Section 4

CSE 451: Asst. 1 Preparation

Locks

- `lock_acquire(lock)`
  - Wait until lock is free, then take it
- `lock_release(lock)`
  - Release lock, waking up someone waiting for it (if any)

- At most one lock holder at a time (safety)
- If no one holding, acquire gets lock (progress)
- If all lock holders finish and no higher priority waiters, waiter eventually gets lock (progress)

Locks – Best Practices

- Lock is initially free
- Always acquire before accessing shared data structure
  - Beginning of procedure!
- Always release after finishing with shared data
  - End of procedure!
  - DO NOT throw lock for someone else to release
- Never access shared data without lock
  - Danger!

Lock Implementation - Multiprocessor

```
Lock::acquire() {
    disableInterrupts();
    spinlock.acquire();
    if (value == BUSY) {
        waiting.add(myTCB);
        suspend(&spinlock);
    } else {
        value = BUSY;
    }
    spinlock.release();
    enableInterrupts();
}
```

```
Lock::release() {
    disableInterrupts();
    spinlock.acquire();
    if (!waiting.Empty()) {
        next = waiting.remove();
        scheduler->makeReady(next);
    } else {
        value = FREE;
    }
    spinlock.release();
    enableInterrupts();
}
```

Spinlocks

- Processor waits in a loop for the lock to become free
  - Assumes lock will be held for a short time
  - Used to protect CPU scheduler and to implement waiting locks
- Uses read-modify-write instructions
  - Atomically read a value from memory, operate on it, and then write it back to memory
  - Intervening instructions prevented in hardware
- Need spinlocks to implement locks on multiprocessor machines
  - Turning off interrupts is not enough!

Condition Variables API

- Waiting inside a critical section
  - Called only when holding a lock

- `cv_wait(cv, lock)`
  - Atomically release lock and relinquish processor
  - Reacquire the lock when wakened
- `cv_signal(cv, lock)`
  - Wake up a waiter, if any
- `cv_broadcast(cv, lock)`
  - Wake up all waiters, if any

Condition Variables Cont.

- ALWAYS hold lock when calling wait, signal, broadcast
  - Condition variable is sync FOR shared state
  - ALWAYS hold lock when accessing shared state
- Condition variable is memoryless
  - If signal when no one is waiting, no op
- Wait atomically releases lock
  - What if wait, then release?
  - What if release, then wait?

Condition Variables Semantics

- When a thread is woken up from wait, it may not run immediately
  - Signal/broadcast puts thread(s) on ready list
  - When lock is released, anyone might acquire it
- Wait MUST be in a loop

```
while (need_to_wait()) {
     cv.wait(lock);
}
```

- Simplifies implementation
  - Of condition variables and locks
  - Of code that uses condition variables and locks

Wait Channels

- Primitive designed for holding sleeping threads
- Protected by a spinlock, not a lock
  - Caller must hold the spinlock for any wchan function call

- `wchan_sleep(wc, lk)`
  - Put the current thread to sleep and place it in the wchan
  - Spinlock is released upon sleep
- `wchan_wakeone(wc, lk)`
  - Pull a thread off of the wchan and place it in the ready list
- `wchan_wakeall(wc, lk)`
  - Pull all threads off of the wchan and place them in the ready list

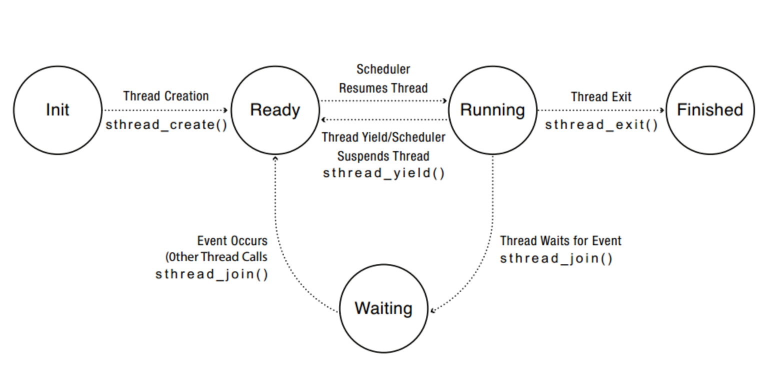
Semaphores

- Semaphores have a non-negative integer value
  - P() atomically waits for value to become > 0, then decrements
  - V() atomically increments value (waking up waiter if needed)
- Semaphores are like integers except:
  - Only operations are P and V
  - Operations are atomic
    - If value is 1, two P's will result in value 0 and one waiter
- Semaphores are useful for
  - "Stateful" wait: interrupt handlers, fork/join
  - But otherwise don't use them

General Synchronization Advice

- When to synchronize?
  - Modifying global variable in different threads
  - Protecting state during forced sleep (i.e. I/O)
- Pick the right primitives
  - Locks – Critical sections, modifying shared state
  - CVs – Waiting for a condition to be satisfied
  - Semaphores – Stateful waiting
  - Mix and match when necessary
- Organize and limit conflicts
  - Try to modularize code to minimize critical sections
  - Keep related synchronization close together
- When in doubt, draw pictures
  - Draw graphs of resources and consumers
  - List the order in which things are acquired
  - Look for inconsistent orders of acquisition and circular dependencies

Thread Lifecycle



- `thread_create(thread, func, args)`
  - Create a new thread to run `func(args)`
  - OS/161: `thread_fork()`
- `thread_yield()`
  - Relinquish processor voluntarily
- `thread_join(thread)`
  - In parent, wait for forked thread to exit, then return
  - OS/161: Your job
- `thread_exit(ret)`
  - Quit thread and clean up, wake up joiner if any

Thread Join

- Parent thread creates child thread and calls `thread_join()`
  - Enters the waiting list
  - Can only join on (joinable) child threads
    - Cannot join on detached threads
- When a child finishes, `thread_join()` returns
  - Parent enters the ready list
  - Can only join once
- What should happened if…
  - The parent joins before the child finishes?
  - The parent joins after the child finishes?
  - The parent joins just as the child is finishing?
  - The parent joins before the child even starts?

sys161.conf

- Specifies the simulated hardware you are running on
  - 31 mainboard ramsize=524288 cpus=1
- cpus specifies number of cores (1 to 4)
- ramsize specifies the amount of memory you have
  - Give yourself as much ram as you need. Right now, free does nothing. Nada. Zip.