Further Java Ticklet 3*

In order to gain a star in the mark sheet you must complete this exercise. Completing the exercise does not gain you any credit in the examination. In Workbook 3 you wrote SafeMessageQueue, a queue which permitted concurrent access by multiple producers and consumers. In your implementation, each producer and consumer obtained a lock on the SafeMessageQueue object before adding or removing items from the queue. When there are more than 2 items in the queue, it’s possible for the producers and consumers to work truly concurrently since they should not interfere with one another, but this requires careful use of two locks: one on the first element of the linked list and one on the last. It turns out that, since Java supports an atomic compare-and-set instruction, you can even write a safe implementation with no locks! In this exercise you will provide a two lock and a no lock implementation of a variant of the MessageQueue interface.

A two-lock version of SafeMessageQueue cannot use the wait-notify paradigm, since the wait-notify paradigm requires any producer or consumer to acquire a single shared lock in Java. (Recall that you must call the wait and notify methods inside a synchronized statement in Java otherwise the JVM will throw a java.lang.IllegalMonitorStateException at runtime.) As a consequence you will need to support the following non-blocking API:

```
package uk.ac.cam.crsid.fjava.tick3star;

public interface ConcurrentQueue<T> {
    public void offer(T message); //Add "message" to queue
    public T poll();              //Return first item from queue or null if empty
}
```

1. Start by forking then cloning the ticklet3star repository to your local machine. Remember to change crsid in `uk.ac.cam.crsid.fjava.tick3star` to match your CRSID.

2. Using SafeMessageQueue from Ticklet 3 as a guide, complete your implementation of OneLockConcurrentQueue to implement the ConcurrentQueue interface instead of the MessageQueue interface. (You should keep the methods offer and poll synchronised just as take and put are so this implementation uses only a single, shared lock.)

3. Test your implementation of OneLockConcurrentQueue by using ConcurrentQueueTest in the repository.

It turns out that fine-grained locking strategies and no-locking strategies are very hard to get right, therefore you should base your implementations on the pseudocode in the paper Simple, Fast, and Practical Non-Blocking and Blocking Concurrent Queue Algorithms by Maged M. Michael and Michael L. Scott.¹ This paper is written for languages which do not have a garbage collector (e.g. C or C++) and therefore there are a couple of points in the paper which you can ignore. Firstly, any reference to free in the paper can be safely ignored since the JVM will garbage collect unused memory on your behalf. Secondly, the function called CAS in the paper (an atomic compare-and-set operator) takes four arguments:

```
CAS(a, b, c, d)
```

which means set a to c iff a equals b. (The argument d is used for version counting, and is not necessary in your implementation since Java has a garbage collector.) In your Java implementation you should use the class java.util.concurrent.atomic.AtomicReference. You can create a new instance as follows:

¹This URL contains the paper together with PDF comments which clarify a couple of parts of the original paper: http://www.cs.rochester.edu/u/scott/papers/1996.Podc_queues.pdf; original paper here https://dl.acm.org/citation.cfm?id=248106
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**AtomicReference ar = new AtomicReference(a);**

You can then do the equivalent of the **CAS** function as follows:

```java
ar.compareAndSet(b, c)
```

which updates `ar` to point to `c` iff `a` equals `b`.

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4. **Complete the implementation of** `TwoLockConcurrentQueue` **which implements the** `ConcurrentQueue` **interface and which supports fine-grained locking by locking on the first and last Link items in the queue as suggested in Figure 2 of the paper.**

5. **Complete the implementation of** `NoLockConcurrentQueue` **which implements the** `ConcurrentQueue` **interface and which uses no locks by making use of the** `AtomicReference` **class in** `java.util.concurrent.atomic`. **An outline of the code required is given in Figure 1 of the paper.**

6. **Test your implementation of** `TwoLockConcurrentQueue` **and** `NoLockConcurrentQueue` **by using** `ConcurrentQueueTest`.

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**Submission**

When you are satisfied you have completed everything, you should commit all outstanding changes and push these to the Gogs server. On the Gogs server, check that the latest version of your files are in the repository, and once you are happy click the **Test results** button at the top of the web page and schedule your code for testing. You can resubmit as many times as you like and there is no penalty for re-submission. If, after waiting one hour, you have not received any response you should notify ticks1b-admin@cl.cam.ac.uk of the problem. You should submit a version of your code which successfully passes the automated checks by the deadline, so don’t leave it to the last minute!