CSE 451: Operating Systems

Section 6

Project 2b

Midterm

- Scores are up on Catalyst and midterms were handed back on Wednesday in class
- Talk to Ed or me (Elliott) about grading questions
  - Office hours are the best time for this

Project 2a learnings

- What sort of interesting behavior did you see in experimenting with test-burgers?
- What was the hardest part of the library to implement?

Project 2b

- Parts 4, 5 and 6 of project 2
- Due at 11:59pm, Friday May 18

Part 4: web server

- web/sioux.c – singlethreaded web server
  - Read in command line args, run the web server loop

Part 4: web server

- web/sioux_run.c – the web server loop
  - Open a socket to listen for connections (`listen(2)`)
  - Wait for a connection (`accept(2)`)
  - Handle connection:
    - Parse the HTTP request
    - Find and read the requested file
    - Send the file back
    - Close the connection

Thread pools

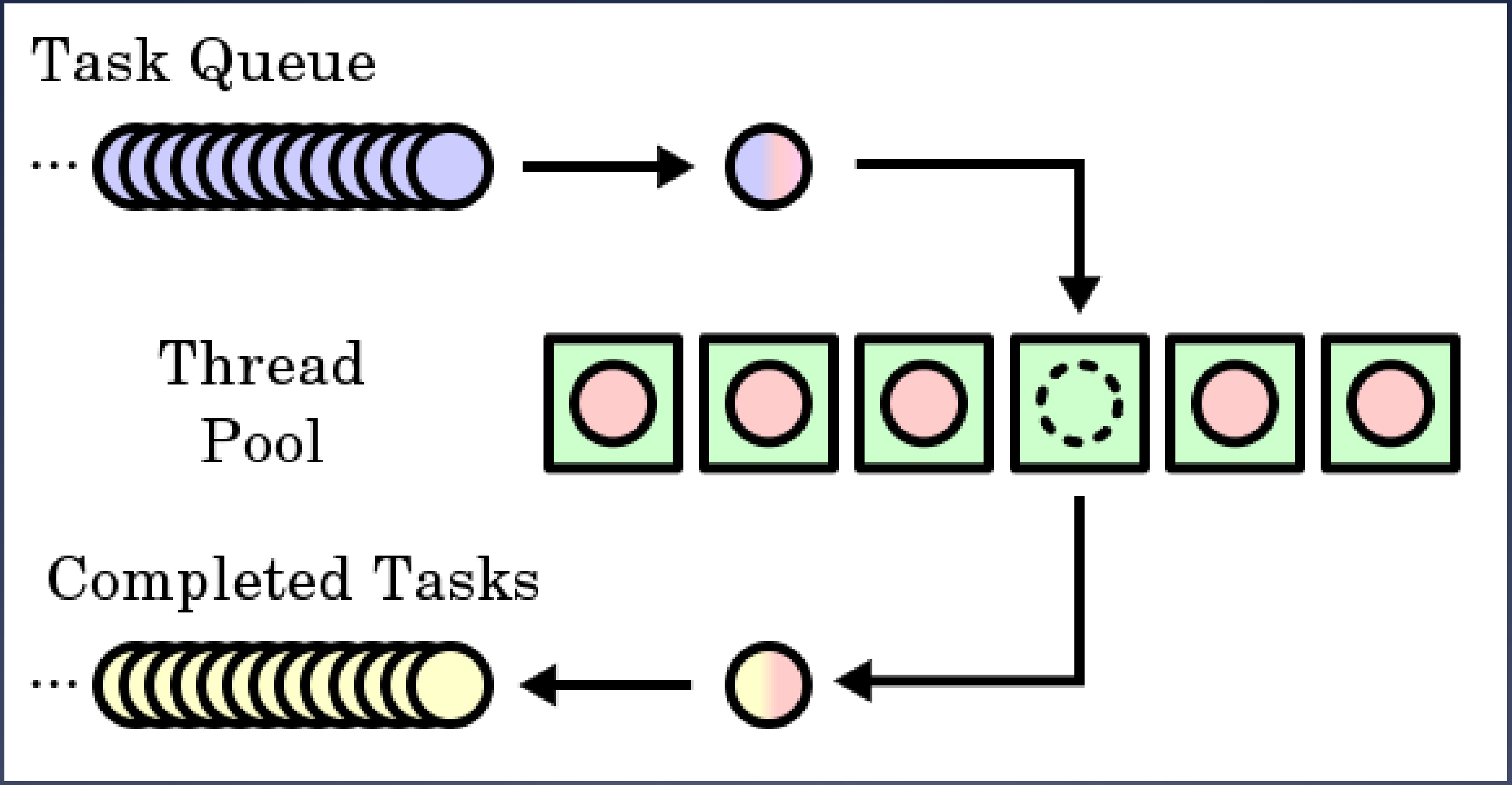

Image from http://en.wikipedia.org/wiki/Thread_pool_pattern
More info: http://www.ibm.com/developerworks/java/library/j-jtp0730.html

What you need to do

- Make the web server multithreaded
  - Create a thread pool
    - Suggestion: create separate thread_pool.h, thread_pool.c
  - Wait for a connection
  - Find an available thread to handle the request
    - Request waits (where?) if all threads busy
  - Once the request is handed to a thread, it uses the same processing code as before
  - See `web_runloop()` in sioux_run.c

Hints

* Each connection is identified by a socket file descriptor returned by `accept(2)`
  * File descriptor (fd) is just an int
* Threads should sleep while waiting for a new connection
  * Condition variables are perfect for this

Hints

* Don’t forget to protect any global variables
  * Use mutexes and CVs from part 2
* Develop and test with pthreads initially
* Use only the sthread.h interface
* Mostly modify sioux_run.c, and your own files

Part 5: preemption

- What we give you (see `sthread_preempt.c`):
  - Timer interrupts
  - Function to turn interrupts on and off
  - Synchronization primitives `atomic_test_and_set`, `atomic_clear`
    - x86/amd64 architectures only

Part 5: preemption

- What you have to do:
  - Add code that will run every time a timer interrupt is generated
  - Add synchronization to your part 1 and part 2 implementations so that everything works with preemptive thread scheduling
- Can be done independently of part 4

sthread_preempt.h

```
/* Start preemption - func will be called
 * every period microseconds
 */
void sthread_preemption_init
  (sthread_ctx_start_func_t func,
   int period);

/* Turns interrupts on (LOW) or off (HIGH)
 * Returns the last state of the
 * interrupts
 */
int splx(int splval);
```

sthread_preempt.h

```
/* atomic_test_and_set - using the native
 * compare and exchange on the Intel x86.
 *
 * Example usage:
 *   lock_t lock;
 *   while(atomic_test_and_set(&lock))
 *     {} // spin
 *   _critical section_
 *   atomic_clear(&lock);
 */
int atomic_test_and_set(lock_t *l);
void atomic_clear(lock_t *l);
```

Signals

- Used to notify processes of events asynchronously
- Every process has a *signal handler* table
- When a signal is sent to a process, OS interrupts that process and calls the handler registered for that signal

Signal manipulation

- A process can:
  - Override the default signal handlers using `sigaction(2)`
  - Block / unblock signals with `sigprocmask(2)`
  - Send a signal via `kill(2)`
- Signals:
  - `SIGINT (CTRL-C), SIGQUIT (CTRL-\), SIGKILL, SIGFPE, SIGALRM, SIGSEGV…`

What you need to do

* Add a call to sthread_preemption_init() as the last line in your sthread_user_init() function
  * sthread_preemption_init() takes a pointer to a function that will be called on each timer interrupt
    * This function should cause thread scheduler to switch to a different thread!

What you need to do

- Add synchronization to *critical sections* in thread management routines
  - Think: what would happen if the code was interrupted at this point?
    - Would it resume later with no problems?
    - Could the interrupting code mess with any variables that this code is currently using?
  - Don’t have to worry about simplethreads code that you didn’t write (i.e. sthread_switch): already done for you

What you need to do

- Before doing a context switch, interrupts should be disabled to avoid preemption. How can they be reenabled after the switch?
  - Hint: Think of the possible execution paths

Interrupt disabling

Non-thread-safe

```
/* returns next thread
 * on the ready queue */
sthread_t
sthread_user_next() {
  sthread_t next;
  next = sthread_dequeue

(ready_q);
  if (next == NULL)
    exit(0);
  return next;
}
```

Thread-safe

```
sthread_t
sthread_user_next() {
  sthread_t next;
  int old = splx(HIGH);
  next = sthread_dequeue
                (ready_q);
  splx(old);
  if (next == NULL)
    exit(0);
  return next;
}
```

Interrupt disabling

* Why do we call `splx(old)` after dequeuing instead of just `splx(LOW)`?

Thread-safe

```
sthread_t
sthread_user_next() {
  sthread_t next;
  int old = splx(HIGH);
  next = sthread_dequeue
              (ready_q);
  splx(old);
  if (next == NULL)
    exit(0);
  return next;
}
```

Atomic locking

- So what is `atomic_test_and_set()` for?
  - Primarily to implement higher-level synchronization primitives (mutexes, CVs)
- One way to think about preemption-safe thread library:
  - Disable/enable interrupts in “library” context
  - Use atomic locking in “application” context

Race conditions and testing

* How can you test your preemption code?
* How can you know that you've found all of the critical sections?

Part 6: report

- Covers *all* parts of project 2
- Discuss your design decisions
- Performance evaluation:
  - Measure throughput and response time of your web server using web benchmarking tool
    - Vary the number of threads and number of "clients"
  - Present results in *graphical* form
  - Explain results: expected or not?

Project 2 questions?