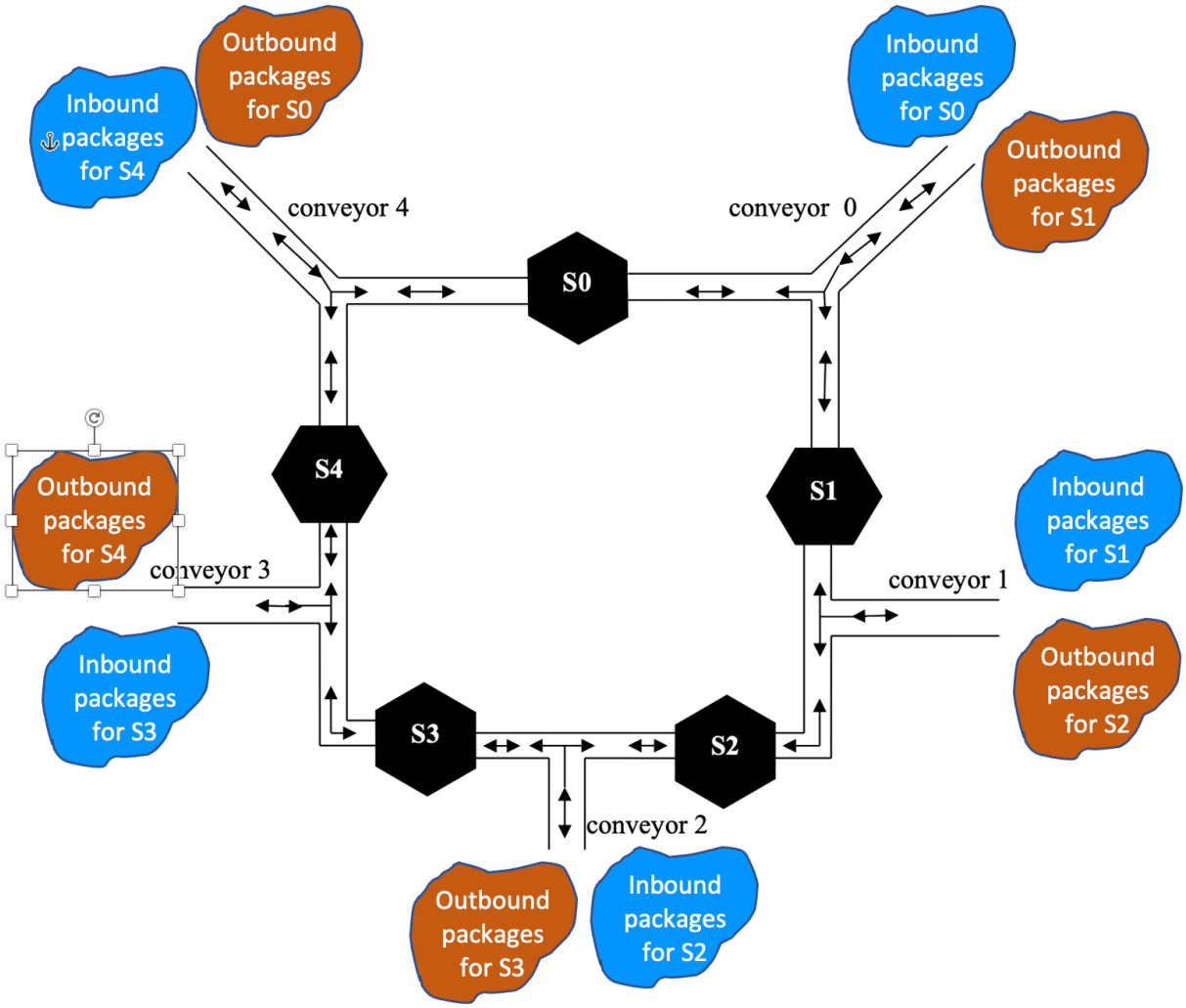
CNT 4714 – Project 2 – Fall 2022

Title: "Project 2: Multi-threaded Programming in Java"
Points: 100
Due Date: Sunday October 2, 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 project you will simulate a package routing 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. A single conveyor is shared by two stations as packages are moved from one part of the facility to another. 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 in not important in our simulation, so we can fix a flow direction, as shown in the diagram above.

A routing station moves groups of packages from one of its connected conveyors to the other. In other words, a station moves a group of packages from its "Input" side to its "Output" side. A station's workload is the number of times that a routing station will move groups of 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 a movement of packages. Two adjacent routing stations cannot be moving packages at the same time. For example, in the diagram above, Station S0 cannot be working (moving packages) at the same time as either Station 4 or Station 1 is moving packages, as Station S0 shares conveyor 4 with Station S4 and shares conveyor 0 with Station S1.

Since the package groups that a station moves vary in size, each station will move packages for some random amount of time to simulate the random number of packages in each group. Moving packages is considered to be a workflow. 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 using modulo arithmetic).

Restrictions:

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

```
/*
        Name: <your name goes here>
        Course: CNT 4714 Fall 2022
        Assignment title: Project 2 – Multi-threaded programming in Java
        Date:  October 2, 2022

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

2. You must use a 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 Has Total Workload of n Package Groups.`

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: holds 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.`
   `SYNCHRONIZATION ISSUE: Station n currently holds the lock on output conveyor Cn – releasing lock on input conveyor CX.`

9. A routing station has completed its workload:
   `# # Station X: Workload successfully completed. * * Station X preparing to go 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:

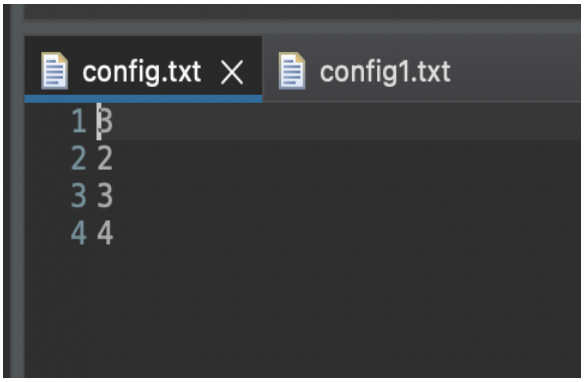
Submit the following items via WebCourses no later than 11:59pm October 2, 2022.

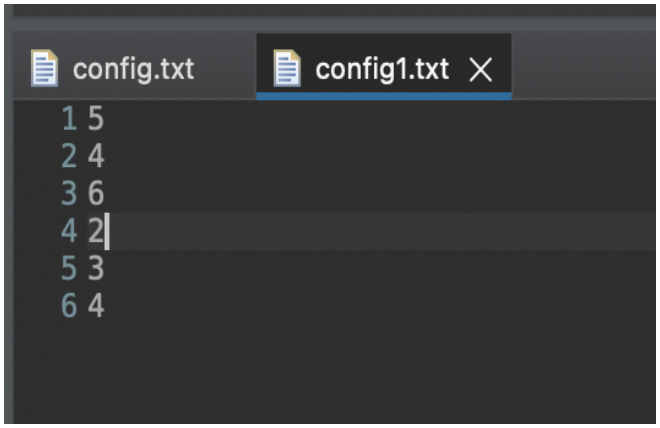
(1) All of your `.java` files.

(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. Note that this must be a complete simulation run with a minimum of three stations in the simulation. This is not a screenshot of a partial simulation run.

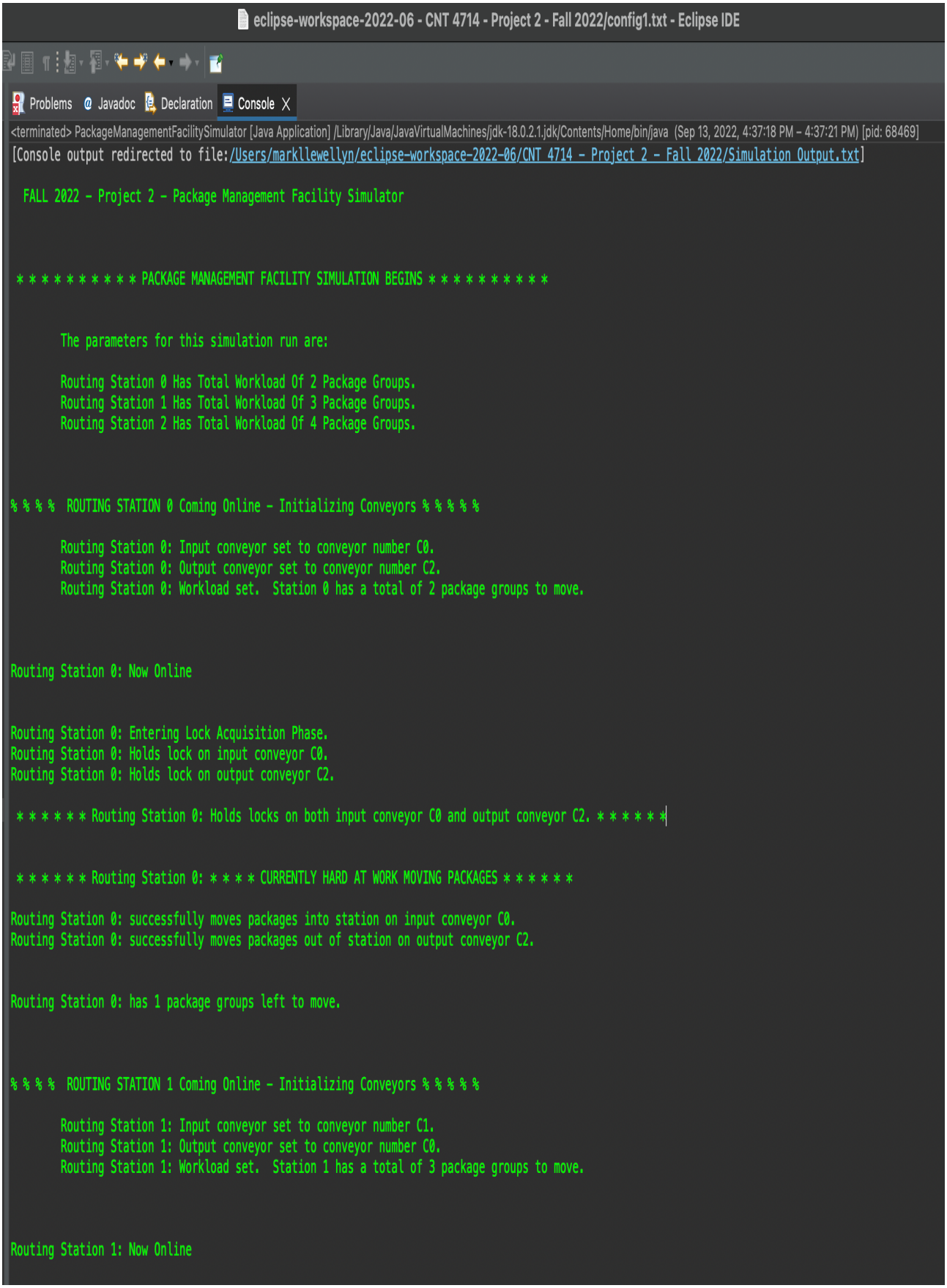
Additional Information:

Shown below are two different input files that you can use when developing your project.
An actual simulation run in Eclipse (console output redirected in this example) with **`config.txt` containing 3 2 3 4**, is shown starting on page 5.





The next several pages show a sample simulation run output using the config.txt file.


eclipse-workspace-2022-06 - CNT 4714 - Project 2 - Fall 2022/config1.txt - Eclipse IDE
Problems
Javadoc
Declaration
Console
<terminated> PackageManagementFacilitySimulator [Java Application] /Library/Java/JavaVirtualMachines/jdk-18.0.2.1.jdk/Contents/Home/bin/java (Sep 13, 2022, 4:37:18 PM – 4:37:21 PM) [pid: 68469]
[Console output redirected to file:/Users/markllewellyn/eclipse-workspace-2022-06/CNT 4714 - Project 2 - Fall 2022/Simulation Output.txt]
FALL 2022 - Project 2 - Package Management Facility Simulator
* * * * * * * * * * PACKAGE MANAGEMENT FACILITY SIMULATION BEGINS * * * * * * * * * *
The parameters for this simulation run are:
Routing Station 0 Has Total Workload Of 2 Package Groups.
Routing Station 1 Has Total Workload Of 3 Package Groups.
Routing Station 2 Has Total Workload Of 4 Package Groups.
% % % % ROUTING STATION 0 Coming Online - Initializing Conveyors % % % % %
Routing Station 0: Input conveyor set to conveyor number C0.
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 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 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

```
<terminated> PackageManagementFacilitySimulator [Java Application] /Library/Java/JavaVirtualMachines/jdk-18.0.2.1.jdk/Contents/Home/bin/java  (Sep 13, 2022, 4:37:18 PM – 4:37:21 PM) [pid: 68469]


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. SYNCHRONIZATION ISSUE: Station 0 currently holds the lock on output conveyor C0 – releasing lock on input conveyor C1.


%%%%  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 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 0: Holds lock on input conveyor C0.
Routing Station 0: Unable to lock output conveyor C2. SYNCHRONIZATION ISSUE: Station 2 currently holds the lock on output conveyor C2 – releasing lock on input conveyor C0.

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 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.
```

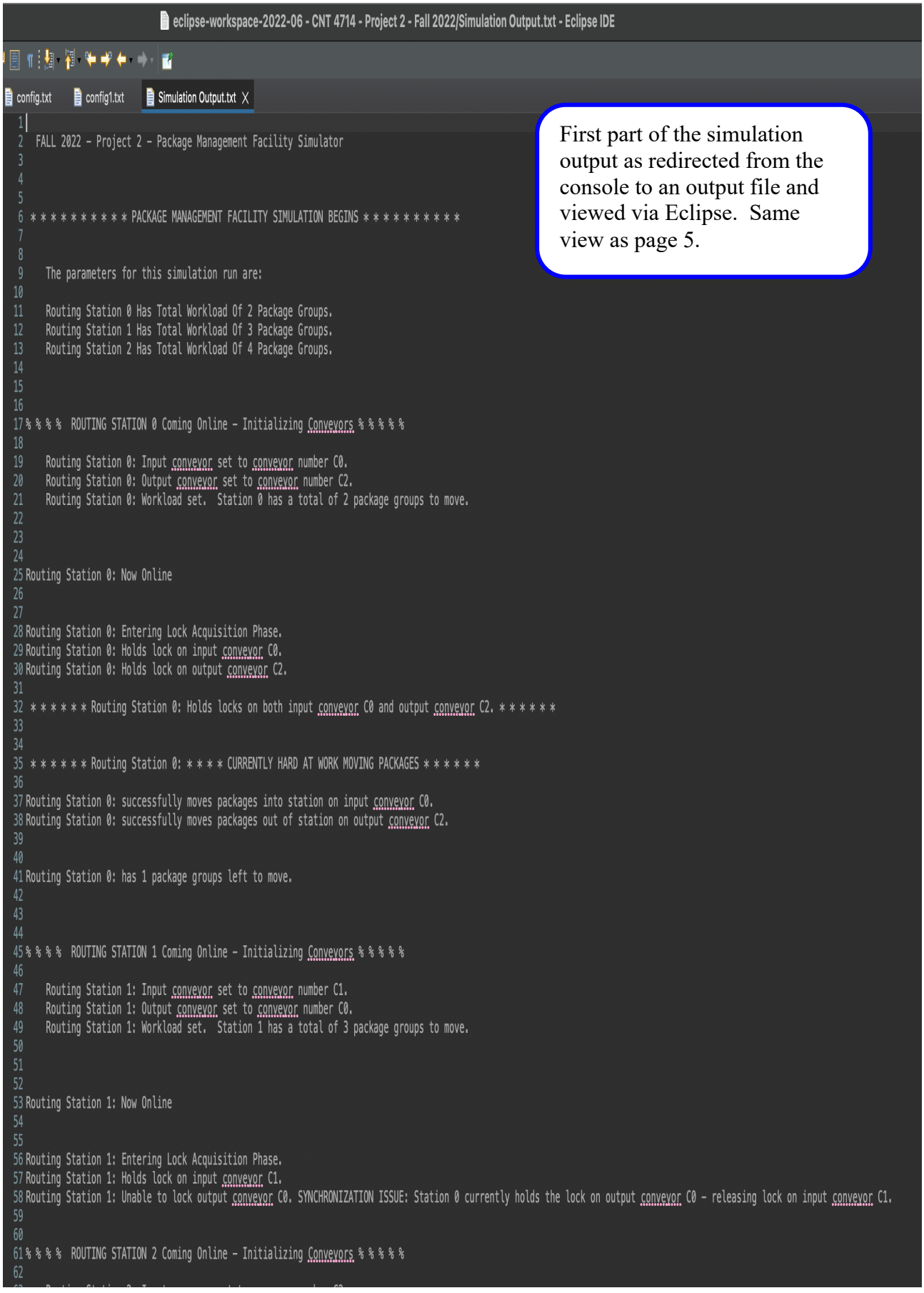
```
<terminated> PackageManagementFacilitySimulator [Java Application] /Library/Java/JavaVirtualMachines/jdk-18.0.2.1.jdk/Contents/Home/bin/java  (Sep 13, 2022, 4:37:18 PM – 4:37:21 PM) [pid: 68469]


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


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 1 package groups left to move.


Routing Station 0: Holds lock on input conveyor C0.
Routing Station 0: Unable to lock output conveyor C2. SYNCHRONIZATION ISSUE: Station 2 currently holds the lock on output conveyor C2 - releasing lock on 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 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 2 package groups left to move.


Routing Station 2: Unable to lock output conveyor C1. SYNCHRONIZATION ISSUE: Station 1 currently holds the lock on output conveyor C1 - releasing lock on input conveyor C2.

Routing Station 1: Entering Lock Release Phase.
Routing Station 1: Unlocks/releases 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. ******
```

```
<terminated> PackageManagementFacilitySimulator [Java Application] /Library/Java/JavaVirtualMachines/jdk-18.0.2.1.jdk/Contents/Home/bin/java  (Sep 13, 2022, 4:37:18 PM – 4:37:21 PM) [pid: 68469]

 * * * * * * 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 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. SYNCHRONIZATION ISSUE: Station 0 currently holds the lock on output conveyor C0 – releasing lock on input conveyor C1.


 # # # # # 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 going off line – work completed!




 @ @ @ @ @ @ ROUTING STATION 0: 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 0 package groups left to move.



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

```
<terminated> PackageManagementFacilitySimulator [Java Application] /Library/Java/JavaVirtualMachines/jdk-18.0.2.1.jdk/Contents/Home/bin/java  (Sep 13, 2022, 4:37:18 PM – 4:37:21 PM) [pid: 68469]


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 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 going off line - work completed!




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


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 0 package groups left to move.



 # # # # # 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 going off line - work completed!



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


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


  * % * % * % SIMULATION ENDS % * % * % *
```

First part of the simulation output as redirected from the console to an output file and viewed via Sublime. Same view as page 5.



First part of the simulation output as redirected from the console to an output file and viewed via Eclipse. Same view as page 5.