Section 6: Scheduling, Deadlock

CS 162

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Contents

1 Vocabulary

- **Scheduler** - Routine in the kernel that picks which thread to run next given a vacant CPU and a ready queue of unblocked threads.
- **Linux CFS** - Linux scheduling algorithm designed to optimize for fairness. It gives each thread a weighted share of some target latency and then ensures that each thread receives that much virtual CPU time in its scheduling decisions.
- **Multi-Level Feedback Queue Scheduling** - MLFQS uses multiple queues with priorities, dropping CPU-bound jobs that consume their entire quanta into lower-priority queues.
- **Priority Inversion** - If a higher priority thread is blocking on a resource (a lock, as far as you're concerned but it could be the Disk or other I/O device in practice) that a lower priority thread holds exclusive access to, the priorities are said to be inverted. The higher priority thread cannot continue until the lower priority thread releases the resource. This can be amended by implementing priority donation.
- **Priority Donation** - If a thread attempts to acquire a resource (lock) that is currently being held, it donates its effective priority to the holder of that resource. This must be done recursively until a thread holding no locks is found, even if the current thread has a lower priority than the current resource holder. (Think about what would happen if you didn't do this and a third thread with higher priority than either of the two current ones donates to the original donor.) Each thread's effective priority becomes the max of all donated priorities and its original priority.
- **Deadlock** - A case of starvation due to a cycle of waiting. Computer programs sharing the same resource effectively prevent each other from accessing the resource, causing both programs to cease to make progress.
- **Banker's Algorithm** - A resource allocation and deadlock avoidance algorithm that tests for safety by simulating the allocation for predetermined maximum possible amounts of all resources, before deciding whether allocation should be allowed to continue.

2 Scheduling

2.1 Simple Priority Scheduler

We are going to implement a new scheduler in Pintos we will call it SPS. We will just split threads into two priorities "high" and "low". High priority threads should always be scheduled before low priority threads. Turns out we can do this without expensive list operations.

For this question make the following assumptions:

- Priority Scheduling is NOT implemented
- High priority threads will have priority 1
- Low priority threads will have priority 0
- The priorities are set correctly and will never be less than 0 or greater than 1
- The priority of the thread can be accessed in the field `int priority` in `struct thread`
- The scheduler treats the ready queue like a FIFO queue
- Dont worry about pre-emption.

Modify `thread_unblock` so SPS works correctly.

You are not allowed to use any non constant time list operations

```
void
thread_unblock (struct thread *t)
{
  enum intr_level old_level;
  ASSERT (is_thread (t));
  old_level = intr_disable ();
  ASSERT (t->status == THREAD_BLOCKED);

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  ------------------------------------------------
  list_push_back (&ready_list, &t->elem);

  ------------------------------------------------
  t->status = THREAD_READY;
  intr_set_level (old_level);
}
```

2.1.1 Fairness

In order for this scheduler to be "fair" briefly describe when you would make a thread high priority and when you would make a thread low priority.

2.1.2 Better than Priority Scheduler?

If we let the user set the priorities of this scheduler with `set_priority`, why might this scheduler be preferable to the normal pintos priority scheduler?

2.1.3 Tradeoff

How can we trade off between the coarse granularity of SPS and the super fine granularity of normal priority scheduling? (Assuming we still want this fast insert)

2.2 Totally Fair Scheduler

You design a new scheduler, you call it TFS. The idea is relatively simple, in the begining, we have three values `BIG_QUANTA`, `MIN_LATENCY` and `MIN_QUANTA`. We want to try and schedule all threads every `MIN_LATENCY` ticks, so they can get atleast a little work done, but we also want to make sure they run *atleast* `MIN_QUANTA` ticks. In addition to this we want to account for priorities. We want a threads priority to be inversely proportial to its `vruntime` or the amount of ticks its spent in the CPU in the last `BIG_QUANTA` ticks.

You may make the following assumptions in this problem:

- Priority scheduling in Pintos is functioning properly,
- Priority donation is not implemented.
- Alarm is not implemented.
- `thread_set_priority` is never called by the thread
- You may ignore the limited set of priorities enforced by pintos (priority values may span any `float` value)
- For simplicity assume floating point operations work in the kernel

2.2.1 Per thread quanta

How long will a particular thread run? (use the threads priority value)

2.2.2 struct thread

Below is the declaration of `struct thread`. What field(s) would we need to add to make TFS possible? You may not need all the blanks.

```
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. */
    float priority;                       /* Priority, as a float. */
    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
    ___________________________         /* What goes here? */
```

```
    ____________________________        /* What goes here? */

    ____________________________        /* What goes here? */

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

2.2.3 thread tick

What is needed for `thread_tick()` for TFS to work properly? You may not need all the blanks.

```
void
thread_tick (void)
{
  struct thread *t = thread_current ();

  /* Update statistics. */
  if (t == idle_thread)
    idle_ticks++;
#ifdef USERPROG
  else if (t->pagedir != NULL)
    user_ticks++;
#endif
  else
    kernel_ticks++;

  ____________________________________________;

  ____________________________________________;
  /* Enforce preemption. */
  if (++thread_ticks >= TIME_SLICE) {  /* TIME_SLICE may need to be replaced with something else */
    intr_yield_on_return ();

    _________________________________;

    _________________________________;

    _________________________________;

    _________________________________;

    _________________________________;

    _________________________________;

    _________________________________;
  }
}
```

2.2.4 timer interrupt

What is needed for `timer_interrupt` for TFS to function properly.

```
static void
timer_interrupt (struct intr_frame *args UNUSED)
{
  ticks++;
  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  ____________________________________;

  thread_tick ();
}
```

2.2.5 thread create

What is needed for `thread_create()` for TFS to work properly? You may not need all the blanks.

```
tid_t
thread_create (const char *name, int priority, thread_func *function, void *aux)
{
  /* Body of thread_create omitted for brevity */

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```

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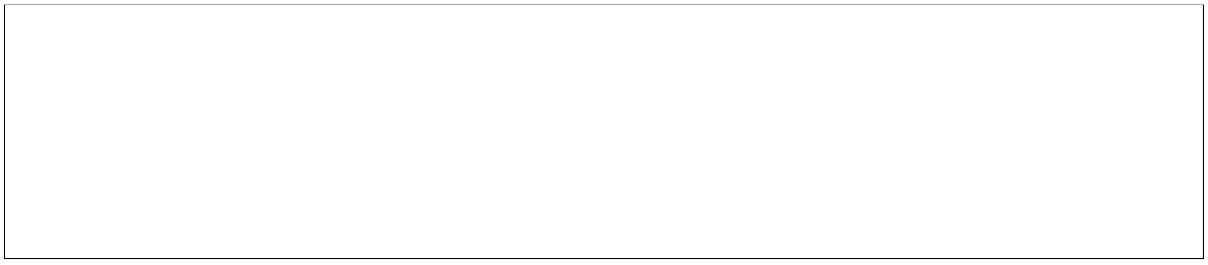
  /* Add to run queue. */
  thread_unblock (t);
  if (priority > thread_get_priority ())
    thread_yield ();

  return tid;
}
```

2.2.6 Analysis

Explain the high level behavior of this scheduler; what exactly is it trying to do? How is it different/similar from/to the multilevel feedback scheduler we could've implemented instead?



3 Deadlock

3.1 Introduction

What are the four requirements for Deadlock?

What is starvation and what is deadlock? How are they different?

3.2 Banker's Algorithm

Suppose we have the following resources: A, B, C and threads T1, T2, T3 and T4. The total number of each resource as well as the current/max allocations for each thread are as follows:

Total		
A	B	C
7	8	9

	Current			Max		
T/R	A	B	C	A	B	C
T1	0	2	2	4	3	3
T2	2	2	1	3	6	9
T3	3	0	4	3	1	5
T4	1	3	1	3	3	4

Is the system in a safe state? If so, show a non-blocking sequence of thread executions.

Repeat the previous question if the total number of C instances is 8 instead of 9.