Tutorial for coursework Part 2

UG3 Computer Communications & Networks (COMN)

Myungjin Lee
myungjin.lee@ed.ac.uk

Overview

- To understand the purpose of multithreading
- To describe Java's multithreading mechanism
- To explain concurrency issues caused by multithreading
- To outline synchronized access to shared resources

What is multithreading?

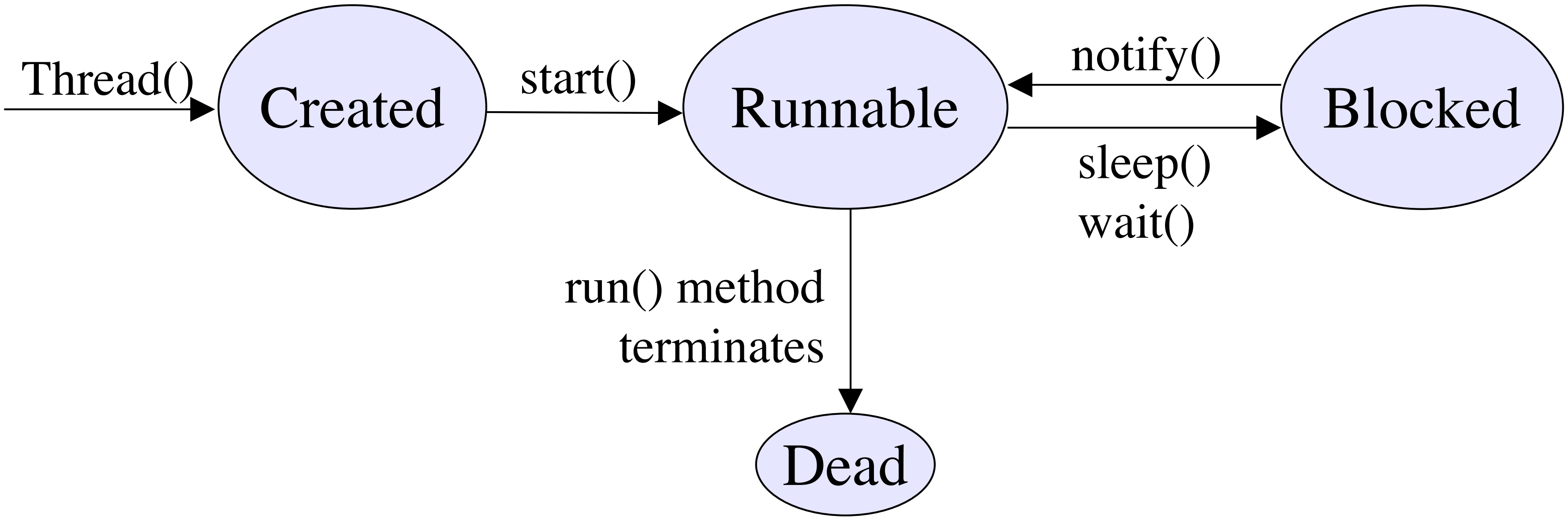
- Multithreading is similar to multi-processing
- A multi-processing OS can run several processes at the same time
  - Each process has its own address/memory space
  - Separate processes to not have access to each other's memory space
- In a multithreaded application, there are several points of execution within the same memory space
  - Each point of execution is called a thread
  - Threads share access to memory

Thread Support in Java

- The Java Virtual machine has its own runtime threads
  - Used for garbage collection
- Threads are represented by a Thread class
  - A thread object maintains the state of the thread
  - It provides control methods such as interrupt, start, sleep, yield, wait
- When an application executes, the main method is executed by a single thread
  - If the application requires more threads, the application must create them

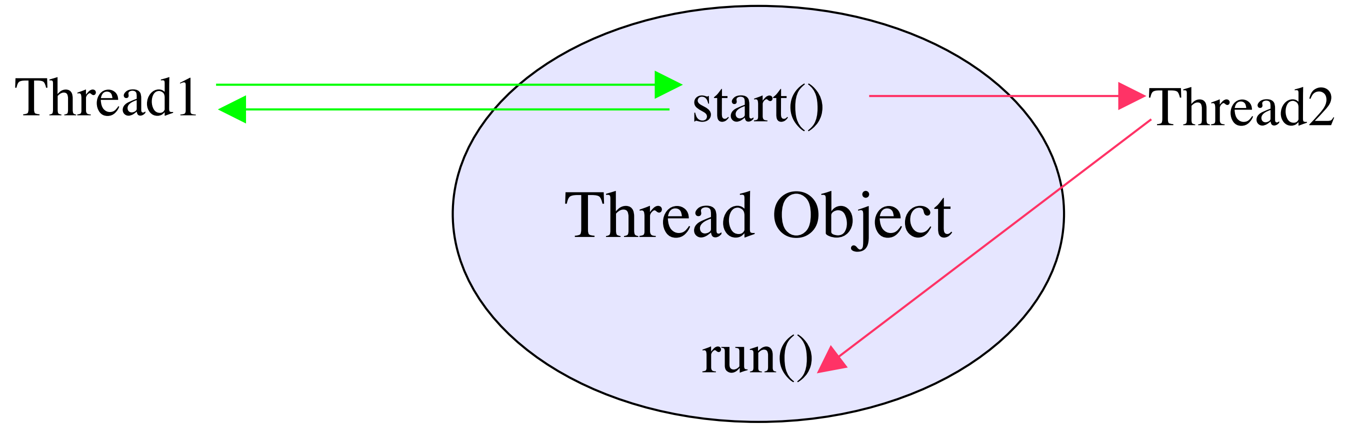
Thread States

- Threads can be in one of four states
  - Created, Running, Blocked, and Dead
- A thread's state changes based on:
  - Control methods such as start, sleep, yield, wait, notify
  - Termination of the run method



How does a thread run?

- The thread class has a run() method
  - run() is executed when the thread's start() method is invoked
- The thread terminates if the run method terminates
  - run() method often has an endless loop to prevent thread termination
- One thread starts another by calling its start method

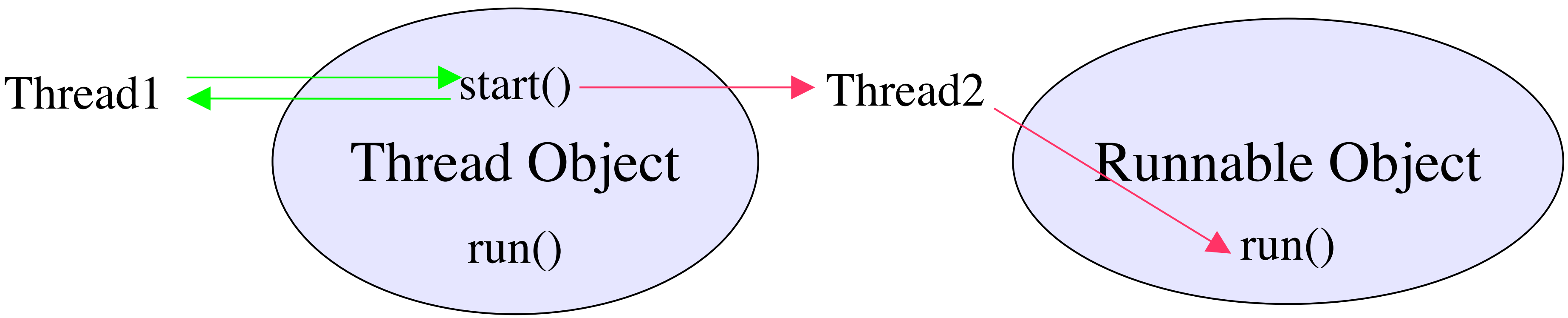


Creating your own Threads

- A way to create your own threads is to subclass the Thread class and then override the run() method
  - This is the easiest way to do it although not recommended
- The object which provides the run method is usually a subclass of some other class
  - If it inherits from another class, it cannot inherit from Thread
- The solution to this problem is Runnable interface
  - Runnable defines one method - public void run()
  - Thread class constructor can take a reference to a Runnable object
  - When the thread is started, it invokes the run method in the runnable object instead of its own run method

Using Runnable

- When the Thread object is instantiated, it is passed a reference to a "Runnable" object
  - The Runnable object must implement the “run” method
- When the thread object receives a start message, it checks if it has a reference to a Runnable object:
  - If it does, it runs the "run" method of that object
  - If not, it runs its own "run" method



Example Code

```
public class thdexp1 {
    public static int count = 0;
    private static class MyThread implements Runnable {
        public void run() {
            while (count <= 10) {
                System.out.println("MyThread: " + count++);
                try {
                    Thread.sleep (100);
                } catch (InterruptedException e) {}
            }
        }
    }
```

Example Code

```
    public static void main(String[] args) {
        System.out.println ("Starting Main Thread...");
        MyThread mythd = new MyThread();
        Thread t = new Thread (mythd);
        t.start();
        while (count <= 10) {
            System.out.println ("MainThread: " + count++);
            try {
                Thread.sleep (100);
            } catch (InterruptedException e) {}
        }
    }
}
```

Creating Multiple Threads

- The previous example illustrates a Runnable class which creates its own thread when the start method is invoked

- To create multiple threads, one could simple create multiple instances of the Runnable class and send each object a start message
  - Each instance would create its own thread object

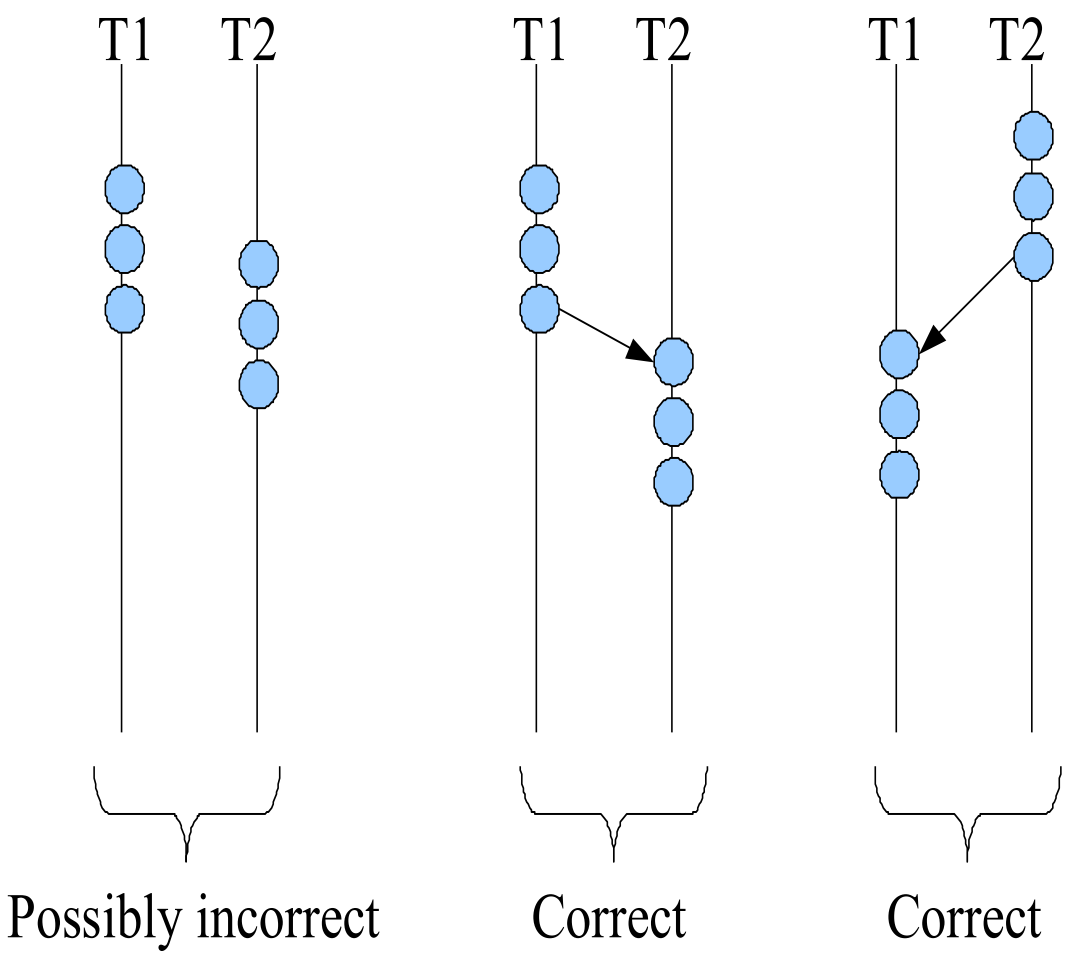
Synchronization

Critical Sections / Mutual Exclusion

- Sequences of instructions that may get incorrect results if executed simultaneously are called critical sections
- (We also use the term race condition to refer to a situation in which the results depend on timing)
- Mutual exclusion means "not simultaneous"
  - A < B or B < A
  - We don't care which
- Forcing mutual exclusion between two critical section executions is sufficient to ensure correct execution – guarantees ordering
- One way to guarantee mutually exclusive execution is using locks

Critical sections

→ *is the "happens-before" relation*



When do critical sections arise?

- One common pattern:
  - read-modify-write of
  - a shared value (variable)
  - in code that can be executed concurrently
- Shared variable:
  - Globals and heap-allocated variables
  - NOT local variables (which are on the stack)

Example: shared bank account

- Suppose we have to implement a function to withdraw money from a bank account:

```
int withdraw(account, amount) {
  int balance = get_balance(account);    // read
  balance -= amount;         // modify
  put_balance(account, balance);     // write
  spit out cash;
}
```

- Now suppose that you and your partner share a bank account with a balance of $100.00
  - what happens if you both go to separate ATM machines, and simultaneously withdraw $10.00 from the account?

- Assume the bank's application is multi-threaded
- A random thread is assigned a transaction when that transaction is submitted

```
int withdraw(account, amount) {
  int balance = get_balance(account);
  balance -= amount;
  put_balance(account, balance);
  spit out cash;
}
```

```
int withdraw(account, amount) {
  int balance = get_balance(account);
  balance -= amount;
  put_balance(account, balance);
  spit out cash;
}
```

Interleaved schedules

- The problem is that the execution of the two threads can be interleaved, assuming preemptive scheduling:

Execution sequence as seen by CPU

```
balance = get_balance(account);
balance -= amount;
```

context switch

```
balance = get_balance(account);
balance -= amount;
put_balance(account, balance);
spit out cash;
```

context switch

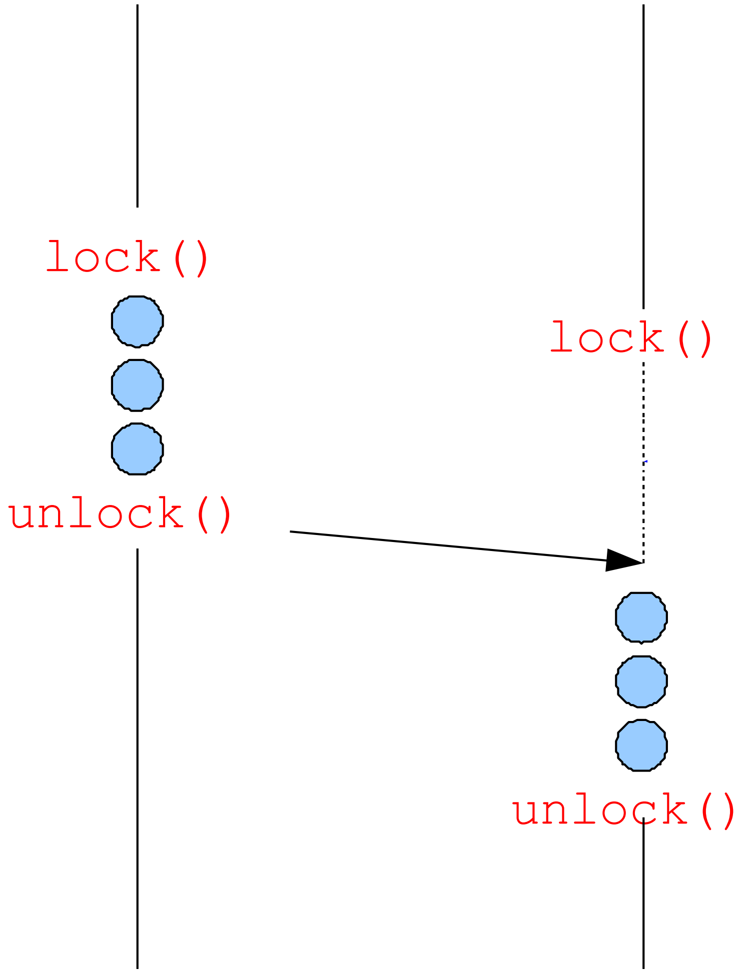
```
put_balance(account, balance);
spit out cash;
```

- What's the account balance after this sequence?
  - who's happy, the bank or you?

Locks

- A lock is a memory object with two operations:
  - `acquire()`: obtain the right to enter the critical section
  - `release()`: give up the right to be in the critical section
- `acquire()` prevents progress of the thread until the lock can be acquired
- Note: terminology varies: acquire/release, lock/unlock

Locks: Example



Java Synchronization Mechanism

- Java has a keyword called synchronized
- In Java, every object has a lock
  - To obtain the lock, you must synchronize with the object
- The simplest way to use synchronization is by declaring one or more methods to be synchronized

Example 1

```
public class SavingsAccount
{
  private float balance;

  public synchronized void withdraw(float anAmount)
  {
      if ((anAmount>0.0) && (anAmount<=balance))
           balance = balance - anAmount;
  }

  public synchronized void deposit(float anAmount)
  {
      if (anAmount>0.0)
           balance = balance + anAmount;
  }
```

Example 2

```
public class SavingsAccount {
  private float balance;

  public void withdraw(float anAmount) {
    if (anAmount<0.0)
      throw new IllegalArgumentException("Withdraw amount negative");
    synchronized(this) {
      if (anAmount<=balance)
        balance = balance - anAmount;
    }
  }

  public void deposit(float anAmount) {
    if (anAmount<0.0)
      throw new IllegalArgumentException("Deposit amount negative");
    synchronized(this) {
      balance = balance + anAmount;
    }
  }
```

Example Codes

thdexp1.java and thdexp2.java
from

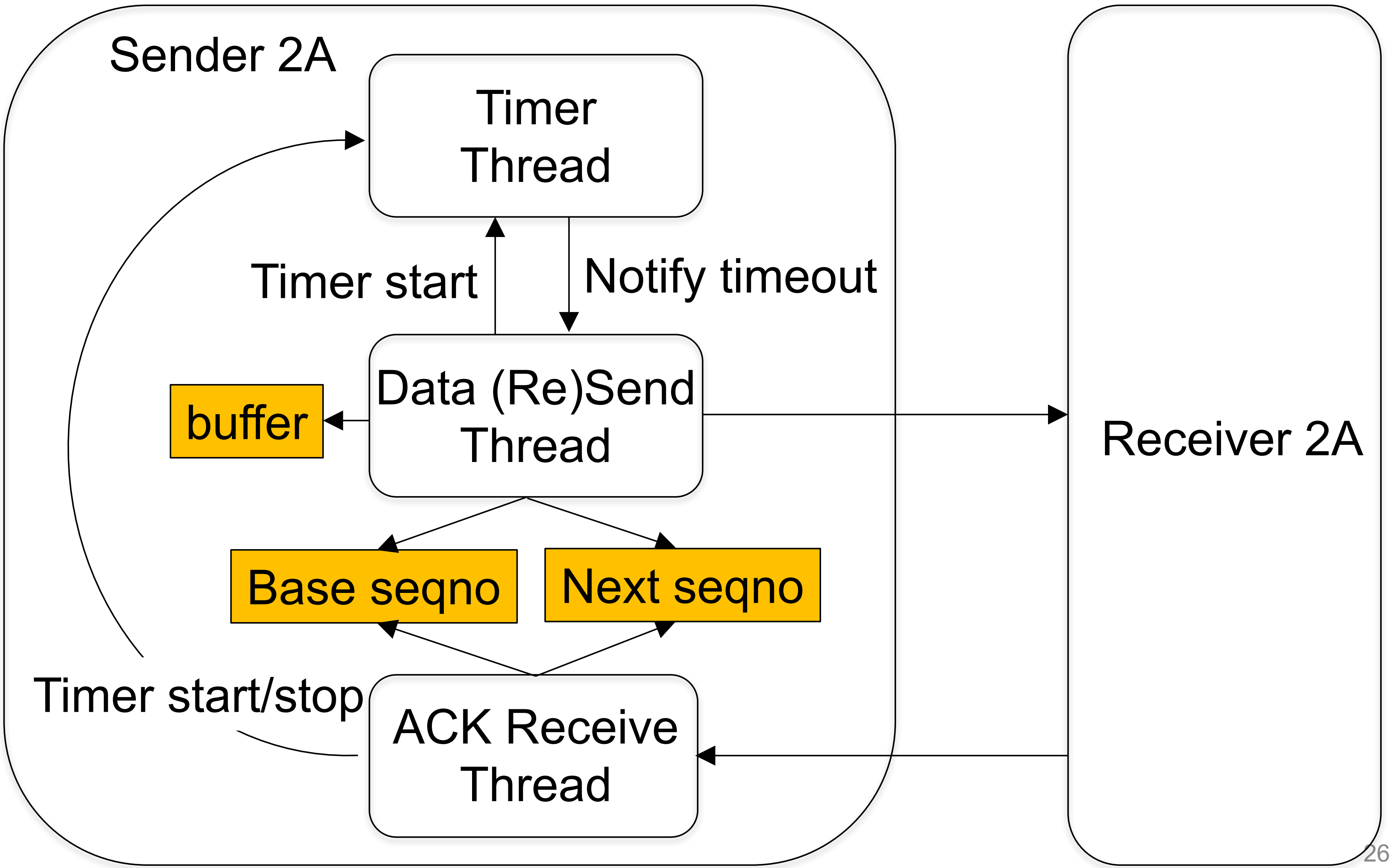
https://drive.google.com/open?id=0B6rUEJFM3QjTWUUxT2E0WHFNOWc

Design choices for Part 2

- Both sender and receiver are implementable without multithreading
  – Definitely no need for multithreading at the receiver side
  – Multithreading may be useful for sender implementation

- Many design choices for the sender are possible

Sketch of one design for Part 2A



Sketch of one design for Part 2B