Fault Injection Framework and Development Guide

Table of contents

1 Introduction

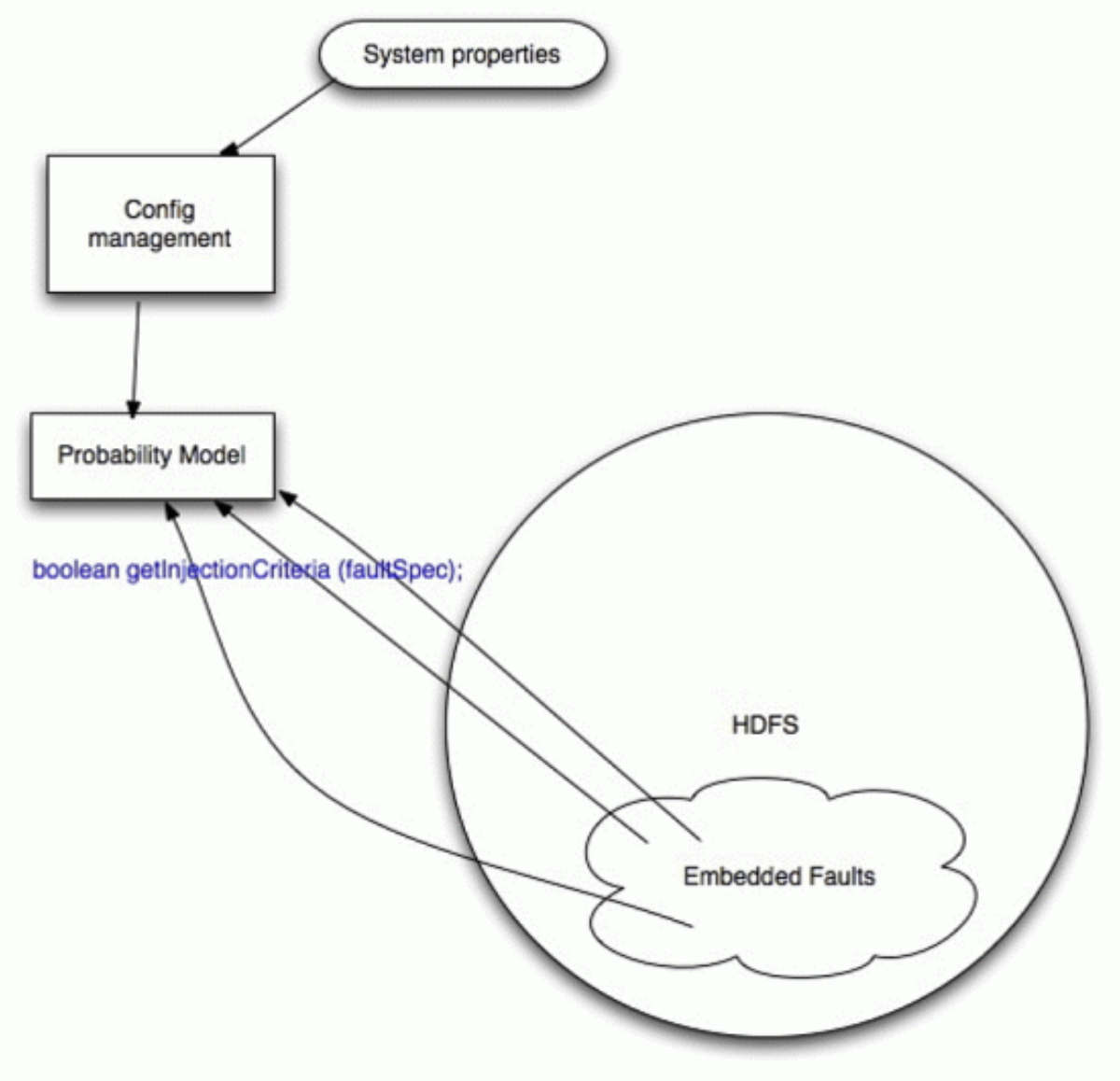
This guide provides an overview of the Hadoop Fault Injection (FI) framework for those who will be developing their own faults (aspects).

The idea of fault injection is fairly simple: it is an infusion of errors and exceptions into an application's logic to achieve a higher coverage and fault tolerance of the system. Different implementations of this idea are available today. Hadoop's FI framework is built on top of Aspect Oriented Paradigm (AOP) implemented by AspectJ toolkit.

2 Assumptions

The current implementation of the FI framework assumes that the faults it will be emulating are of non-deterministic nature. That is, the moment of a fault's happening isn't known in advance and is a coin-flip based.

3 Architecture of the Fault Injection Framework



3.1 Configuration Management

This piece of the FI framework allows you to set expectations for faults to happen. The settings can be applied either statically (in advance) or in runtime. The desired level of faults in the framework can be configured two ways:

- editing `src/aop/fi-site.xml` configuration file. This file is similar to other Hadoop's config files

- setting system properties of JVM through VM startup parameters or in `build.properties` file

3.2 Probability Model

This is fundamentally a coin flipper. The methods of this class are getting a random number between 0.0 and 1.0 and then checking if a new number has happened in the range of 0.0 and a configured level for the fault in question. If that condition is true then the fault will occur.

Thus, to guarantee the happening of a fault one needs to set an appropriate level to 1.0. To completely prevent a fault from happening its probability level has to be set to 0.0.

Note: The default probability level is set to 0 (zero) unless the level is changed explicitly through the configuration file or in the runtime. The name of the default level's configuration parameter is `fi.*`

3.3 Fault Injection Mechanism: AOP and AspectJ

The foundation of Hadoop's FI framework includes a cross-cutting concept implemented by AspectJ. The following basic terms are important to remember:

- **A cross-cutting concept** (aspect) is behavior, and often data, that is used across the scope of a piece of software
- In AOP, the **aspects** provide a mechanism by which a cross-cutting concern can be specified in a modular way
- **Advice** is the code that is executed when an aspect is invoked
- **Join point** (or pointcut) is a specific point within the application that may or not invoke some advice

3.4 Existing Join Points

The following readily available join points are provided by AspectJ:

- Join when a method is called
- Join during a method's execution
- Join when a constructor is invoked
- Join during a constructor's execution
- Join during aspect advice execution
- Join before an object is initialized
- Join during object initialization
- Join during static initializer execution
- Join when a class's field is referenced
- Join when a class's field is assigned
- Join when a handler is executed

4 Aspect Example

```
package org.apache.hadoop.hdfs.server.datanode;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.apache.hadoop.fi.ProbabilityModel;
import org.apache.hadoop.hdfs.server.datanode.DataNode;
import org.apache.hadoop.util.DiskChecker.*;

import java.io.IOException;
import java.io.OutputStream;
import java.io.DataOutputStream;

/**
* This aspect takes care about faults injected into datanode.BlockReceiver
* class
*/
public aspect BlockReceiverAspects {
  public static final Log LOG = LogFactory.getLog(BlockReceiverAspects.class);

  public static final String BLOCK_RECEIVER_FAULT="hdfs.datanode.BlockReceiver";
    pointcut callReceivePacket() : call (* OutputStream.write(..))
      && withincode (* BlockReceiver.receivePacket(..))
    // to further limit the application of this aspect a very narrow 'target' can be used
 as follows
    // && target(DataOutputStream)
      && !within(BlockReceiverAspects +);

  before () throws IOException : callReceivePacket () {
    if (ProbabilityModel.injectCriteria(BLOCK_RECEIVER_FAULT)) {
      LOG.info("Before the injection point");
      Thread.dumpStack();
      throw new DiskOutOfSpaceException ("FI: injected fault point at " +
      thisJoinPoint.getStaticPart( ).getSourceLocation());
    }
  }
}
```

The aspect has two main parts:

- The join point `pointcut callReceivepacket()` which servers as an identification mark of a specific point (in control and/or data flow) in the life of an application.
- A call to the advice - `before () throws IOException : callReceivepacket()` - will be injected (see Putting It All Together) before that specific spot of the application's code.

The pointcut identifies an invocation of class' `java.io.OutputStream write()` method with any number of parameters and any return type. This invoke should take place within the body of method `receivepacket()` from class`BlockReceiver`. The method can have any parameters and any return type. Possible invocations of `write()` method

happening anywhere within the aspect `BlockReceiverAspects` or its heirs will be ignored.

Note 1: This short example doesn't illustrate the fact that you can have more than a single injection point per class. In such a case the names of the faults have to be different if a developer wants to trigger them separately.

Note 2: After the injection step (see Putting It All Together) you can verify that the faults were properly injected by searching for `ajc` keywords in a disassembled class file.

5 Fault Naming Convention and Namespaces

For the sake of a unified naming convention the following two types of names are recommended for a new aspects development:

- Activity specific notation (when we don't care about a particular location of a fault's happening). In this case the name of the fault is rather abstract: `fi.hdfs.DiskError`
- Location specific notation. Here, the fault's name is mnemonic as in: `fi.hdfs.datanode.BlockReceiver[optional location details]`

6 Development Tools

- The Eclipse AspectJ Development Toolkit may help you when developing aspects
- IntelliJ IDEA provides AspectJ weaver and Spring-AOP plugins

7 Putting It All Together

Faults (aspects) have to injected (or woven) together before they can be used. Follow these instructions:

- To weave aspects in place use:

```
% ant injectfaults
```

- If you misidentified the join point of your aspect you will see a warning (similar to the one shown here) when 'injectfaults' target is completed:

```
[iajc] warning at
src/test/aop/org/apache/hadoop/hdfs/server/datanode/ \
          BlockReceiverAspects.aj:44::0
advice defined in org.apache.hadoop.hdfs.server.datanode.BlockReceiverAspects
has not been applied [Xlint:adviceDidNotMatch]
```

- It isn't an error, so the build will report the successful result.
  To prepare dev.jar file with all your faults weaved in place (HDFS-475 pending) use:

```
% ant jar-fault-inject
```

- To create test jars use:

```
% ant jar-test-fault-inject
```

- To run HDFS tests with faults injected use:

```
% ant run-test-hdfs-fault-inject
```

7.1 How to Use the Fault Injection Framework

Faults can be triggered as follows:

- During runtime:

```
% ant run-test-hdfs -Dfi.hdfs.datanode.BlockReceiver=0.12
```

To set a certain level, for example 25%, of all injected faults use:

```
% ant run-test-hdfs-fault-inject -Dfi.*=0.25
```

- From a program:

```
package org.apache.hadoop.fs;

import org.junit.Test;
import org.junit.Before;
import junit.framework.TestCase;

public class DemoFiTest extends TestCase {
  public static final String BLOCK_RECEIVER_FAULT="hdfs.datanode.BlockReceiver";
  @Override
  @Before
  public void setUp(){
    //Setting up the test's environment as required
  }

  @Test
  public void testFI() {
    // It triggers the fault, assuming that there's one called
 'hdfs.datanode.BlockReceiver'
    System.setProperty("fi." + BLOCK_RECEIVER_FAULT, "0.12");
    //
    // The main logic of your tests goes here
    //
    // Now set the level back to 0 (zero) to prevent this fault from happening again
    System.setProperty("fi." + BLOCK_RECEIVER_FAULT, "0.0");
    // or delete its trigger completely
    System.getProperties().remove("fi." + BLOCK_RECEIVER_FAULT);
  }

  @Override
  @After
  public void tearDown() {
    //Cleaning up test test environment
```

```
  }
}
```

As you can see above these two methods do the same thing. They are setting the probability level of `hdfs.datanode.BlockReceiver` at 12%. The difference, however, is that the program provides more flexibility and allows you to turn a fault off when a test no longer needs it.

8 Additional Information and Contacts

These two sources of information are particularly interesting and worth reading:

- http://www.eclipse.org/aspectj/doc/next/devguide/
- AspectJ Cookbook (ISBN-13: 978-0-596-00654-9)

If you have additional comments or questions for the author check HDFS-435.