

CNT 4714 – Project 2 – Spring 2022

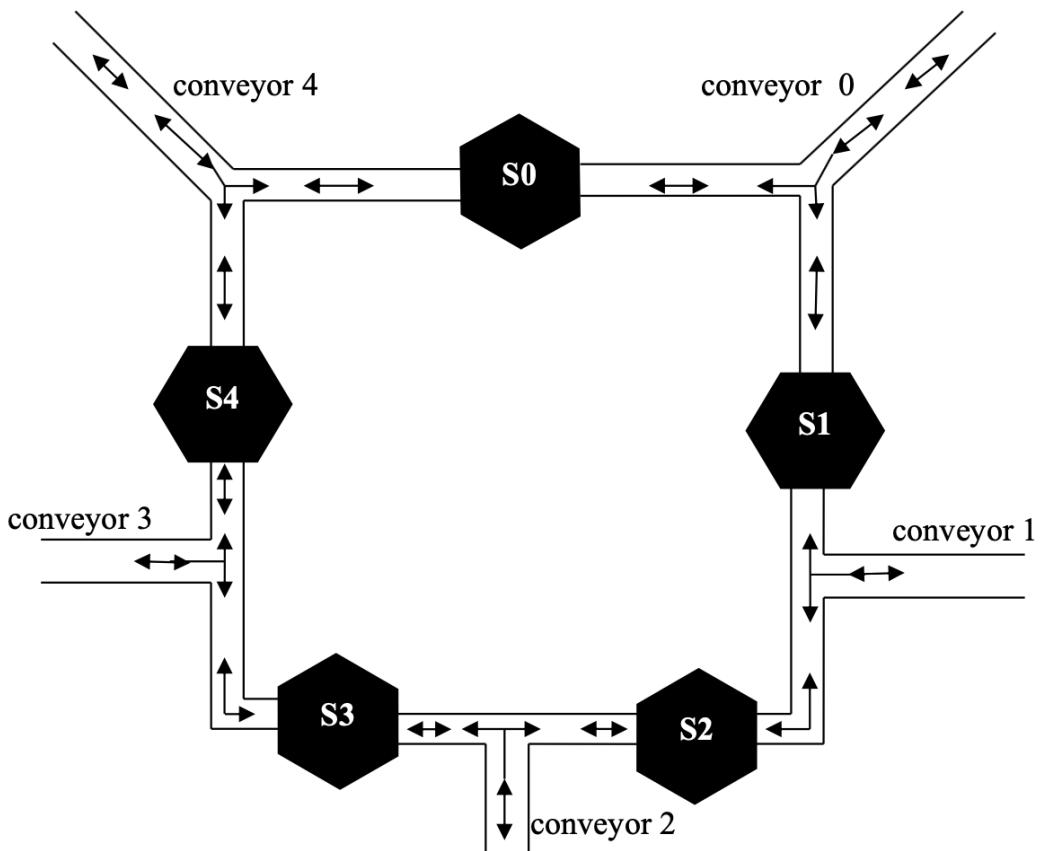
Title: “Project 2: Multi-threaded Programming in Java”

Points: 100

Due Date: Sunday February 13, 2022 by 11:59pm WebCourses time

Objectives: To practice programming an application with multiple threads of execution and synchronizing their access to necessary shared objects.

Description: In this programming assignment you will simulate the package shipping management system for an automated package shipping operation similar to the one depicted here:



This example package shipping operation has five routing stations (S0 – S4), each of which has an input and output conveyor connecting to conveyor lines (C0 – C4) that go elsewhere in the system. Resources were limited when the system was built so each conveyor going to the rest of the facility must be shared between two routing stations. Since each routing station simultaneously needs an input and output connection to function, access to the shared conveyor lines must be strictly regulated. Flow direction is not important in our simulation.

You have been hired to design a simulator for a new package management system being built with the same design, but possibly fewer/more stations. You are to implement this simulator in Java and

have each routing station function in its own thread. A routing station moves packages from one of its connected conveyors to the other. A station's workload is the number of times that a routing station will move packages. There are a varied and unspecified number of packages in a package group and each station will have different workloads (number of package groups). A station must have exclusive access to the requested input and output conveyors during movement of packages. A station will move packages for a random amount of time to simulate the random number of packages in each group. Once a station has moved all of the packages in one group, it will reduce its total workload by 1 and go into an idle state (i.e., sleeping) for a random period of time before moving its next package group. A routing station thread terminates when its workload reaches 0.

To prevent deadlock from occurring, you must ensure that each routing station acquires the necessary locks in increasing numerical order (serial order).

Restrictions:

1. Your source files should begin with comments containing the following information:

```
/*
```

```
Name: <your name goes here>
```

```
Course: CNT 4714 Spring 2022
```

```
Assignment title: Project 2 – Multi-threaded programming in Java
```

```
Date: February 13, 2022
```

```
Class: <name of class goes here>
```

```
*/
```

2. You must use the `java.util.concurrent.locks.ReentrantLock` interface. In other words, do not create your own locking system nor implement a Boolean semaphore-like system to control the locking.
3. **Do not** use a monitor to control the synchronization in your program (i.e., do not use the Java synchronize statement).
4. You must use an `ExecutorService` object to manage a `FixedThreadPool(MAX)`, where `MAX` is the upper limit on the number of stations which we'll set to be 10 (see below under Input Specification).
5. Your station threads must implement the `Runnable` interface and not extend the `Thread` class in order to utilize the `ExecutorService` object mentioned in 4 above.

Input Specification:

Your program must initially read from a text file (`config.txt`) to gather configuration information for the simulator. The first line of the text file will be the number of routing stations to use during the simulation. Afterwards, there will be one line for each station. These lines will hold the workload value for each station (i.e, the number of times it needs to move packages on the conveyor system). Only use integers in your configuration file, decimals will not be needed. You can assume that the maximum number of stations will be 10.

Output Specification:

Your simulator must output **at least** the following text to let the user know what the simulator is doing in each of these situations:

1. An input conveyor is assigned to a routing station:
Routing Station X: Input conveyor set to conveyor number Cn.
2. An output conveyor is assigned to a routing station:
Routing Station X: Output conveyor set to conveyor number Cn.
3. A routing station's workload is set:
Routing Station X: Workload set. Station X has a total of n package groups to move.
4. A routing station is granted access to its input conveyor:
Routing Station X: holds lock on input conveyor Cn.
5. A routing station is granted access to its output conveyor:
Routing Station X: hold lock on output conveyor Cn.
6. A routing station unlocks its input conveyor:
Routing Station X: unlocks/releases input conveyor Cn.
7. A routing station unlocks its output conveyor:
Routing Station X: unlocks/releases output conveyor Cn.
8. A routing station unable to lock its output conveyor and releases its input conveyor lock:
Routing Station X: unable to lock output conveyor Cn, unlocks input conveyor Cm.
9. A routing station has completed its workload:
*** * Station X: Workload successfully completed. * * Station X releasing locks and going offline * ***
10. A routing station successfully moves packages in and out of the routing station:
Routing Station X: CURRENTLY HARD AT WORK MOVING PACKAGES.
11. A routing station completes a workflow:
Routing Station X: has n package groups left to move.

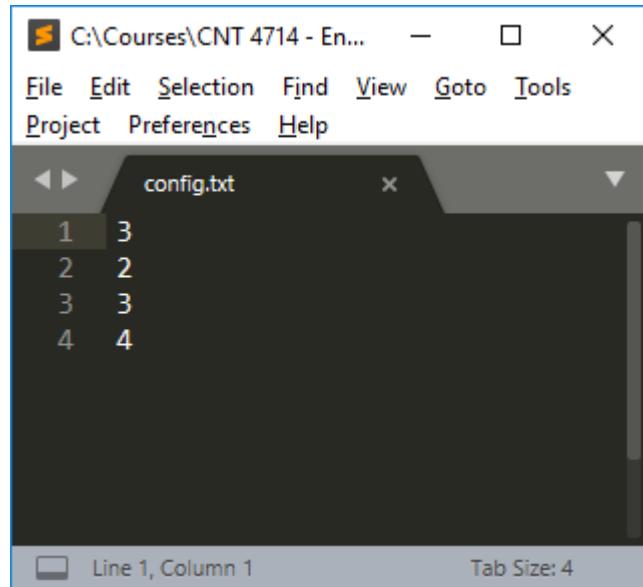
Deliverables:

Submit the following items via WebCourses no later than 11:59pm February 13, 2022.

- (1) All of your .java files.
- (2) A copy of a sample execution of your program, i.e., the output produced by your simulator (this should just be a text file). In your IDE redirect console output to a file, do this and include a complete copy of the output file produced by your application for a sample run using the sample configuration file shown below.

Additional Information:

Actual simulation run in Eclipse (console output redirected in this example) with **config.txt** containing **3 2 3 4**, is shown below.



The screenshot shows a dark-themed Eclipse console window titled "config.txt". The window contains the following text:

```
1 3
2 2
3 3
4 4
```

The status bar at the bottom indicates "Line 1, Column 1" and "Tab Size: 4".

The next several pages show a sample simulation run output.

```
eclipse-workspace-2021-12 - CNT 4714 - Project 2 - Spring 2022/src/PackageManagementFacilitySimulator.java - Eclipse IDE
Console X
<terminated> NileDotCom [Java Application] /Library/Java/JavaVirtualMachines/jdk-17.jdk/Contents/Home/bin/java (Jan 30, 2022, 2:13:12 PM – 2:13:15 PM)
[Console output redirected to file:/Users/marklewellyn/CNT 4714 – Spring 2022/PROJECTS/Project 2/simulation-output.txt]

***** PACKAGE MANAGEMENT FACILITY SIMULATION BEGINS *****

Routing Station 0 Has Total Workload Of 2
Routing Station 1 Has Total Workload Of 3
Routing Station 2 Has Total Workload Of 4

% % % % % ROUTING STATION 0 Coming Online – Initializing Conveyors % % % % %

Routing Station 0: Input conveyor set to conveyor number C0.

% % % % % ROUTING STATION 1 Coming Online – Initializing Conveyors % % % % %

Routing Station 1: Input conveyor set to conveyor number C1.
Routing Station 1: Output conveyor set to conveyor number C0.
Routing Station 1: Workload set. Station 1 has a total of 3 package groups to move.

Routing Station 1: Now Online

Routing Station 1: Entering Lock Acquisition Phase.
Routing Station 1: holds lock on input conveyor C1.
Routing Station 1: holds lock on output conveyor C0.

***** Routing Station 1: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 1: successfully moves packages into station on input conveyor C1.
Routing Station 1: successfully moves packages out of station on output conveyor C0.

Routing Station 1: has 2 package groups left to move.

% % % % % ROUTING STATION 2 Coming Online – Initializing Conveyors % % % % %

Routing Station 2: Input conveyor set to conveyor number C2.
Routing Station 2: Output conveyor set to conveyor number C1.
Routing Station 2: Workload set. Station 2 has a total of 4 package groups to move.

Routing Station 2: Now Online
```

```
Routing Station 2: Entering Lock Acquisition Phase.  
Routing Station 2: holds lock on input conveyor C2.  
Routing Station 2: unable to lock output conveyor C1 - unlocks input conveyor C2.  
Routing Station 0: Output conveyor set to conveyor number C2.  
Routing Station 0: Workload set. Station 0 has a total of 2 package groups to move.
```

Routing Station 0: Now Online

```
Routing Station 0: Entering Lock Acquisition Phase.  
Routing Station 2: holds lock on input conveyor C2.  
Routing Station 2: unable to lock output conveyor C1 - unlocks input conveyor C2.  
Routing Station 1: Entering Lock Release Phase.  
Routing Station 1: unlocks/releases input conveyor C1.  
Routing Station 1: unlocks/releases output conveyor C0.  
Routing Station 1: Entering Lock Acquisition Phase.  
Routing Station 1: holds lock on input conveyor C1.  
Routing Station 1: holds lock on output conveyor C0.
```

* * * * * Routing Station 1: holds locks on both input conveyor C1 and output conveyor C0. * * * * *

* * * * * Routing Station 1: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

```
Routing Station 1: successfully moves packages into station on input conveyor C1.  
Routing Station 1: successfully moves packages out of station on output conveyor C0.
```

Routing Station 1: has 1 package groups left to move.

```
Routing Station 2: holds lock on input conveyor C2.  
Routing Station 2: unable to lock output conveyor C1 - unlocks input conveyor C2.  
Routing Station 1: Entering Lock Release Phase.  
Routing Station 1: unlocks/releases input conveyor C1.  
Routing Station 1: unlocks/releases output conveyor C0.  
Routing Station 1: Entering Lock Acquisition Phase.  
Routing Station 1: holds lock on input conveyor C1.  
Routing Station 1: unable to lock output conveyor C0 - unlocks input conveyor C1.  
Routing Station 0: holds lock on input conveyor C0.  
Routing Station 0: holds lock on output conveyor C2.
```

* * * * * Routing Station 0: holds locks on both input conveyor C0 and output conveyor C2. * * * * *

* * * * * Routing Station 0: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 0: successfully moves packages into station on input conveyor C0.
Routing Station 0: successfully moves packages out of station on output conveyor C2.

Routing Station 0: has 1 package groups left to move.

Routing Station 1: holds lock on input conveyor C1.
Routing Station 1: unable to lock output conveyor C0 - unlocks input conveyor C1.
Routing Station 1: holds lock on input conveyor C1.
Routing Station 1: unable to lock output conveyor C0 - unlocks input conveyor C1.
Routing Station 1: holds lock on input conveyor C1.
Routing Station 1: unable to lock output conveyor C0 - unlocks input conveyor C1.
Routing Station 0: Entering Lock Release Phase.
Routing Station 0: unlocks/releases input conveyor C0.
Routing Station 0: unlocks/releases output conveyor C2.
Routing Station 0: Entering Lock Acquisition Phase.
Routing Station 2: holds lock on input conveyor C2.
Routing Station 2: holds lock on output conveyor C1.

* * * * * Routing Station 2: holds locks on both input conveyor C2 and output conveyor C1. * * * * *

* * * * * Routing Station 2: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 2: successfully moves packages into station on input conveyor C2.
Routing Station 2: successfully moves packages out of station on output conveyor C1.

Routing Station 2: has 3 package groups left to move.

Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.
Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.
Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.
Routing Station 2: Entering Lock Release Phase.
Routing Station 2: unlocks/releases input conveyor C2.
Routing Station 2: unlocks/releases output conveyor C1.
Routing Station 2: Entering Lock Acquisition Phase.
Routing Station 2: holds lock on input conveyor C2.
Routing Station 2: holds lock on output conveyor C1.

* * * * * Routing Station 2: holds locks on both input conveyor C2 and output conveyor C1. * * * * *

* * * * * Routing Station 2: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 2: successfully moves packages into station on input conveyor C2.
Routing Station 2: successfully moves packages out of station on output conveyor C1.

Routing Station 2: has 2 package groups left to move.

Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.
Routing Station 2: Entering Lock Release Phase.
Routing Station 2: unlocks/releases input conveyor C2.
Routing Station 2: unlocks/releases output conveyor C1.
Routing Station 2: Entering Lock Acquisition Phase.
Routing Station 1: holds lock on input conveyor C1.
Routing Station 1: holds lock on output conveyor C0.

* * * * * Routing Station 1: holds locks on both input conveyor C1 and output conveyor C0. * * * * *

* * * * * Routing Station 1: * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 1: successfully moves packages into station on input conveyor C1.
Routing Station 1: successfully moves packages out of station on output conveyor C0.

Routing Station 1: has 0 package groups left to move.

Routing Station 2: holds lock on input conveyor C2.
Routing Station 2: unable to lock output conveyor C1 - unlocks input conveyor C2.

Routing Station 1: WORKLOAD SUCCESSFULLY COMPLETED. * * * Routing Station 1 preparing to go offline. # # # #

Routing Station 1: Entering Lock Release Phase.
Routing Station 1: unlocks/releases input conveyor C1.
Routing Station 1: unlocks/releases output conveyor C0.

@ @ @ @ @ ROUTING STATION 1: OFF LINE @ @ @ @ @

Routing Station 2: holds lock on input conveyor C2.
Routing Station 2: holds lock on output conveyor C1.

* * * * * Routing Station 2: holds locks on both input conveyor C2 and output conveyor C1. * * * * *

* * * * * Routing Station 2: * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 2: successfully moves packages into station on input conveyor C2.
Routing Station 2: successfully moves packages out of station on output conveyor C1.

Routing Station 2: has 1 package groups left to move.

Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.
Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.
Routing Station 2: Entering Lock Release Phase.
Routing Station 2: unlocks/releases input conveyor C2.
Routing Station 2: unlocks/releases output conveyor C1.
Routing Station 2: Entering Lock Acquisition Phase.
Routing Station 2: holds lock on input conveyor C2.
Routing Station 2: holds lock on output conveyor C1.

* * * * * Routing Station 2: holds locks on both input conveyor C2 and output conveyor C1. * * * * *

* * * * * Routing Station 2: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 2: successfully moves packages into station on input conveyor C2.
Routing Station 2: successfully moves packages out of station on output conveyor C1.

Routing Station 2: has 0 package groups left to move.

Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: unable to lock output conveyor C2 - unlocks input conveyor C0.

Routing Station 2: WORKLOAD SUCCESSFULLY COMPLETED. * * * Routing Station 2 preparing to go offline. # # # #

Routing Station 2: Entering Lock Release Phase.
Routing Station 2: unlocks/releases input conveyor C2.
Routing Station 2: unlocks/releases output conveyor C1.

@ @ @ @ @ ROUTING STATION 2: OFF LINE @ @ @ @ @

Routing Station 0: holds lock on input conveyor C0.
Routing Station 0: holds lock on output conveyor C2.

* * * * * Routing Station 0: holds locks on both input conveyor C0 and output conveyor C2. * * * * *

* * * * * Routing Station 0: * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *

Routing Station 0: successfully moves packages into station on input conveyor C0.

Routing Station 0: successfully moves packages out of station on output conveyor C2.

Routing Station 0: has 0 package groups left to move.

Routing Station 0: WORKLOAD SUCCESSFULLY COMPLETED. * * * Routing Station 0 preparing to go offline. # # # #

Routing Station 0: Entering Lock Release Phase.

Routing Station 0: unlocks/releases input conveyor C0.

Routing Station 0: unlocks/releases output conveyor C2.

@ @ @ @ @ ROUTING STATION 0: OFF LINE @ @ @ @ @

* * * * * * * * * ALL WORKLOADS COMPLETE * * * PACKAGE MANAGEMENT FACILITY SIMULATION ENDS * * * * * * * * *

First part of the simulation output as redirected from the console to an output file and viewed via Sublime.

```
simulation-output.txt ~/CNT 4714 - Spring 2022/PROJECTS/Project 2/simulation-output.txt

1 | * * * * * PACKAGE MANAGEMENT FACILITY SIMULATION BEGINS * * * * *
2 |
3 |
4 Routing Station 0 Has Total Workload Of 2
5 Routing Station 1 Has Total Workload Of 3
6 Routing Station 2 Has Total Workload Of 4
7
8
9
10 % % % % ROUTING STATION 0 Coming Online - Initializing Conveyors % % % %
11
12 Routing Station 0: Input conveyor set to conveyor number C0.
13
14 % % % % ROUTING STATION 1 Coming Online - Initializing Conveyors % % % %
15
16 Routing Station 1: Input conveyor set to conveyor number C1.
17 Routing Station 1: Output conveyor set to conveyor number C0.
18 Routing Station 1: Workload set. Station 1 has a total of 3 package groups to move.
19
20
21 Routing Station 1: Now Online
22
23
24 Routing Station 1: Entering Lock Acquisition Phase.
25 Routing Station 1: holds lock on input conveyor C1.
26 Routing Station 1: holds lock on output conveyor C0.
27
28 * * * * Routing Station 1: holds locks on both input conveyor C1 and output conveyor C0. * * * *
29
30
31 * * * * * Routing Station 1: * * * * CURRENTLY HARD AT WORK MOVING PACKAGES * * * * *
32
33 Routing Station 1: successfully moves packages into station on input conveyor C1.
34 Routing Station 1: successfully moves packages out of station on output conveyor C0.
35
36
37 Routing Station 1: has 2 package groups left to move.
38
39
40
41 % % % % ROUTING STATION 2 Coming Online - Initializing Conveyors % % % %
```