CS 140 Project 1: Threads

January 15, 2021

Today’s Topics

- Project Overview
- Project 1 Requirements
  - Alarm Clock
  - Priority Scheduler
  - Advanced Scheduler
- Getting Started

Project Overview

Reference Implementation:

```
devices/timer.c          |   42 +++++-
threads/fixed-point.h |  120 ++++++++++++++++++
threads/synch.c          |   88 ++++++++++++-
threads/thread.c         |  196 ++++++++++++++++++++++++++----
threads/thread.h         |   23 +++
5 files changed, 440 insertions(+), 29 deletions(-)
```

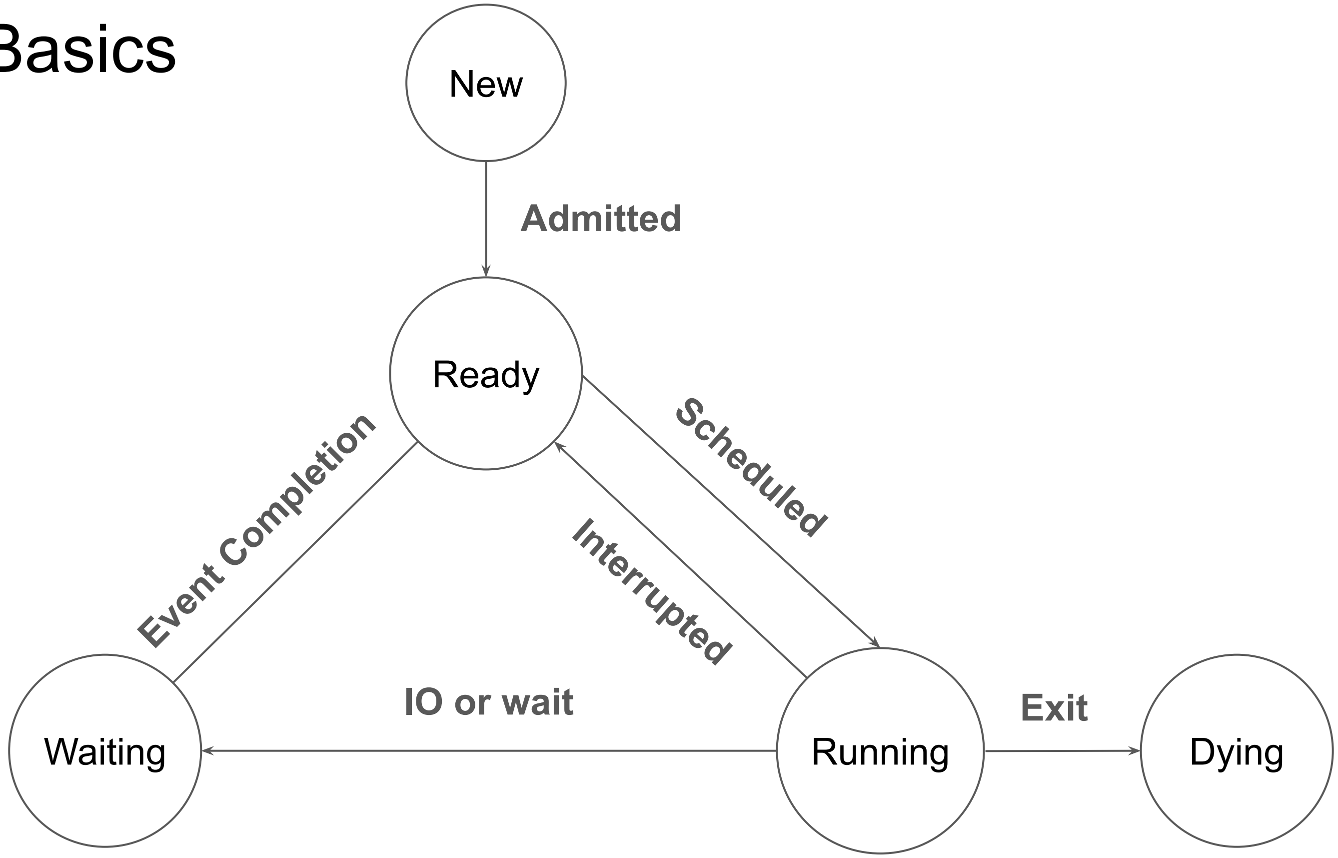
- Most changes in `threads` and `device` directories
- Also look in `lib/kernel` for useful data structures: `list`, `hash`, `bitmap`

Synchronization

Serializing access to shared resource

- **Disabling interrupts:**
  - Turns off thread preemption; only one thread can run
  - Undesirable unless absolutely necessary
- **Synchronization primitives:** (`threads/synch.h`)
  - Semaphores
  - Locks
  - Condition Variables

Thread Basics



Project 1 Requirements

(Chapter 2.2)

Alarm Clock

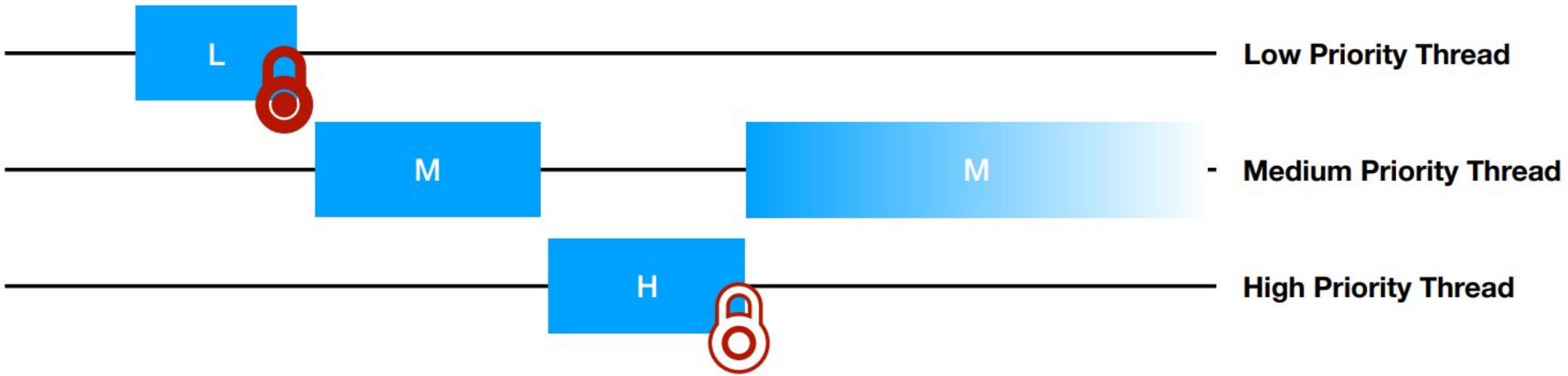
- **Reimplement** `timer_sleep()` **to avoid busy waiting**
- `void timer_sleep(int64_t ticks)`
  - Suspends execution of the calling thread until time as advanced by at least `ticks` timer ticks
  - Existing implementation uses “busy waiting”
- Details in [Section 2.2.2]

Priority Scheduling

- **Replace round-robin scheduler with a priority-based scheduler**
  - Always run a thread with the highest priority among all ready threads
    - Round-robin threads of the same highest priority
    - Yield immediately when a higher priority thread is ready
    - May starve other threads
  - Most code will be in `thread.h/c`
- **Implement “Priority Donation” (solves “Priority Inversion”)**
- Details in Section 2.2.3

Priority Inversion

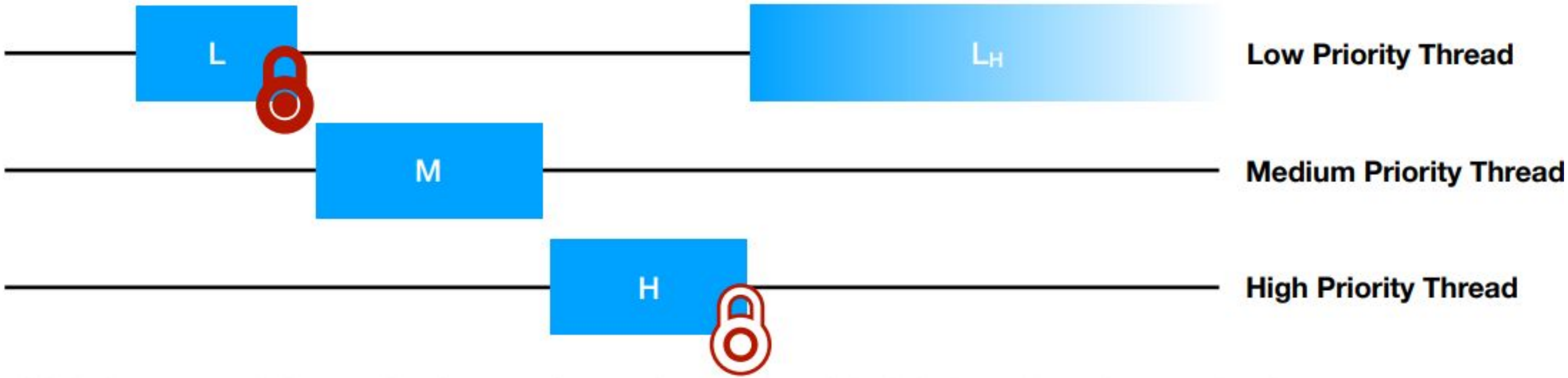
- **Priority Inversion:** *A low priority thread holds a resource needed by a higher priority thread*



- H is blocked while waiting on L, and M has a higher priority than L
- H can’t run because L can’t release its lock because M is running
- Solution: **priority donation**

Priority Donation

- **Priority Donation:** *A higher priority thread "donates" its priority to the lower priority thread it is blocked on*



- H "donates" its priority to L so that L runs with high effective priority
- When L releases the lock, L's priority returns to its old value
- H then runs immediately

Priority Donation

Things to consider:

- To how many threads can a donor donate its priority?
- From how many threads may a donee receive priority?
- What happens when a priority recipient donates to another thread?

Advanced Scheduler

- **Implement a multilevel feedback queue scheduler similar to the 4.4 BSD Scheduler**
- Multilevel feedback queue scheduler tries to be fair with CPU time
  - No priority donation
  - Give highest priority to thread that has used the least CPU time recently
  - Prioritizes interactive and I/O-bound threads
  - De-prioritizes CPU-bound threads
- **The scheduling algorithm must be configurable at startup time**
- Details in Section 2.2.4 and Appendix B

Advanced Scheduler

```
priority = PRI_MAX - recent_cpu/4 - nice*2
```

- Details in Appendix B.2

Advanced Scheduler: `nice`

- `nice` allows threads to declare how generous they want to be with their own CPU time
- Integer value between -20 and 20
    - `nice > 0`: lower effective priority, gives away CPU time
    - `nice < 0`: higher effective priority, takes away CPU time from other threads
- Details in Appendix B.1

Advanced Scheduler: `recent_cpu`

- `recent_cpu`: amount of CPU time a thread has “recently” received
- Exponentially weighted moving average
- Incremented every *clock tick* when a thread is running
- Recomputed for all threads every *second*:

  ```
  recent_cpu = (2*load_avg)/(2*load_avg + 1) * recent_cpu + nice
  ```

- Details in [Appendix B.3]()

Advanced Scheduler: `load_avg`

- `load_avg`: Average number of ready threads in the last minute
- Single value system-wide
- Initialized to zero
- Recomputed every second:

```
load_avg = (59/60)*load_avg + (1/60)*ready_threads
```

- Details in Appendix B.4

Getting Started

- Start early!
- Read the documentation and the source code
- Setup/use version control (git)
  - Remember to **keep your repositories private**
- Design your solution, data structure, and synchronization scheme *before* you start coding
- Work together: meet/commit/merge often
- Grading: 50% project tests, **50% code and write-up**

Git Commands

- git clone
- git add
- git commit
- git branch
- git merge
- git stash
- git pull
- git push
- git rebase

Git Recommendations

Some guidelines & ideas:

- Write helpful commit messages. They exist only for you and your team!
- Host your code on Github or Bitbucket as a "master" copy. **Use a private repository!**
- Create per-assignment branches. Work on topic branches; merge into assignment branches and delete once the topic is "done".
- Stay synchronized with your team: `fetch` and `push` often.
- Commit often. Use `git bisect` to find regression bugs.

Read or skim Pro Git for fuller advice.