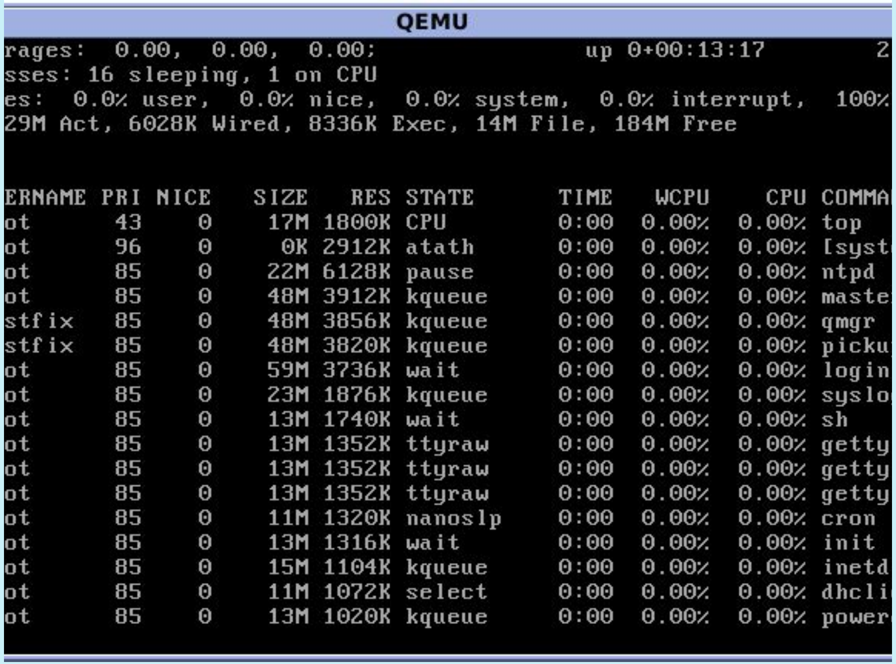
Completely Fair Scheduler

- Another approach to fairness
- Track cumulative CPU usage (vruntime) for each task and try to even it out
- Priorities can be handled by weighting runtime adjustments differently
- Minimum time quantum is set to avoid excessive context switching
- Manage state with Red-black tree
- New tasks start with the minimum vruntime in the system



Nice

- Feature of Linux systems to adjust process importance
- Used by the scheduler in priority calculations
- The “nicer” a process is, the higher it’s nice value, and the lower its priority
- Can be adjusted by users with the “nice” command



EEVDF (Not Tested)

Earliest Eligible Virtual Deadline First

- Current scheduler for Linux
- Similar goal to CFS, but aims to also consider latency
- Tasks with shorter time slices are prioritized in a virtual deadline calculation
  - Often latency-sensitive tasks
- Task with earliest virtual deadline is selected

Recitation Check-In

Must submit by **7:00pm** on Gradescope for credit.

Thread Execution

```c
#define NUM_PROCESSES N
#define LOOP_NUM M

int sum_total = 0;

void loop_incr() {
  for (int i = 0; i < LOOP_NUM; i++) {
    sum_total++;
  }
  printf("Process ID: %d with sum total of %d.\n", getpid(), sum_total);
}

int main(int argc, char** argv) {

  pid_t pids[NUM_PROCESSES];  // array of process ids

  // create processes to run loop_incr()
  for (int i = 0; i < NUM_PROCESSES; i++) {
    pids[i] = fork();
    if (pids[i] == 0) {    // child
      loop_incr();
      exit(EXIT_SUCCESS);
    }
  }
  // wait for all child processes to finish
  for (int i = 0; i < NUM_PROCESSES; i++) {
    waitpid(pids[i], NULL, 0);
  }

  printf("The ultimate sum total is %d\n", sum_total);
  return EXIT_SUCCESS;
}
```

What is the maximum value of sum_total after main executes?

Algorithm Selection

You're developing a Linux distribution with a graphical user interface packaged in it and recurring long-running background jobs on a single-core CPU. Rank the following scheduling algorithms from most to least supportive of the interactivity requirements of the system.

1. FCFS
2. RR
3. CFS

Scheduling

Assume Job A (length 3) arrives at time 0, Job B (length 2) arrives after A but also at time 0 (before scheduling), and Job C (length 2) arrives some time strictly between time 1 and 2.

Task lengths are multiples of 1 time quantum, and 1 unit of time is a time quantum. Assume switching has no overhead.
For round robin, assume a process is immediately added to the end of the queue once it completes its time quantum.

Which task is scheduled at time 5 under each of the following policies:

1. First Come First Serve
2. Shortest Job First
3. Classic Round Robin

Let's Have A Great Midterm!