More Synchronization; Concurrency in Java

CS 475, Spring 2018

Concurrent & Distributed Systems

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Review: Semaphores

- Synchronization tool that provides more sophisticated ways (than Mutex locks) for process to synchronize their activities.
- Semaphore S – integer variable
- Can only be accessed via two indivisible (atomic) operations
- wait(): consumes a resource (once available)
- signal(): release a resource

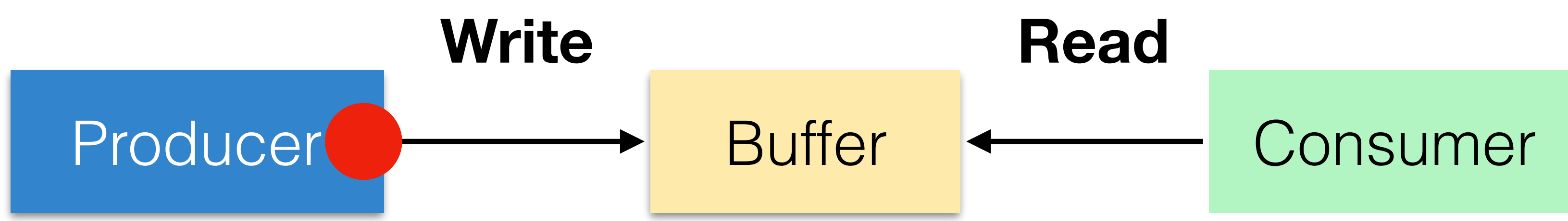
Review: Semaphores

- Implementation of wait and signal. Starting value is # of permits

```
wait(S):
    S.value--;
    if (S.value < 0) {
        enqueue(this,S.L);
        block();
    }

signal(S):
    S.value++;
    if (S.value <= 0) {
        Thread toWake = pop(s.L);
        wakeup(toWake);
}
```

Review: Bounded Buffer Example



Example: buffer can only hold 2 items

mutex = **0**	Makes sure buffer is viewed atomically
full = **2**	Represents number of full slots, tracks threads waiting to add more (if totally full)
empty = **0**	Represents number of empty slots, tracks threads waiting to read (if empty)

Review: Bounded Buffer Pseudocode

Producer

```
do {
    /* produce an item in next_produced */
    wait(empty);
    wait(mutex);
    /* add next produced to the buffer */
    signal(mutex);
    signal(full);
} while (true);
```

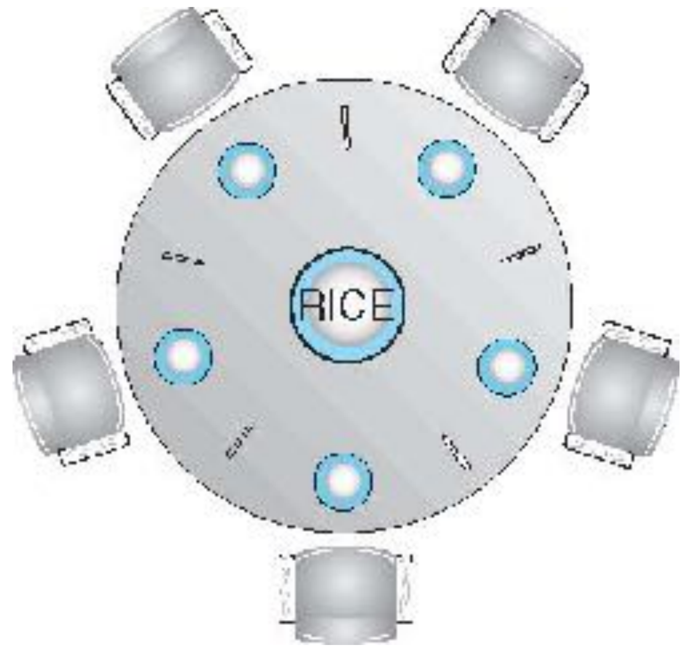
Consumer

```
do {
    wait(full);
    wait(mutex);
    /* remove an item from buffer to next_consumed */
    signal(mutex);
    signal(empty);
    /* consume the item in next consumed */
} while (true);
```

Starting state:

mutex =1	Makes sure buffer is viewed atomically
full = 0	Represents number of full slots, tracks threads waiting to add more (if totally full)
empty = 2	Represents number of empty slots, tracks threads waiting to read (if empty)

Review: Dining Philosophers



- Philosophers spend their lives alternating thinking and eating
- Don't interact with their neighbors, occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl
- Need both to eat, then release both when done
- In the case of 5 philosophers
- Solution: everybody acquires semaphores in the same order (even # seats pick up left first, right # seats pick up right first)

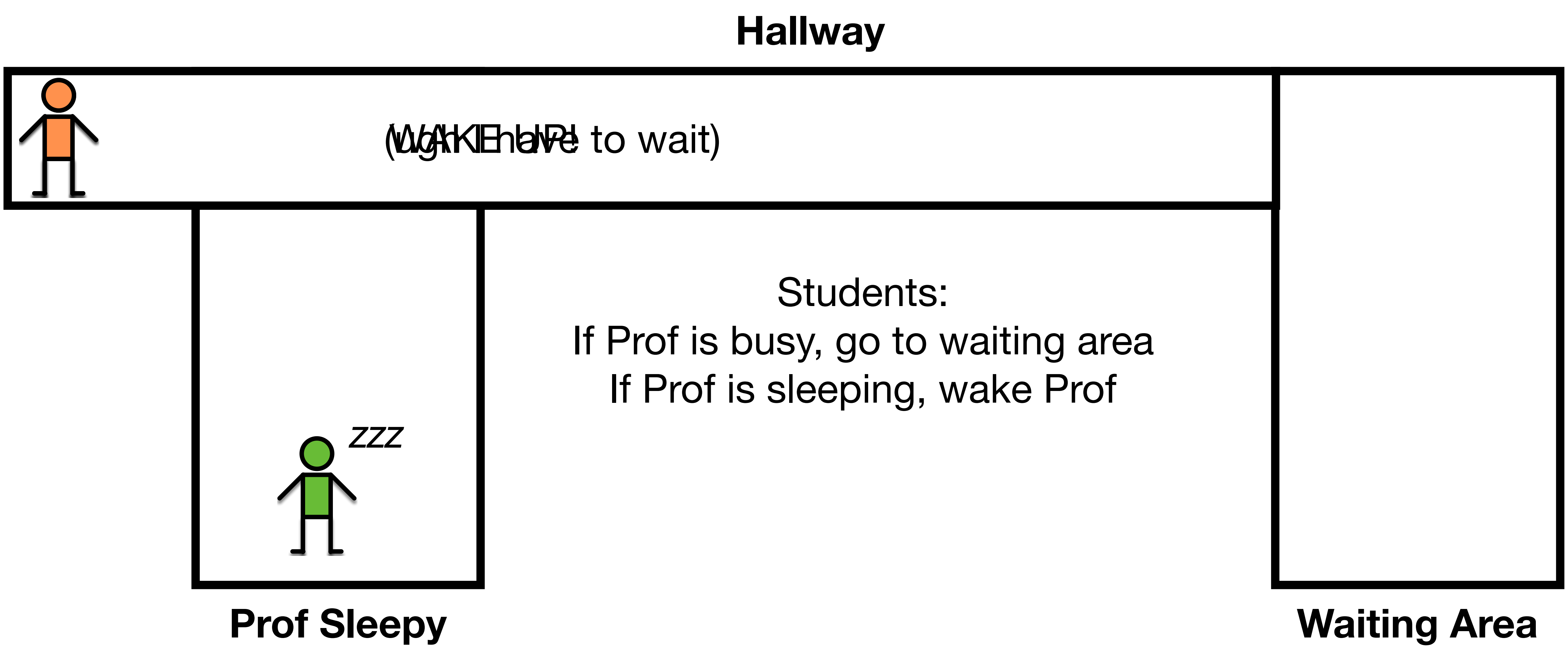
Announcements

- HW1 Discussion
  - Please complete brief poll on socrative.com (class CS475)
- Reminder: HW2 is out
  - http://www.jonbell.net/gmu-cs-475-spring-2018/homework-2/

Synchronization: The Sleeping Professor

- Professor Sleepy holds his office hours, and in between students, likes to take a nap
- Professor Sleepy has stressed to his students that if they see him sleeping - just wake him up, and he will be happy to help them
- Sometimes, there are a lot of students who want to see Professor Sleepy. If Professor Sleepy is busy when a student comes, that new student will go sit in the open area at the end of the hall
- When Professor Sleepy finishes with a student, he checks the waiting area, if there are no students, he takes a nap

The Sleeping Professor

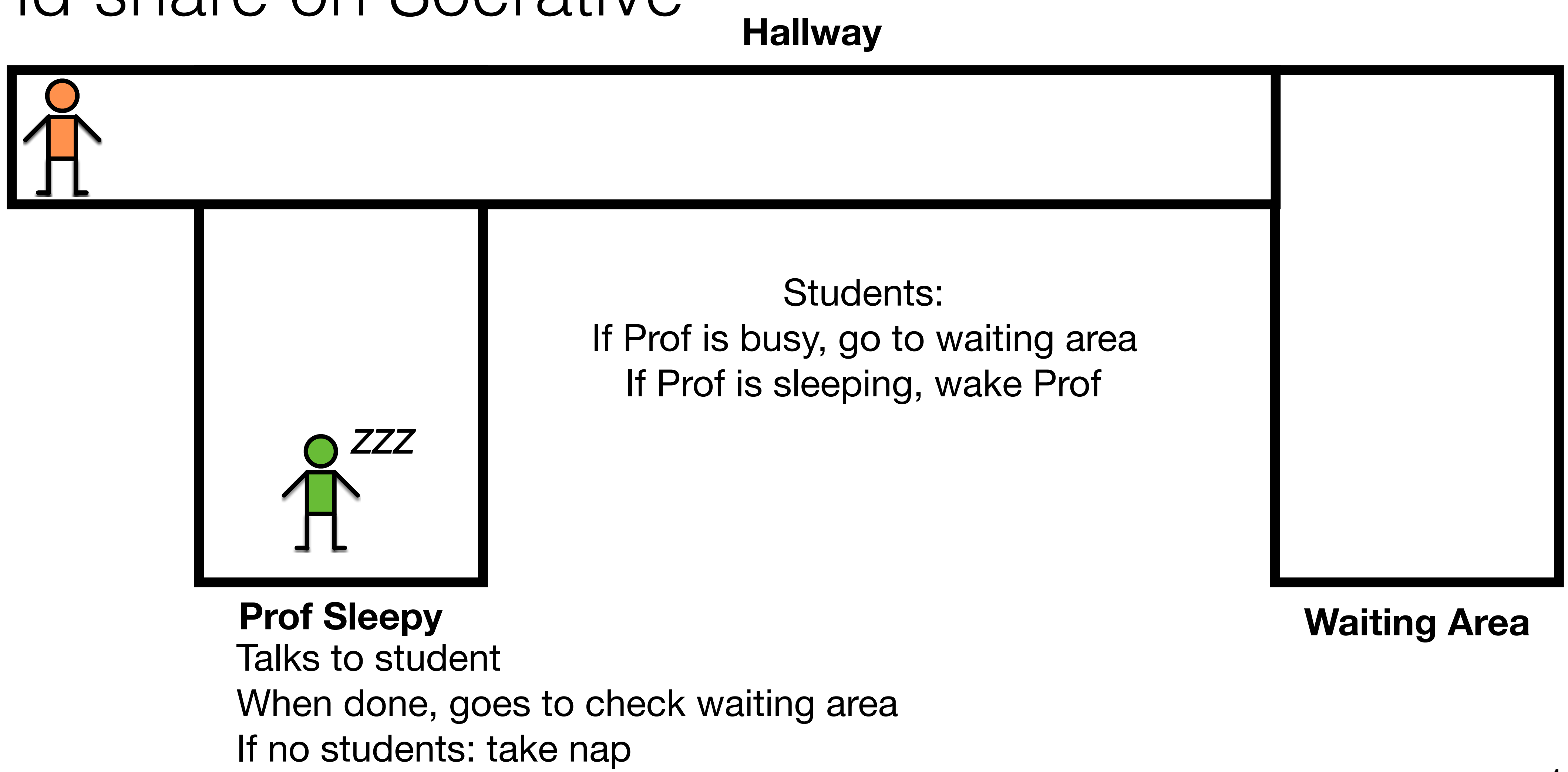


Students:
If Prof is busy, go to waiting area
If Prof is sleeping, wake Prof

Talks to student
When done, goes to check waiting area
If no students: take nap

Activity: The Sleeping Professor

- Go on socrative.com, class CS475
- Pair up in groups of 2-4
- There is a problem with this protocol. Discuss in your group and share on Socrative



High-level synchronization mechanisms

- Semaphores are a very powerful mechanism for process synchronization, but they are a low-level mechanism
- Several high-level mechanisms that are easier to use have been proposed
- Monitors (Condition variables and locks)
- Read/Write Locks
- Java and Pthreads provide both semaphores and high-level synchronization mechanisms
- NOTE: high-level mechanisms easier to use but equivalent to semaphores in power

Locking in Java

- Most locks are *reentrant*: if you hold it, and ask for it again, you don't have to wait (because you already have it)
- Basic primitives:
  - synchronized{}
  - wait
  - notify
- Plus…
  - Lock API… lock.lock(), lock.unlock()
  - The *preferred* way

Synchronized methods in Java

```java
public synchronized static void increment()
{
    i = i + 1;
}
```

Result: Before entering **increment()**, thread gets a lock on the Class object of **increment()**

wait and notify()

- Two mechanisms to enable coordination between multiple threads using the same monitor (target of synchronized)
- While holding a monitor on an object, a thread can **wait** on that monitor, which will temporarily release it, and put that thread to sleep
- Another thread can then acquire the monitor, and can **notify** a waiting thread to resume and re-acquire the monitor

wait and notify() example

Only one thread can be in put or take of the same queue

```
public class BlockingQueue<T> {

    private Queue<T> queue = new LinkedList<T>();
    private int capacity;

    public BlockingQueue(int capacity) {
        this.capacity = capacity;
    }

    public synchronized void put(T element) throws InterruptedException {
        while(queue.size() == capacity) {
            wait();
        }

        queue.add(element);
        notify(); // notifyAll() for multiple producer/consumer threads
    }

    public synchronized T take() throws InterruptedException {
        while(queue.isEmpty()) {
            wait();
        }

        T item = queue.remove();
        notify(); // notifyAll() for multiple producer/consumer threads
        return item;
    }
}
```

Synchronized methods in Java

```
public synchronized static void increment()
{
    i = i + 1;
}
```

Result: Before entering **increment()**, thread gets a lock on the Class object of **increment()**

```
public synchronized static void incrementOther()
{
    j = j + 1;
}
```

Result: Before entering **incrementOther()**, thread gets a lock on the Class object of **incrementOther()**

Problem?

Synchronized blocks in Java

- Can also use *any* object as that monitor

```
static Object someObject = new Object();
public static void increment()
{
    synchronized(someObject){
        i = i + 1;
    }
}
static Object someOtherObject = new Object();
public static void incrementOther()
{
    synchronized(someOtherObject){
        j = j + 1;
    }
}
```

Now, two different threads could call **increment()** and **incrementOther()** at the same time

Java Lock API

- **Synchronized** gets messy: what happens when you need to synchronize many operations? What if we want more complicated locking?
- **ReentrantLock**: same semantics as synchronized
- **ReadWriteLock**: allows many readers simultaneously, but writes are exclusive

```
static ReentrantLock lock = new ReentrantLock();
public static void increment()
{
    lock.lock();
    try{
        i = i + 1;
    } finally{
        lock.unlock();
    }
}
```

Java Lock API

```
static ReadWriteLock lock = new ReentrantReadWriteLock();
static int i;
public static void increment()
{
    lock.writeLock().lock();
    try{
        i = i + 1;
    } finally{
        lock.writeLock().unlock();
    }
}
public static int getI()
{
    lock.readLock().lock();
    try{
        return i;
    } finally{
        lock.readLock().unlock();
    }
}
```

Locking Granularity

- BIG design question in writing concurrent programs: how many locks should you have?
- Example: Distributed filesystem
  - It would be *correct* to block all clients from reading *any* file, when one client writes a file
  - However, this would not be performant at all!
  - It would be much better to instead lock on *individual files*
- *More locks -> more complicated semantics and tricky to avoid deadlocks, races*

Assignment 2 Discussion

- http://www.jonbell.net/gmu-cs-475-spring-2018/homework-2/

Roadmap

- Next week: More concurrency patterns, then networks!