

Chapter 5: Fault Injection

After implementing the necessary changes from Deliverable 4, the team set to work finding potential faults in the ThreadSafeCircularFifoQueue.java program. Throughout all of the methods being tested and the associated internal methods that are called by these methods, the following changes to the code will produce the following changes in the test cases, with pictures of the output when that change is triggered.

Change 1 - In line 353, in the toArray method, changing the conditional from "if (result.length > size) {" to "if (result.length >= size) {" will trigger an off-by-one error and populate the final space with a null value in all toArray test cases, causing them all to fail.

```
Date and Time Test Ran: 23/11/2020 22:59:36 EST
Test Case ID: TC011
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: toArray
Test Arguments: 48, 20, 57
Expected Result: {48, 20, 57}
Test Result: {48, 20, null}
Test case FAILED. Result of the test is not the expected result.
```

```
Date and Time Test Ran: 23/11/2020 22:59:41 EST
Test Case ID: TC012
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: toArray
Test Arguments: 22, 47, 20, 57
Expected Result: {22, 47, 20, 57}
Test Result: {22, 47, 20, null}
Test case FAILED. Result of the test is not the expected result.
```

```
Date and Time Test Ran: 23/11/2020 22:59:46 EST
Test Case ID: TC013
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: toArray
Test Arguments: 48, 99, 57
Expected Result: {48, 99, 57}
Test Result: {48, 99, null}
Test case FAILED. Result of the test is not the expected result.
```

```
Date and Time Test Ran: 23/11/2020 22:59:51 EST
Test Case ID: TC014
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: toArray
Test Arguments: 8, 11
Expected Result: {8, 11}
Test Result: {8, null}
Test case FAILED. Result of the test is not the expected result.
```

```
Date and Time Test Ran: 23/11/2020 22:59:56 EST
Test Case ID: TC015
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: toArray
Test Arguments: 48, 20, 57, 77, 30
Expected Result: {48, 20, 57, 77, 30}
Test Result: {48, 20, 57, 77, null}
Test case FAILED. Result of the test is not the expected result.
```

Change 2 - In line 160, in the containsAll method, changing the logical operator from "||" to "&&" in the conditional will trigger a failed null check in test case 24, which results in a failure for this test case.

Date and Time Test Ran: 23/11/2020 23:11:19 EST

Test Case ID: TC023

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 4710, 3094} {390, 4709}

Expected Result: false

Test Result: false

Test case **PASSED**.

Date and Time Test Ran: 23/11/2020 23:11:24 EST

Test Case ID: TC024

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 10} null

Expected Result: true

Test Result:

Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 23/11/2020 23:11:29 EST

Test Case ID: TC025

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 40, 10} {390, 40, 10}

Expected Result: true

Test Result: true

Test case **PASSED**.

Change 3 - In line 422, in the internalContains method, which is called by both "contains" and "containsAll," changing the ".equals" comparator to the "==" triggers a fault in test cases 5 and 25 only.

Date and Time Test Ran: 30/11/2020 14:55:26 EST

Test Case ID: TC004

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: contains

Test Arguments: {3, 1234, 4321, 25} foo

Expected Result: false

Test Result: false

Test case **PASSED**.

Date and Time Test Ran: 30/11/2020 14:55:30 EST

Test Case ID: TC005

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: contains

Test Arguments: {3, 1234, 4321, 25} 1234

Expected Result: true

Test Result: false

Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 23/11/2020 23:19:36 EST

Test Case ID: TC023

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 4710, 3094} {390, 4709}

Expected Result: false

Test Result: false

Test case **PASSED**.

Date and Time Test Ran: 23/11/2020 23:19:41 EST

Test Case ID: TC024

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 10} null

Expected Result: true

Test Result: true

Test case **PASSED**.

Date and Time Test Ran: 23/11/2020 23:19:46 EST

Test Case ID: TC025

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 40, 10} {390, 40, 10}

Expected Result: true

Test Result: false

Test case **FAILED**. Result of the test is not the expected result.

Change 4 - In line 168, removing the negation on the internalContains() method call will cause all containsAll test cases to fail that do not use the null check to bypass checking the array.

Date and Time Test Ran: 23/11/2020 23:29:05 EST

Test Case ID: TC021

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {10, 32, 15} {10, 15}

Expected Result: true

Test Result: false

Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 23/11/2020 23:29:10 EST

Test Case ID: TC022

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: null {10}

Expected Result: false

Test Result: true

Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 23/11/2020 23:29:15 EST

Test Case ID: TC023

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 4710, 3094} {390, 4709}

Expected Result: false

Test Result: false

Test case **PASSED**.

Date and Time Test Ran: 23/11/2020 23:29:20 EST

Test Case ID: TC024

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 10} null

Expected Result: true

Test Result: true

Test case **PASSED**.

Date and Time Test Ran: 23/11/2020 23:29:24 EST

Test Case ID: TC025

File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java

Method Being Tested: containsAll

Test Arguments: {390, 40, 10} {390, 40, 10}

Expected Result: true

Test Result: false

Test case **FAILED**. Result of the test is not the expected result.

Change 5 - In line 160, changing the "==" equality operator in "c == null" check to a "!=" equality operator, this causes 3 out of the 5 test cases to fail, interestingly enough, one test case that does not rely on null at all, but passes under normal circumstances.

Date and Time Test Ran: 24/11/2020 00:00:31 EST
Test Case ID: TC021
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: containsAll
Test Arguments: {10, 32, 15} {10, 15}
Expected Result: true
Test Result: true
Test case **PASSED**.

Date and Time Test Ran: 24/11/2020 00:00:35 EST
Test Case ID: TC022
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: containsAll
Test Arguments: null {10}
Expected Result: false
Test Result: true
Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 24/11/2020 00:00:40 EST
Test Case ID: TC023
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: containsAll
Test Arguments: {390, 4710, 3094} {390, 4709}
Expected Result: false
Test Result: true
Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 24/11/2020 00:00:45 EST
Test Case ID: TC024
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: containsAll
Test Arguments: {390, 10} null
Expected Result: true
Test Result:
Test case **FAILED**. Result of the test is not the expected result.

Date and Time Test Ran: 24/11/2020 00:00:51 EST
Test Case ID: TC025
File Being Tested: ../project/openmrs-core/api/src/main/java/org/openmrs/util/ThreadSafeCircularFifoQueue.java
Method Being Tested: containsAll
Test Arguments: {390, 40, 10} {390, 40, 10}
Expected Result: true
Test Result: true
Test case **PASSED**.

Overall, this learning experience was one of patience and determination. The codebase that we were working with tended to be scarce at certain points, which made finding potential faults much more difficult for certain methods. As a result, we had to work around those and try to capitalize on certain methods that were a little more substantial. We also tried to emphasize minimal changes that would be common for a programmer who is unfamiliar with the problem or unfamiliar with Java would likely make to determine whether the program was sufficiently redundant to protect against these. Off-By-One errors are very common and in the case highlighted, could potentially cause errors with the list. As well, the switch from "||" to "&&" is a very common mistake, especially with complex data structures, it can be very easy to mix the two up and make an error of this kind, which, as we saw, only triggered one error in one case, which would be significantly hard to detect.