JBoss AOP - Aspect-Oriented Framework for Java

JBoss AOP Reference Documentation

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JBoss AOP - Aspect-Oriented Framework for Java: JBoss AOP Reference Documentation

Preface

Aspect-Oriented Programming (AOP) is a new paradigm that allows you to organize and layer your software applications in ways that are impossible with traditional object-oriented approaches. Aspects allow you to transparently glue functionality together so that you can have a more layered design. AOP allows you to intercept any event in a Java program and trigger functionality based on those events. Mixins allow you to introduce multiple inheritance to Java so that you can provide APIs for your aspects. Combined with annotations, it allows you to extend the Java language with new syntax.

JBoss AOP is a 100% Pure Java aspected oriented framework usable in any programming environment or tightly integrated with our application server.

This document is meant to be a boring reference guide. It focuses solely on syntax and APIs and worries less about providing real world examples. Please see our "User Guide: The Case for Aspects" document for a more interesting discussion on the use of aspects.

If you have questions, use the user forum linked on the JBoss AOP website. We also provide tracking links for tracking bug reports and feature requests. If you are interested in the development of JBoss AOP, post a message on the forum. If you are interested in translating this documentation into your language, contact us on the developer mailing list.

Commercial development support, production support and training for JBoss AOP is available through JBoss Inc. (see http://www.jboss.org/). JBoss AOP is a project of the JBoss Professional Open Source product suite.

In some of the example listings, what is meant to be displayed on one line does not fit inside the available page width. These lines have been broken up. A '\' at the end of a line means that a break has been introduced to fit in the page, with the following lines indented. So:

```
Let's pretend to have an extremely \
   long line that \
   does not fit
This one is short
```

Is really:

```
Let's pretend to have an extremely long line that does not fit
This one is short
```

Terms

1. Overview

The section defines some basic terms that will be used throughout this guide.

Joinpoint
: A joinpoint is any point in your java program. The call of a method. The execution of a constructor the access of a field. All these are joinpoints. You could also think of a joinpoint as a particular Java event. Where an event is a method call, constructor call, field access etc...

Invocation
: An Invocation is a JBoss AOP class that encapsulates what a joinpiont is at runtime. It could contain information like which method is being called, the arguments of the method, etc...

Advice
: An advice is a method that is called when a particular joinpoint is executed, i.e., the behavior that is triggered when a method is called. It could also be thought of as the code that does the interception. Another analogy is that an advice is an "event handler".

Pointcut
: Pointcuts are AOP's expression language. Just as a regular expression matches strings, a pointcut expression matches a particular joinpoint.

Introductions
: An introduction modifies the type and structure of a Java class. It can be used to force an existing class to implement an interface or to add an annotation to anything.

Aspect
: An Aspect is a plain Java class that encapsulates any number of advices, pointcut definitions, mixins, or any other JBoss AOP construct.

Interceptor
: An interceptor is an Aspect with only one advice named "invoke". It is a specific interface that you can implement if you want your code to be checked by forcing your class to implement an interface. It also will be portable and can be reused in other JBoss environments like EJBs and JMX MBeans.

Implementing Aspects

1. Overview

JBoss AOP is a 100% pure Java framework. All your AOP constructs are defined as pure Java classes and bound to your application code via XML or by annotations. This Chapter walks through implementing aspects.

2. Aspect Class

The Aspect Class is a plain Java class that can define zero or more advices, pointcuts, and/or mixins.

```
public class Aspect
 {
   public Object trace(Invocation invocation) throws Throwable {
      try {
         System.out.println("Entering anything");
         return invocation.invokeNext(); // proceed to next advice
 or actual call
      } finally {
         System.out.println("Leaving anything");
      }
   }
}
```

The example above is of an advice `trace` that traces calls to any type of joinpoint. Notice that `Invocation` objects are the runtime encapsulation of joinpoints. The method `invocation.invokeNext()` is used to drive the advice chain. It either calls the next advice in the chain, or does the actual method or constructor invocation.

3. Advice Methods

For basic interception, any method that follows the form:

```
Object methodName(Invocation object) throws Throwable
```

can be an advice. The `Invocation.invokeNext()` method must be called by the advice code or no other advice will be called, and the actual method, field, or constructor invocation will not happen.

JBoss AOP provides five types of advice: before, around, after, finally and after-throwing. The advice sginature above is the default one for an around advice. Advices types, signature rules and overloading will be covered in *Chapter 4, Advices*.

4. Interceptors

Interceptors are a special type of aspect that contains only one advice. This advice has its signature defined by an interface, `org.jboss.aop.advice.Interceptor`:

```
public interface Interceptor
{
   public String getName();

   public Object invoke(Invocation invocation) throws Throwable;
}
```

The method `invoke(Invocation)` is the unique advice contained in an interceptor. The method `getName()` is used for identification in the JBoss AOP framework. So, this method must return a name that is unique in the whole system. It is only really used for aspects added to the `InstanceAdvisor` as shown in *Section 2, “Per Instance AOP”*.

5. Resolving Annotations

JBoss AOP provides an abstraction for resolving annotations. In future versions of JBoss AOP, there will be a way to override annotation values on a per thread basis, or via XML overrides, or even provide VM and cluster wide defaults for annotation values. Also if you want to write a truly generic advice that takes the base Invocation type, you can still get the annotation value of the method, constructor, or field you're invoking on by calling this method:

```
Object resolveAnnotation(Class annotation);
```

That's just resolving for resolving member annotations. If your aspect needs to resolve class level annotations then this method should be called:

```
Object resolveClassAnnotation(Class annotation)
```

6. Metadata

6.1. Resolving XML Metadata

Untyped metadata can be defined within XML files and bound to org.jboss.aop.metadata.SimpleMetaData structures. This XML data can be attached per method, field, class, and constructor. To resolve this type of metadata, the Invocation object provides a method to abstract out where the metadata comes from.

```
Object getMetaData(Object group, Object attr)
```

When this method is called, the invocation will look for metadata in this order:

1. First it looks in the Invocation's metadata (`SimpleMetaData getMetaData()`)
2. Next it looks in `org.jboss.aop.metadata.ThreadMetaData.instance()`. ThreadMetaData allows you to override metadata for the whole thread. The metadata is managed by a ThreadLocal. ThreadMetaData is used by every single invocation object at runtime.
3. Next it looks in either org.jboss.aop.Advisor.getMethodMetaData(), Advisor.getConstructorMetaData(), or Advisor.getFieldMetaData() depending on the invocation type.
4. Next it looks in either Advisor.getDefaultMetaData().

6.2. Attaching Metadata

You can attach untyped metadata to the invocation object, or even to the response. This allows advices to pass contextual data to one another in the incoming invocation or outgoing response for instance if you had advices running on a remote client that wanted to pass contextual data to server-side aspects. This method on invocation gets you access to a `org.jboss.aop.metadata.SimpleMetaData` instance so that you can attach or read data.

```
SimpleMetaData getMetaData()
```

`SimpleMetaData` has three types of metadata, AS_IS, MARSHALLED, and TRANSIENT. This allows you to specify whether or not metadata is marshalled across the wire. TRANSIENT says, attached metadata should not be sent across the wire. MARSHALLED is for classloader sensitive contextual data. AS_IS doesn't care about classloaders. Read the Javadocs for more information.

To piggyback and read metadata on the invocation response, two methods are provided. One to attach data one to read data.

```
Object getResponseAttachment(Object key);
void addResponseAttachment(Object key, Object value);
```

7. Mixin Definition

Mixins are a type of introduction in which you can do something like C++ multiple inheritance and force an existing Java class to implement a particular interface and the implementation of that particular interface is encapsulated into a particular class called a mixin.

Mixin classes have no restrictions other than they must implement the interfaces that you are introducing.

8. Dynamic CFlow

Dynamic CFlows allow you to define code that will be executed that must be resolved true to trigger positive on a cflow test on an advice binding. (See <cflow-stack> for more information). The test happens dynamically at runtime and when combined with a pointcut expression allows you to do runtime checks on whether a advice binding should run or not. To implement a dynamic CFlow you just have to implement the simple org.jboss.aop.pointcut.DynamicCFlow interface. You can then use it within cflow expressions. (See XML or Annotations)

```
public interface DynamicCFlow
{
   boolean shouldExecute(Invocation invocation);
}
```

Joinpoint and Pointcut Expressions

The pointcut language is a tool that allows joinpoint matching. A pointcut expression determines in which joinpoint executions of the base system an advice should be invoked.

In this Chapter, we will explore the syntax of pointcut expressions.

We will also see the API used to represent a matched joinpoint during advice execution, and how this relates to pointcut expression constructs.

1. Wildcards

There are two types of wildcards you can use within pointcut expressions

- `*` Is a regular wildcard that matches zero or more characters. It can be used within any type expression, field, or method name, but not in an annotation expression
- `..` Is used to specify any number of parameters in an constructor or method expression. `..` following a package-name is used to specify all classes from within a given package ut not within sub-packages. e.g `org.acme..` matches `org.acme.Foo` and `org.acme.Bar`, but it does not match `org.acme.sub.SubFoo`.

2. Type Patterns

Type patterns are defined by an annotation or by fully qualified class name. Annotation expressions are not allowed to have wildcards within them, but class expressions are.

- `org.acme.SomeClass` matches that class.
- `org.acme.*` will match `org.acme.SomeClass` as well as `org.acme.SomeClass.SomeInnerClass`
- `@javax.ejb.Entity` will match any class tagged as such.
- `String` or `Object` are illegal. You must specify the fully qualified name of every java class. Even those under the `java.lang` package.

To reference all subtypes of a certain class (or implementors of an interface), the `$instanceof{}` expression can be used. Wildcards and annotations may also be used within `$instanceof{}` expressions.

```
$instanceof{org.acme.SomeInterface}
$instanceof{@org.acme.SomeAnnotation}
$instanceof{org.acme.interfaces.*}
```

are all allowed.

For very complex type expressions, the Typedef construct can be used. To reference a Typedef within a class expression `$typedef{id}` is used.

3. Method Patterns

```
public void org.acme.SomeClass->methodName(java.lang.String)
```

The attributes(`public, static, private`) of the method are optional. If the attribute is left out then any attribute is assumed. Attributes accept the `!` modifier for negation.

```
public !static void org.acme.SomeClass->*(..)
```

`$instanceof{}` can be used in place of the class name.

```
void
 $instanceof{org.acme.SomeInterface}->methodName(java.lang.String)
```

To pick out all `toString()` methods of all classes within the `org.acme` package, we can use `org.acme..` in place of the class name.

```
java.lang.String org.acme..->toString()
```

To only match methods from a given interface you can use the `$implements{}` or `$implementing{}` keywords in place of the method name. `$implements{}` only matches methods from the exact interface(s) given, while `$implementing{}` matches methods from the interface(s) given AND their super interfaces.

```
void $instanceof{org.acme.IfA}->$implements(org.acme.IfA)(..)
```

```
void $instanceof{org.acme.IfB}->$implementing(org.acme.IfA,
 org.acme.IfB)(..)
```

Annotations can be used in place of the class name. The below example matches any methodName() of a tagged @javax.ejb.Entity class.

```
void @javax.ejb.Entity->methodName(java.lang.String)
```

Annotations can be also be used in place of the method name. The below examples matches any method tagged as @javax.ejb.Tx.

```
* *->@javax.ejb.Tx(..)
```

In addition you can use typedefs, `$instanceof{}`, annotations and wildcards for method parameters and return types. The following matches all methods called `loadEntity` that return a class annotated with @javax.ejb.Entity, that takes a class (or a class whose superclass/interface is) annotated as @org.acme.Ann and any class that matches `java.*.String` (such as java.lang.String).

```
@javax.ejb.Entity *->loadEntity($instanceof{@org.acme.Ann},
 java.*.String)
```

You can also include an optional throws clause in the pointcut expression:

```
public void org.acme.SomeClass->methodName(java.lang.String) \
      throws org.acme.SomeException, java.lang.Exception
```

If any exceptions are present in the pointcut expression they must be present in the throws clause of the methods to be matched.

4. Constructor Patterns

```
public org.acme.SomeClass->new(java.lang.String)
```

Constructor expressions are made up of the fully qualified classname and the `new` keyword The attributes(`public, static, private`) of the method are optional. If the attribute is left out then any attribute is assumed. Attributes accept the `!` modifier for negation.

```
!public org.acme.SomeClass->new(..)
```

`$instanceof{}` can be used in the class name.

```
$instanceof{org.acme.SomeInterface}->new(..)
```

To pick out all no-args constructors of all classes within the `org.acme` package, we can use `org.acme..` in place of the class name.

```
org.acme..->new()
```

Annotations can be used in place of the class name. The below example matches any constructor of a tagged @javax.ejb.Entity class.

```
@javax.ejb.Entity->new(..)
```

Annotations can be also be used in place of the `new` keyword. The below examples matches any constructor tagged as `@javax.ejb.MethodPermission`.

```
*->@javax.ejb.MethodPermission(..)
```

In addition, just as for methods you can use typedefs, `$instanceof{}`, annotations and wildcards for constructor parameters. The following matches all constructors that take a class annotated as @org.acme.Ann and any class that matches `java.*.String` (such as java.lang.String).

```
*->new(@org.acme.Ann, java.*.String)
```

You can also include an optional throws clause in the pointcut expression:

```
public void org.acme.SomeClass->new(java.lang.String) \
      throws org.acme.SomeException, java.lang.Exception
```

If any exceptions are present in the pointcut expression they must be present in the throws clause of the constructors to be matched.

5. Field Patterns

```
public java.lang.String org.acme.SomeClass->fieldname
```

Constructor expressions are made up of the type, the fully qualified classname where the field resides and the field's name. The attributes(`public, static, private`) of the field are optional. If the attribute is left out then any attribute is assumed. Attributes accept the `!` modifier for negation.

```
!public java.lang.String org.acme.SomeClass->*
```

`$instanceof{}` can be used in the class name. The below expression matches any field of any type or subtype of `org.acme.SomeInterface`

```
* $instanceof{org.acme.SomeInterface}->*
```

Annotations can be used in place of the class name. The below example matches any field where the type class is tagged with `@javax.ejb.Entity`.

```
* @javax.ejb.Entity->*
```

Annotations can be also be used in place of the field name. The below examples matches any field tagged as `@org.jboss.Injected`.

```
* *->@org.jboss.Injected
```

In addition, you can use typedefs, `$instanceof{}`, annotations and wildcards for field types. The following matches all fields where the type class has been tagged with @javax.ejb.Entity.

```
@javax.ejb.Entity *->*
```

To pick out all fields annotated with `@org.foo.Transient` within the `org.acme` package, we can use `org.acme..` in place of the class name, and `@org.foo.Transient` in please of the field name

```
* org.acme..->@org.foo.Transient
```

6. Pointcuts

Pointcuts use class, field, constructor, and method expressions to specify the actual joinpoint that should be intercepted/watched.

`execution(method or constructor)`

```
execution(public void Foo->method()
execution(public Foo->new())
```

`execution` is used to specify that you want an interception to happen whenever a method or constructor is called. The the first example of matches anytime a method is called, the second matches a constructor. System classes cannot be used within `execution` expressions because it is impossible to instrument them.

`construction(constructor)`

```
construction(public Foo->new())
```

`construction` is used to specify that you want aspects to run within the constructor. The `execution` pointcut requires that any code that calls new() must be instrumented by the compiler. With `construction` the aspects are weaved right within the constructor after all the code in the constructor. The aspects are appended to the code of the constructor.

`get (field expression)`

```
get(public int Foo->fieldname)
```

`get` is used to specify that you want an interception to happen when a specific field is accessed for a read.

`set(field expression)`

```
get(public int Foo->fieldname)
```

`set` is used to specify that you want an interception to happen when a specific field is accessed for a write.

`field(field expression)`

```
field(public int Foo->fieldname)
```

`field` is used to specify that you want an interception to happen when a specific field is accessed for a read or a write.

`all(type expression)`

```
all(org.acme.SomeClass)
all(@org.jboss.security.Permission)
```

`all` is used to specify any constructor, method or field of a particular class will be intercepted. If an annotation is used, it matches the member's annotation, not the class's annotation.

`call(method or constructor)`

```
call(public void Foo->method()
call(public Foo->new())
```

`call` is used to specify any constructor or method that you want intercepted. It is different than `execution` in that the interception happens at the caller side of things and the caller information is available within the Invocation object. `call` can be used to intercept System classes because the bytecode weaving happens within the callers bytecode.

`within(type expression)`

```
within(org.acme.SomeClass)
within(@org.jboss.security.Permission)
```

`within` matches any joinpoint (method or constructor call) within any code within a particular type.

`withincode(method or constructor)`

```
withincode(public void Foo->method()
withincode(public Foo->new())
```

`withincode` matches any joinpoint (method or constructor call) within a particular method or constructor.

`has(method or constructor)`

```
has(void *->@org.jboss.security.Permission(..))
has(*->new(java.lang.String))
```

`has` is an additional requirement for matching. If a joinpoint is matched, its class must also have a constructor or method that matches the `has` expression.

`hasfield(field expression)`

```
hasfield(* *->@org.jboss.security.Permission)
hasfield(public java.lang.String *->*)
```

`has` is an additional requirement for matching. If a joinpoint is matched, its class must also have a field that matches the `hasfield` expression.

7. Pointcut Composition

Pointcuts can be composed into boolean expressions.

- `!` logical not.
- `AND` logical and.
- `OR` logical or.
- Paranthesis can be used for grouping expressions.

Here's some examples.

```
call(void Foo->someMethod()) AND withincode(void Bar->caller())
execution(* *->@SomeAnnotation(..)) OR field(* *->@SomeAnnotation)
```

8. Pointcut References

Pointcuts can be named in XML (*Chapter 5, XML Bindings*) or annotation (*Chapter 6, Annotation Bindings*) bindings. They can be referenced directly within a pointcut expression.

```
some.named.pointcut OR call(void Foo->someMethod())
```

9. Typedef Expressions

Sometimes, when writing pointcuts, you want to specify a really complex type they may or may not have boolean logic associated with it. You can group these complex

type definitions into a JBoss AOP `Typedef` either in XML or as an annotation (See later in this document). Typedef expressions can also be used within `introduction` expressions. Typedef expressions can be made up of `has, hasfield, and class` expressions. `class` takes a fully qualified class name, or an `$instanceof{}` expression.

```
class(org.pkg.*) OR has(* *->@Tx(..)) AND
 !class($instanceof{org.foo.Bar})
```

10. Joinpoints

After getting acquainted with all pointcut constructs, let's see how this reflects on the API available to advices during their execution.

10.1. Joinpoint Beans

JBoss AOP provides JoinPoint Beans, so that an advice can access all information regarding a joinpoint during its execution. This information consists of context values, explained in the next subsection, and of reflection objects (`java.lang.reflection`). The reflection objects describe the joinpoint being intercepted like a `java.lang.Method` for a method execution joinpoint).

There are two groups of beans. The first one is the `Invocation` beans group. All classes of this group are subclasses of `org.jboss.aop.joinpoint.Invocation`. The `Invocation` class was presented in *Chapter 2* as a runtime encapsulation of a joinpoint. An `Invocation` object also contains an interceptor chain, where all advices and interceptors that intercept the joinpoint are stored. Invocation beans provide the `invokeNext()` method, responsible for proceeding execution to the next advice in the interceptor chain (if there is an advice that has not started execution yet) or to the joinpoint itself (if all advices contained in the interceptor chain have already started running). We will see more on this in the next chapter.

The other group of beans contains only information regarding the joinpoint itself, and are called the `JoinPointBean` group. All beans of this group are defined in interfaces, with `org.jboss.joinpoint.JoinPointBean` being their common superinterface.

The `Invocation` objects are available only to around advices. All other types of advices can use the `JoinPointBean` types to access joinpoint specific data.

In both groups there is a specific type for each joinpoint type. The type of bean corresponding to each joinpoint type can be seen in *Table 3.1, " Joinpoint Types Table "*. All beans are in the package `org.jboss.aop.joinpoint`.

10.2. Context Values

According to the type of the joinpoint, there are specific context values available.

The context values are:

- return value: joinpoints like a constructor execution or a non-void method call, have a return value.
- arguments: the arguments of a constructor or method execution joinpoint are the arguments received by the constructor or method. Similarly, the arguments of a call are the arguments received by the method or constructor being called.
- target: the target object of a joinpoint varies according to the joinpoint type. For method executions and calls, it refers to the object whose method is being executed (available only on non-static methods). For field reads and writes, it refers to the object that contains that field.
- caller: the caller object is available only on call joinpoints, and it refers to the object whose method or constructor is performing the call (notice the caller object is not available if the call is inside a static method).

Table 3.1, " Joinpoint Types Table " shows what context values may be available depending on the joinpoint type.

Joinpoint	Pointcut Construct	Bean Invocation	Bean Joinpoint	Context Values: Target	Caller	Argument	Return Value
field read	`read`, `FieldReadInvocation`, `field`, `all`		`FieldAccess`	Yes	No	No	Yes
field write	`write`, `FieldWriteInvocation`, `field`, `all`		`FieldAccess`	Yes	No	Yes	No
method execution	`execution`, `MethodInvocation`, `all`		`MethodExecution`	Yes	No	Yes	Yes
constructor execution	`execution`	`ConstructorInvocation`	`ConstructorExecution`	No	No	Yes	Yes
construction	`construction`	`ConstructionInvocation`	`ConstructorExecution`	Yes	No	Yes	No
method call	`call`, `CallerInvocation`, `MethodCall`, `withincode`, `MethodCalledByConstructor`, `MethodCalledByMethod`		`MethodCallByConstructor`, `MethodCallByMethod`	Yes	Yes	Yes	Yes
constructor call	`call`, `CallerInvocation`, `ConstructorCall`, `withincode`, `ConstructorCalledByConstructor`, `ConstructorCalledByMethod`		`ConstructorCallByConstructor`, `ConstructorCallByMethod`	Yes	Yes	Yes	Yes

Table 3.1. Joinpoint Types Table

Advices

Advices are aspect methods that are invoked during specific joinpoint executions.

JBoss AOP provides five types of advice.

The default one is the around advice, and it can be used on all execution modes. This advice wraps the joinpoint, in a way that it replaces the joinpoint execution in the base system, and is responsible for proceeding execution to the joinpoint.

Besides around advices, you can write advices that, instead of wrapping the joinpoint, are executed before or after it. In this category, JBoss AOP provides before, after, after-throwing and finally advices. These advices are available only when using the generated advisor mode (this is the default mode in JBoss AOP, to learn how to select another weaving mode, refer to Chapter X).

The next sections will explain in detail the binding and signature rules for JBoss AOP advices.

1. Around Advices

An around advice can follow this template:

```
public Object [advice name]([Invocation] invocation) throws
 Throwable
{
   try{
      // do something before joinpoint execution
      ...
      // execute the joinpoint and get its return value
      Object returnValue = invocation.invokeNext();
      // do something after joinpoint has executed successfully ...
      // return a value
      return returnValue;
   }
   catch(Exception e)
   {
      //handle any exceptions arising from calling the joinpoint
      throw e;
   }
   finally
   {
      //Take some action once the joinpoint has completed
 successfully or not
   }
}
```

In the template above, *Invocation* refers to one of the *Invocation beans*, and can be the class `org.jboss.aop.joinpoint.Invocation` or one of its subtypes.

Since an around advice wraps a joinpoint, it must proceed execution to the joinpoint itself during its execution. This can be done by calling the method `invokeNext()` on `invocation`. This method will proceed execution to the next around advice of that joinpoint. At the end of this chain this `invokeNext()` will proceed to the joinpoint itself. The value returned by the around advice will replace the joinpoint return value in the base system.

For example, in the case where there are two around advices bound to a joinpoint, the first around advice will trigger the second around advice by calling `invokeNext()`. The second advice will trigger the joinpoint execution by calling the same method. As a result of the `invokeNext()` execution, the second advice will receive the joinpoint return value. The value returned by this second advice will be received as a result by the first around advice. Finally, the value returned by this advice will replace the joinpoint return value in the base system execution. Normally though, around advices will simply return whatever value the joinpoint returned! This is shown in the preceding template example.

If an around advice wants to completely replace the joinpoint execution, it can skip the call to `invokeNext()`. This will also skip execution of any subsequent around advices in the chain. As a third alternative, the around advice can call the method `invokeTarget()` instead of `invokeNext()`. This method will invoke the target joinpoint directly, skipping any subsequent advices.

The presence of the `Invocation` parameter is optional. If an around advice does not have this parameter, it can replace the call to `invokeNext()` with a call to `org.jboss.aop.joinpoint.CurrentInvocation.proceed()`.

The signature described before is the default around advice signature rule. In addition to it, the around advice signature can also be of this form (only in generated advisor mode):

```
public [return type] [advice name]([annotated parameter],[annotated
 parameter],...[annotated parameter]) throws Throwable
```

This signature is joinpoint dependent. The return type of the advice must be a type assignable to the the return type of the joinpoint to be intercepted (i.e. be the same type; a subclass, if the return type is class; or a subinterface or an implementing class, if the return type is an interface). In case the joinpoint being intercepted does not have a return type, this advice return type must be `void`.

An around advice can have zero or more annotated parameters. The annotated parameters will be covered in detail in *Section 3, “Annotated Advice Parameters”*.

Finally, JBoss AOP also features a special type of around advice: `Interceptor`. An interceptor class implements `org.jboss.aop.Interceptor`, and is described in *Section 4, "Interceptors"*.

2. Before/After/After-Throwing/Finally Advices

These advices are more lightweight in the JBoss AOP framework, since they do not wrap a joinpoint, avoiding the creation of the `Invocation` objects per joinpoint execution.

Instead of `Invocation` objects, JBoss AOP provides *JoinPointBean beans* for these advices. As described in *Section 10.1, "Joinpoint Beans"*, these beans contain all information regarding a joinpoint, like an `Invocation` would do. However, since `JoinPointBean` objects are not used on around advice types, they do not provide proceeding methods, like `invokeNext()`. They also do not allow you to attach metadata for a particular invocation.

The rules for before, after, after-throwing and finally advices are quite similar. All of them can have zero or more annotated advice parameters in their signature, which will be described in the next subsection.

2.1. Before Advice Signature

A before advice is executed before the joinpoint. The signature for a before advice must be of this form:

```
public void [advice name]([annotated parameter], [annotated
 parameter],...[annotated parameter])
```

2.2. After Advice Signature

Since an after advice is executed after a joinpoint, it can return a value to replace the joinpoint return value in the base system. So, they can follow one of these signatures:

```
public void [advice name]([annotated parameter], [annotated
 parameter],...[annotated parameter])

public [return type] [advice name]([annotated parameter],
 [annotated parameter],...[annotated parameter])
```

In the first signature, the after advice does not overwrite the joinpoint return value. On the other hand, when using the second signature, the after advice return value will replace the joinpoint return value. As with around advices, this return type must be assignable to the joinpoint return type.

2.3. After-Throwing Advice Signature

The fourth type of advice provided by JBoss AOP is the after-throwing type. This advice is invoked only after the execution of a joinpoint that has thrown a `java.lang.Throwable` or one of its subtypes.

The signature of such an advice is the same as the one for before advices:

```
public void [advice name]([annotated parameter], [annotated
 parameter],...[annotated parameter])
```

Different from the other advice types, an after-throwing advice has a mandatory annotated parameter. This parameter is the exception thrown by the joinpoint execution, as we will see in the next subsection.

2.4. Finally Advice Signature

Lastly, JBoss AOP provides the finally advice type. It is invoked from inside a finally block, after the joinpoint execution.

This advice is the only one that is called after a joinpoint execution in a deterministic way. Calls to after and after-throwing advices take place depending on the joinpoint execution outcome. After advices are not called when the joinpoint execution terminates abruptly with an exception. After-throwing ones, on the other hand, are not called when the joinpoint execution returns normally, since no exception is thrown this time. So, if an advice needs to be run no matter what is the outcome of the joinpoint, it should be a finally advice.

Pretty much as after advices, finally advices can follow one of the signatures below:

```
public void [advice name]([annotated parameter], [annotated
 parameter],...[annotated parameter])

public [return type] [advice name]([annotated parameter],
 [annotated parameter],...[annotated parameter])
```

The last signature shows that finally advices can also overwrite the joinpoint execution return value by returning a value themselves. But notice that this return value will not be received by the base system if an exception has been thrown. However, it is easy to know whether this condition is met, by making use of annotated parameters.

3. Annotated Advice Parameters

This section lists the annotated parameters that can be used on JBoss AOP advices (available only in generated advisor execution mode). *Table 4.1, “Annotated Parameters Table”* lists all annotations and their semantics.

Except for the `@JoinPoint` annotation, used to refer to joinpoint beans, all other annotations are used on parameters that contain joinpoint context values.

Notice that the types of annotated parameters are dependent on the joinpoint being intercepted by the advice.

JBoss AOP will accept any type that is assignable from the type referred by that parameter, as shown in the *Type Assignable From* column of the table below. For example, for a joinpoint whose target is of type `POJO`, the annotated parameter that receives the target must be of `POJO` type, one of `POJO`'s superclasses, or one of the interfaces implemented by `POJO`.

Regarding the type of joinpoint bean parameters, the rules are the same for the default signature of around advices (without annotations). For example, an around advice that intercepts a method execution, can receive either a `MethodInvocation`, or an `Invocation` (the complete list of joinpoint beans and their relationship with joinpoint types was shown in *Table 3.1, " Joinpoint Types Table "*). As already explained, around advices use `Invocation` instances, while the other advices use `JoinPointBean` objects.

Notice also that only one annotated parameter can be mandatory: `@Thrown`. This will be further explained in *Section 3.1, "@Thrown annotated parameter"*.

Except for `@Arg`, all annotations are single-enforced, i.e., there must be at most only one advice parameter with that annotation per advice.

Annotation	Semantics	Type assignable from	Mandatory	Advice type			
				Before	Around	After	After-Finally Throwing
`@JoinPoint`	*JoinPoint bean*	Joinpoint invocation type	No	No	Yes	No	No	No
		JoinpointBean interface type	No	Yes	No	Yes	Yes	Yes
`@Target`	Joinpoint target	Joinpoint target type	No	Yes	Yes	Yes	Yes	Yes
`@Caller`	Joinpoint caller	JoinPoint caller type (only for call joinpoints)	No	Yes	Yes	Yes	Yes	Yes
`@Thrown`	Joinpoint thrown exception	`java.lang.Throwable` If used on an after-throwing advice, this parameter can also be: - assignable from any exception declared to be thrown by the joinpoint - `java.lang.RuntimeException` or any subtype of this class	Yes - for after-throwing advices - for finally advices only if `@Return` is present No: otherwise	No	No	No	Yes	Yes
`@Return`	Joinpoint return value	JoinPoint return type	No	No	No	Yes	No	Yes
`@Arg`	One of the joinpoint arguments	JoinPoint argument type	No	Yes	Yes	Yes	Yes	Yes
`@Args`	All joinpoint arguments	`Object[]`	No	Yes	Yes	Yes	Yes	Yes

Table 4.1. Annotated Parameters Table

Due to the fact that most of these parameters represent context values, their availability depends on the joinpoint type. If an advice receives as a parameter a context value that is not available during a joinpoint execution, the parameter value will be null. The exception to this rule is @Return. If an advice has this parameter, it will not intercept joinpoints that don't have a return value.

The only exception to this rule is `@Args` on field read joinpoints. Such an advice will be called with an empty arguments array, in that case.

3.1. @Thrown annotated parameter

As shown in *Table 4.1, "Annotated Parameters Table"*, the presence of a `@Thrown` annotated parameter can be mandatory depending on the advice type and its parameters.

This annotation is available only for after-throwing and finally advices. For after-throwing advices this parameter is always mandatory:

```
public class Aspect
{
   public void throwing1(@Thrown RuntimeException thrownException)
   {
      ...
   }

   public void throwing2()
   {
      ...
   }
}


<aop>
   <aspect class="Aspect"/>
   <bind pointcut="...">
      <throwing aspect="Aspect" name="throwing1"/>
      <throwing aspect="Aspect" name="throwing2"/>
   </bind>
</aop>
```

The advice `throwing1` follows this rule; advice `throwing2`, on the other hand, is invalid, because it does not contain the mandatory `@Thrown` annotated parameter.

For finally advices, the `@Thrown` annotation is compulsory only if a `@Return` annotated parameter is present. This way, a finally advice can identify whether the return value is valid or not. If the `@Thrown` parameter is `null`, it means that the joinpoint returned normally and that the value contained in the `@Return` annotated-parameter is valid. Otherwise, the value contained in `@Return` annotated

parameter must be ignored (it will be `null` if the return type is not primitive, `0` if it is a primitive number or `false` if it is boolean). If the finally advice does not receive the joinpoint return value, the use of the `@Thrown` annotated parameter is optional and, as expected, its value will be `null` if the joinpoint being intercepted did not throw an exception. Take a look at the next example:

```
public class Aspect
{
   public void finally1(@Thrown Throwable thrownException)
   {
      ...
   }

   public void finally2()
   {
      ...
   }

   public void finally3(@Return int returnedValue, @Thrown
 Throwable thrownException)
   {
      if (thrownException == null)

      {

         //We returned normally, the @Return parameter is valid

         int i = returnedValue;

      }

      else

      {

         //An exception happened while invoking the target
 joinpoint

         //The return value is invalid

      }

    }

   public void finally4(@Return int returnedValue)
   {
      ...
   }
```

```
}


<aop>
   <aspect class="Aspect"/>
   <bind pointcut="execution(public int *->*(..))">
      <finally aspect="Aspect" name="finally1"/>
      <finally aspect="Aspect" name="finally2"/>

      <finally aspect="Aspect" name="finally3"/>

      <finally aspect="Aspect" name="finally4"/>

   </bind>
</aop>
```

This example binds four finally advices to the execution of all public methods that return an int value. Take note on the type of the `@Thrown`-annotated parameters, which must be `Throwable` for this type of advice.

The presence of `@Thrown` is not mandatory in advices `finally1()` and `finally2()`, because they do not have a `@Return` annotated parameter. Hence, both advices are valid. Besides, `finally1()` will receive a non-null exception only when the joinpoint being intercepted throws an exception.

For advice method `finally3()` the presence of a `@Thrown` annotated parameter is mandatory because this advice also has a `@Return` annotated parameter. If an exception happens when invoking the target joinpoint, this advice will receive a non-null `@Thrown` parameter, meaning that the `@Return` annotated parameter is invalid. If the joinpoint completes normally, the `@Thrown` annotated parameter will be `null` and the `@Return` annotated parameter will contain the return value of the target joinpoint.

The `finally4()` advice is invalid, it contains a `@Return` parameter, but has no `@Thrown` annotated parameter. Finally advices require a `@Thrown` parameter if a `@Return` annotated parameter is present.

3.2. JoinPoint Arguments

As we saw, an advice can receive the joinpoint arguments as annotated parameters. This can be achieved with the use of two different annotations: `@Arg` and `@Args`.

There is a great difference between these two approaches, though. With `@Arg`, each parameter is equivalent to a single joinpoint parameter. With `@Args`, one single parameter, of type `Object[]`, receives an array containing all joinpoint arguments. This last possibility is more generic than the first one, since it can be used independently of the joinpoint argument types. Plus, it allows changes to the argument values. Any changes performed on the values of this array will be

perpetuated to the joinpoint execution. However, the use of `@Args` parameters on a join point interception means the arguments array needs creation. The same happens with the use of `getArguments()` and `setArguments()` methods on `Invocation` classes. So the use of `@Arg` annotated parameters is more lightweight, and should be used whenever there is no need to changing the joinpoint arguments.

When using `@Arg` annotated parameters, the types of these parameters depend on the joinpoint being intercepted. Not all the target joinpoint arguments need to be included as parameters to the advice method. An advice can receive only the argument values that are relevant to its execution.

Given all the possibilities in the usage of `@Arg`, JBoss AOP will match the advice parameters with the joinpoint ones, to infer to which joinpoint argument each advice parameter refers to. This matching process consists of the following steps:

- Each advice parameter will be matched to the first unmatched joinpoint argument that has the same type. This is done in the order that the advice parameters appear in the advice method.
- If any advice parameter is left unmatched, we proceed to an additional step. Each advice parameter will be matched to the first unmatched joinpoint argument that is assignable to it. This is done in the order that the advice parameters appear in the advice method declaration.

To illustrate this mechanism, consider the following scenario:

```
public class POJO
{
    void method(Collection arg0,  List arg1, int arg2, String
 arg3){}
}


<aop>
   <aspect class="MyAspect"/>
   <bind pointcut="execution(* POJO->method(..))">
      <before aspect="MyAspect" name="advice"/>
   </bind>
</aop>
```

The example above shows a xml-declared binding. We will use examples with those to illustrate signature concepts from now on. Detailed syntax of xml bindings is shown in *Chapter 5, XML Bindings*.

Class `POJO` is a plain java old object that contains only one method. When calling this method, we want to trigger `MyAspet.advice()` before this method is called. `POJO.method()` receives four distinct arguments, all of them can be available to an

advice by using `@Arg` annotated parameters. If `MyAspect.advice()` has the following signature:

```
public class MyAspect
{
   public void advice(@Arg Collection param0, @Arg List param1,
 @Arg int param2, @Arg String param3)
   {
      ...
   }
}
```

`MyAspect.advice()` parameters will be trivially matched to `POJO.method()` arguments as follows:

```
param0 <- arg0
param1 <- arg1
param2 <- arg2
param3 <- arg3
```

The matching outcome will be the same if `MyAspect.advice()` signature changes slightly in the following manner, since `Collection` is assignable from `List` for `param2`:

```
public class MyAspect
{
   public void advice (@Arg Collection param0, @Arg Collection
 param1, @Arg int param2, @Arg String param3)
   {
      ...
   }
}
```

If `MyAspect.advice()` receives only one parameter, of type `java.lang.Object`:

```
public class MyAspect
{
   public void advice(@Arg Object param0)
   {
      ...
   }
}
```

The parameter matching outcome will be:

```
```

```
param0 <- arg0
```

Since there is no joinpoint argument of type `Object`, we proceed to the additional matching step in this case. Because `arg0` is the first unmatched argument that is assignable to `Object`, we assign this argument to `param0`.

Notice that JBoss AOP will match all parameters correctly if we invert the order of parameters:

```
public class MyAspect
{
   public void advice(@Arg int param2, @Arg Collection param0, @Arg
 String param3, @Arg List param1)
   {
      ...
   }
}
```

If one writes an advice whose unique parameter is a `Collection`, and we want to refer to the second joinpoint argument:

```
public class MyAspect
{
   public void advice (@Arg Collection param1)
   {
      ...
   }
}
```

It will not work as desired. JBoss AOP will assign `arg0` to `param1`:

```
param1 <- arg0
```

In cases like this, it is possible to enforce the correct matching of joinpoint arguments and advice parameters. The annotation `@Arg` has an attribute, index, whose purpose is to define the index of the argument to which that parameter refers.

So, in this case, the `MyAspect.advice()` parameter list below:

```
public class MyAspect
{
   public void advice (@Arg(index=1) Collection param1)
   {
      ...
   }
```

```
}
```

Will have the desired matching, which is:

```
param1 <- arg1
```

In the example just shown in this section, `MyAspect.advice()` was a before advice, but the same rules are used for all advices using `@Arg` annotated parameters.

4. Overloaded Advices

Method names can be overloaded for interception in different joinpoint scenarios. For instance, let's say you wanted to have a different trace advice for each invocation type. You can specify the same method name `trace` and just overload it with the concrete invocation type.

```
public class AroundAspect
{
   public Object trace(MethodInvocation invocation) throws Throwabl
   {
      try
      {
         System.out.println("Entering method: " +
 invocation.getMethod()");
         return invocation.invokeNext(); // proceed to next advice
 or actual call
      }
      finally
      {
         System.out.println("Leaving method: " +
 invocation.getMethod()");
      }
   }

   public Object trace(ConstructorInvocation invocation) throws
 Throwable
   {
      try
      {
         System.out.println("Entering constructor: " +
 invocation.getConstructor()");
         return invocation.invokeNext(); // proceed to next advice
 or actual call
      }
      finally
      {
```

```
         System.out.println("Leaving constructor: " +
 invocation.getConstructor()");
      }
   }
}
```

As you can see, the selection of the advice method is very dynamic. JBoss AOP will select the most appropriate advice method for each joinpoint interception. For the following setup:

```
class POJO
{
   public POJO(){}
   public someMethod(){}
}

<aop>
   <aspect class="AroundAspect"/>
   <bind pointcut="all(POJO)">
      <advice aspect="AroundAspect" name="trace"/>
   </bind>
</aop>
```

When calling POJO's constructor:

```
pojo.someMethod();
```

JBoss AOP will call the `trace()` method taking a `ConstructorInvocation`, and when calling:

```
pojo.someMethod();
```

JBoss AOP will call the `trace()` method taking a `MethodInvocation`.

This examples shows that JBoss AOP will select the most appropriate advice method for each joinpoint interception. The capability of selecting overloaded advices is available for all types of advices. And its impact in the system performance is minimal since this selection is done once.

In this section, we will describe every rule JBoss AOP uses to select an advice method when this one is overloaded.

4.1. Annotated-parameter Signature

Let's start with the selection of advices when all of them use the annotated-parameter signature. As we will see later, very similar rules are used for selecting advices with the default signature.

The process of selection of advices that follow the annotated-parameter signature depends on the priority of each kind of parameter:

`@JoinPoint` > `@Target` > `@Caller` > `@Throwable` = `@Return` > `@Arg` > `@Args`

This priority is used in two different criteria:

- presence of the annotated parameter
- assignability degree of the annotation parameter

4.1.1. Presence priority

This rule is quite simple, it means that an advice that receives only a joinpoint bean (`@JoinPoint`) as its parameter will have a higher priority than another advice that receives all other annotated parameters available (notice we are following the *annotation priority order* just described).

In other words, the first `OneAspect.after()` advice method will be chosen when calling `POJO.someMethod()` in this example:

```
public class POJO
{
   String someMethod(String s){}
}

<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->someMethod(..))">
      <after aspect="OneAspect" name="after"/>
   </bind>
</aop>


public class OneAspect
{
   public void after(@JoinPoint MethodJoinPoint mjp){} //1
   public String after(@Target POJO pojo, @Return String ret, @Arg
 String arg0){} //2
}
```

Again in the following example, the first `OneAspect.after()` advice method will be chosen when calling `POJO.someMethod()`. The first `after()` advice method's highest priority parameter is `@Target`, the second advice parameter's highest priority parameter is `@Return`, and `@Target` has a higher priority than `@Return`:

```
public class POJO
{
   String someMethod(String s){}
```

```
}

<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->someMethod(..))">
      <after aspect="OneAspect" name="after"/>
   </bind>
</aop>


public class OneAspect
{
   public void after(@Target POJO pojo){} //1
   public String after(@Return String ret, @Arg String arg0){} //2
}
```

In cases where the highest priority annotated parameter of two advice methods is the same, we move on to the next highest priority annotated parameter of both advices. In the following scenario, both `OneAspect.after()` methods have the `@JoinPoint` parameter as the highest priority parameter. The first one has a `@Target` as its second-highest priority parameter while the second one has `@Return` as its second-highest priority parameter. Since `@Target` has a higher priority than `@Return`, the first `OneAspect.after()` is chosen for `POJO.someMethod()`.

```
public class POJO
{
   String someMethod(String s){}
}

<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->someMethod(..))">
      <after aspect="OneAspect" name="after"/>
   </bind>
</aop>


public class OneAspect
{
   public void after(@JoinPoint MethodJoinPoint mjp, @Target POJO
 pojo){} //1
   public String after(@JoinPoint MethodJoinPoint mjp, @Return
 String ret){} //2
}
```

In the next example, the first `OneAspect.before()` advice is chosen over the second one when calling `POJO.someMethod()`. The reason is that, all else being equal, the first one matches more parameters:.

```
public class POJO
{
   String someMethod(String s, int i){}
}

<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->someMethod(..))">
      <before aspect="OneAspect" name="before"/>
   </bind>
</aop>


public class OneAspect
{
   public void before(@Arg String s, @Arg int i){} //1
   public String before(@Arg String s){} //2
}
```

If the priority of annotated parameters using the presence criterion is the same on more than one advice, the next criterion, the assignability degree, is used.

4.1.2. Assignability Degree

The assignability degree rule will select the advice with the lowest assignability degree on the highest priority parameter. The assignability degree is simply the distance in the class hierarchy between the parameter type, and the type it must be assignable from.

As an example, let us look at the following class hierarchy:

```
public interface POJOInterface{}

public class POJOSuperClass extends java.lang.Object{}

public class POJO extends POJOSuperClass implements POJOInterface
{
   void method(){}
}
```

And this advice binding:

```
<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->method(..))">
      <before aspect="OneAspect" name="before"/>
   </bind>
</aop>
```

```
public class OneAspect
{
   public void before(@Target POJO target){} //1
   public void before(@Target POJOInterface target){} //2
   public void before(@Target POJOSuperClass target){} //3
   public void before(@Target Object target){} //4
}
```

With `POJO` as the target of a joinpoint, the parameter list fo the first `OneAspect.before()` advice method has an assignability degree 0 on `@Target`.

The parameter lists for the second and third `OneAspect.before()` advice methods both have an assignability degree of 1 for `@Target`, since it takes one step through the hierarchy to reach the desired type, `POJO`.

Finally, the parameter list for the fourth `OneAspect.before()` advice method has an assignability degree of 2 on `@Target`.

Hence, JBoss AOP will select the first advice in the example above, since it has the lowest asignability degree on `@Target`.

The assignability degree rule is, similarly to the presence rule, applied on the highest priority annotated parameter, which is `@JoinPoint`. In case there is a match using this criteria (i.e., either both advices lack a `@JoinPoint` annotated parameter, or they both have the same type on the `@JoinPoint` parameter), we move to the next highest priority annotated parameter, which is `@Target`. The same rule is applied until we can find an advice with the highest priority.

Notice that the assignability degree of an advice on `@Arg` is the sum of the assignability degree on all `@Arg` parameters. In the following scenario:

```
public class POJO
{
   public void method(POJO argument0, String argument1, int
 argument2)
}


<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->method(..))">
      <before aspect="OneAspect" name="before"/>
   </bind>
</aop>


public class OneAspect
{
```

```
    public void before(@Arg POJO p, @Arg String s, @Arg int i){} //1
    public void before(@Arg POJOSuperClass p, @Arg String s, @Arg
 int i){} //2
    public void before(@Arg POJO p, @Arg Object s, @Arg int i){} //3
    public void before(@Arg Object p, @Arg Object s, @Arg int i){}
 //4
}
```

The first advice has assignability degree of 0 (for `POJO`) + 0 (for `String`) + 0 (for `int`). Notice how primitive types don't have superclasses, and, hence, have always a 0 value of assinability degree.

The second advice has a larger assignability degree, since `POJOSuperClass` is the superclass of `POJO`, `@Arg POJOSuperClass p` has assignability degree of 1. Hence, this advice assignability degree on `@Arg` is: 1 + 0 + 0 = 1.

The third one also has an assignability degree of 1, since `Object` is the superclass of `String`.

Finally, the last advice has assignability degree of 3 on `@Arg`. The first parameter, `@Arg Object p`, refers to `POJO` and has assignability degree of 2. The second one, assignability degree of 1, since it refers to `String`. And, since `@Arg int` refers to the `int` argument of `POJO.method()`, we have 2 + 1 + 0 = 3.

In the above example, JBoss AOP would select the first advice to intercept `POJO.method()` execution.

4.1.3. Return Types

For annotated parameters typed around advices, there is a third rule, which is the return type. This rule also applies to after and finally advices. If the joinpoint has a non-void return type, the assignability degree of the advice return type is analyzed, pretty much in the same way we do with annotated parameters. So, for overloaded around advices, these three criteria are applied:

- presence of annotated parameter
- assignability degree of annotated parameter
- assignability degree of return type

If two advices have the same ranking on the first two criteria, we check their return types and pick the advice with the lowest assignability degree:

```
public class POJO
{
   public Collection method(int arg0, boolean arg1, short arg2) {…}
}
```

```
<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->method(..))">
      <advice aspect="OneAspect" name="around"/>
   </bind>
</aop>


public class OneAspect
{
   public Collection around(@JoinPoint Invocation inv, @Arg int
 param0) throws Throwable
   {...} //1

   public List around(@JoinPoint Invocation inv, @Arg boolean
 param1) throws Throwable
   {...} //2

}
```

In OneAspect above, we have two around advices. Both of them are equal when compared using the presence criteria. When comparing them using the assignability of annotated parameter, both of them have the same degrees on `@JoinPoint` and on `@Arg` parameters. In this case, we will compare their return type assignability degree.

Notice that, when it comes to return types, it is the return type that must be assignable to the joinpoint type, and not the contrary. This is due to the fact that JBoss AOP will assign the advice return value to the joinpoint return result in the base system. Hence, in the example above, the caller of `POJO.method()` expects a `Collection` return value. So, it is ok to receive either a `Collection` from the first advice, as the more specific type `List` from the second advice. But JBoss AOP will complain if your advice returns an `Object` (`Object` return type is allowed only in the default signature; here we are discussing the annotated-parameter signature), because we can't give an `Object` to the base system when it is expecting a `Collection`.

So, in the above example, the first advice has an assignability degree of 0 on the return type, becase it takes 0 steps in the hierarchy to go from Collection to `Collection`. In the second advice, this value is 1, because it takes 1 step to go from `List` to `Collection`. JBoss AOP would select the first advice.

On overloaded after and finally advices, we also have a return type rule. But, since the return type is optional (these advices can return a value, but is not enforced to it), we have a total of four rules for this advice:

- presence of annotated parameter

- assignability degree of annotated parameter
- presence of non-void return type
- assignability degree of return value type

The third rule, presence of non-void return type, states that JBoss AOP will give preference to an after advice that returns a value:

```
<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->method(..))">
      <after aspect="OneAspect" name="around"/>
   </bind>
</aop>


public class OneAspect
{
   public Collection after(@Arg int param0) {...} //1
   public List after(@Arg boolean param1) { ... } //2
   public void after(@Arg short param2) { ... }   //3
}
```

Considering the same `POJO` class defined previously (with `public void method(int, boolean, short)`), all three overloade versions of `OneAspect.after()` advice wil be considered equivalent in the first two criteria. Hence, we move to the third rule, that states that JBoss AOP prefers an after advice that returns a value over another one that is `void`. So, in the example above, the third advice is ruled out, and JBoss AOP still has two advices to select. Moving to the next rule, he assignability degree of the return type, we have the same result as the `OneAspect.around()` advice: the first one has a 0 degree, and the second one, a 1 degree value. As a conclusion of these degrees, JBoss AOP will select the first advice, with the lowest return assignability degree.

4.1.4. A Match

Notice that, iIf JBoss AOP cannot find an advice with highest priority, it just selects one of the methods arbitrarily. This would be the case of the following advice method scenario:

```
public class POJO
{
   public void method(int arg0, long arg1) {…}
}


<aop>
```

```
   <aspect class="OneAspect"/>
   <bind pointcut="execution(* POJO->method(..))">
      <before aspect="OneAspect" name="before"/>
   </bind>
</aop>


public class OneAspect
{
   public void advice(@Arg int arg0) {}
   public void advice(@Arg long arg1) {}
}
```

4.1.5. Lowest Priority

There are exceptions for the rules we've seen. Advices with one or more of the following characteristics will be considered lowest priority, regardless of any other criteria:

- an advice that receives `@Target` parameter to intercept a joinpoint with no target available
- an advice that receives `@Caller` parameter to intercept a joinpoint with no caller available
- an advice that receives `@Arg` parameter to intercept a field read joinpoint

4.2. Default Signature

For the default around advice signature (i.e., without annotated parameters), there is only one parameter to analyze, the invocation. So, the priority rules are very simple:

- presence of the invocation parameter
- assignability degree of the invocation parameter.

Lets revisit the example given in the beginning of this section, in augmented version:

```
class POJO
{
   public int field;
   public POJO(){}
   public someMethod(){}
}


public class OneAspect
```

```
{
   public Object trace(MethodInvocation invocation) throws
 Throwable {...} //1
   public Object trace(ConstructorInvocation invocation) throws
 Throwable {...} //2
   public Object trace(Invocation invocation) throws Throwable
 {...} //3
   public Object trace() throws Throwable {...} //4
}


<aop>
   <aspect class="OneAspect"/>
   <bind pointcut="all(POJO)">
      <advice aspect="OneAspect" name="trace"/>
   </bind>
</aop>
```

The fourth advice above will never be called, considering the presence rule. It is the only one that lacks the `Invocation` parameter, and would be called only if all others were considered invalid in a scenario, which won't happen in this example. By ruling out this advice with the presence rule, all other advices are equivalent: the invocation parameter is present in all of them. So, we need to move on to the assignability degree rule to select one of them. However, the assignability degree needs to be calculated accordingly to the joinpoint being intercepted. JBoss AOP needs to evaluate each joinpoint type to be intercepted to do the correct selection for each case.

Consider the interception of the constructor of `POJO`. In that case, the first advice is considered invalid, becase a `MethodInvocation` is not assignable from the invocation type that JBoss AOP will provide, `ConstrucorInvocation`. We are now left with the second and third advices. The second one has assignability degree of 0 on the invocation type. The third one, assignability degree of 1 (it takes one step in the hierarchy to go fom `ConstructorInvocation` to `Invocation`). So, in this case, JBoss AOP will select the second advice, because it is the valid advice with the lower assignability degree on the invocation.

Similary, to intercept the execution of `POJO.someMethod()`, JBoss AOP will consider the second advice invalid, because it is supposed to receive an invocation whose type is assignable from `MethodInvocation`. Since the first advice has an assignability degree of 0 on the invocation, and the third one, assignability degree of 1, JBoss AOP will select the first one.

Given that `Invocation` will always be the super class of the expected invocation type, JBoss AOP will select this advice, whose assignability degree will always be 1, only when the other two advices are invalid. That would be the case of a field read, where the invocation type is `FieldReadInvocation`.

4.3. Mixing Different Signatures

Finally, when we mix default signature methods with annotated parameter ones, an advice in one of the forms:

```
public Object [advice name]([Invocation] invocation) throws
 Throwable

public Object [advice name]([Invocation] invocation) throws
 Throwable

public Object [advice name]() throws Throable
```

Has the highest priority over all annotated-parameter advices. If there is more than one with the default signature, the criteria described in the previous section will be used to select one of them..

Notice that mixing different signatures is possible only with around advices, since only these ones can follow the default signature.

5. Common Mistakes

While writing advices and bindings, it is possible to make some mistakes, like, for example, mistyping the advice name, or writing an advice with an invalid signature.

Whenever there is a mistake in the advice name or signature, JBoss AOP will throw an exception with a message stating the cause of the error. The exception thrown is a runtime exception and should not be treated. Instead, it indicates a mistake that must be fixed.

There are two types of exceptions JBoss AOP can throw on those cases:

- `org.jboss.InvalidAdviceException`

  This exception indicates that an advice's signature is considered invalid for the type used on the binding.

  This can happen when the advice is mistakenly declared to be of the wrong type, or when one of the signature rules was not followed.

- `org.jboss.NoMatchingAdviceException`

  This exception is thrown when JBoss AOP can not find an advice method suitable for a specific joinpoint to be intercepted.

  A possible scenario is when there is no advice method with the name used on the bind declaration. To solve it, just fix the advice name on the declaration or add a method with the declared advice name.

When there is one or more methods with the advice name, this exception indicates that JBoss was not able to find an advice with a signature that suits the joinpoint to be intercepted. In this case, the solution can be to alter the signature of one of the existent advice methods, or to add an overloaded advice method that matches the joinpoint to be intercepted.

XML Bindings

1. Intro

In the last sections you saw how to code aspects and how pointcut expressions are formed. This chapter puts it all together. There are two forms of bindings for advices, mixins, and introductions. One is XML which will be the focus of this chapter. The Annotated Bindings chapter discusses how you can replace XML with annotations.

2. Resolving XML

JBoss AOP resolves pointcut and advice bindings at runtime. So, bindings are a deployment time thing. How does JBoss AOP find the XML files it needs at runtime? There are a couple of ways.

2.1. Standalone XML Resolving

When you are running JBoss AOP outside of the application server there are a few ways that the JBoss AOP framework can resolve XML files.

- `jboss.aop.path` This is a system property that is a ';' (Windows) or ':' (Unix) delimited list of XML files and/or directories. If the item in the list is a directory, JBoss AOP will load any xml file in those directories with the filename suffix `-aop.xml`
- `META-INF/jboss-aop.xml` Any JAR file in your CLASSPATH that has a `jboss-aop.xml` file in the `META-INF/` will be loaded. JBoss AOP does a `ClassLoader.getResources("META-INF/jboss-aop.xml")` to obtain all these files.

2.2. Application Server XML Resolving

On the other hand, when you are running JBoss AOP integrated with the application server, XML files can be deployed in two different ways. One is to place an XML file with the suffix `*-aop.xml` in the deploy directory. The other way is to JAR up your classes and provide a `META-INF/jboss-aop.xml` file in this JAR. This JAR file must be suffixed with `.aop` and placed within the deploy/ directory or embedded as a nested archive.

Note that in JBoss 5, you MUST specify the schema used, otherwise your information will not be parsed correctly. You do this by adding the `xmlns="urn:jboss:aop-beans:1:0` attribute to the root `aop` element, as shown here:

```
<aop xmlns="urn:jboss:aop-beans:1.0">
<!--  The exact contents will be explained below -->
</aop>
```

3. XML Schema

The xml schema can be found in the distribution's `etc/`literal> folder.

4. aspect

The `<aspect>` tag specifies to the AOP container to declare an aspect class. It is also used for configuring aspects as they are created and defining the scope of the aspects instance.

4.1. Basic Definition

```
<aspect class="org.jboss.MyAspect"/>
```

In a basic declaration you specify the fully qualified class name of the aspect. If you want to reference the aspect at runtime through the AspectManager, the name of the aspect is the same name as the class name. The default Scope of this aspect is `PER_VM`. Another important note is that aspect instances are created on demand and NOT at deployment time.

4.2. Scope

```
<aspect class="org.jboss.MyAspect" scope="PER_VM"/>
```

The `scope` attribute defines when an instance of the aspect should be created. An aspect can be created per vm, per class, per instance, or per joinpoint.

Name	Description
PER_VM	One and only instance of the aspect class is allocated for the entire VM.
PER_CLASS	One and only instance of the aspect class is allocated for a particular class. This instance will be created if an advice of that aspect is bound to that particular class.
PER_INSTANCE	An instance of an aspect will be created per advised object instance. For instance, if a method has an advice attached to it, whenever an instance of that advised class is allocated, there will also be one created for the aspect.
PER_JOINPOINT	An instance of an aspect will be created per joinpoint advised. If the joinpoint is a static member (constructor, static field/method), then there will be one instance of the aspect created per class, per joinpoint. If the joinpoint is a regular non-static member, than an instance of the aspect will be created per object instance, per joinpoint.
PER_CLASS_JOINPOINT	An instance of an aspect will be created per advised joinpoint. The aspect instance is shared between all instances of the class (for that joinpoint).

Table 5.1. Aspect instance scope

4.3. Configuration

```
<aspect class="org.jboss.SomeAspect">
     <attribute name="SomeIntValue">55</attribute>
     <advisor-attribute name="MyAdvisor"/>
     <instance-advisor-attribute name="MyInstanceAdvisor"/>
     <joinpoint-attribute name="MyJoinpoint"/>
</aspect>
```

Aspects can be configured by default using a Java Beans style convention. The `<attribute>` tag will delegate to a setter method and convert the string value to the type of the setter method.

primitive types (int, float, String, etc...)
java.lang.Class
java.lang.Class[]
java.lang.String[]
java.math.BigDecimal
org.w3c.dom.Document
java.io.File
java.net.InetAddress
java.net.URL
javax.management.ObjectName (if running in JBoss)

Table 5.2. Supported Java Bean types

Besides types, you can also inject AOP runtime constructs into the aspect. These types of attributes are referenced within XML under special tags. See the table below.

<advisor-attribute>	org.jboss.aop.Advisor
<instance-advisor-attribute>	org.jboss.aop.InstanceAdvisor
<joinpoint-attribute>	org.jboss.aop.joinpoint.Joinpoint

Table 5.3. Injecting AOP runtime constructs

4.3.1. Names

If there is no `name` attribute defined, the name of the aspect is the same as the `class` or `factory` attribute value.

4.3.2. Example configuration

```
<aspect class="org.jboss.SomeAspect">
        <attribute name="SomeIntValue">55</attribute>
        <advisor-attribute name="MyAdvisor"/>
        <instance-advisor-attribute name="MyInstanceAdvisor"/>
        <joinpoint-attribute name="MyJoinpoint"/>
</aspect>
```

The above example would would need a class implemented as follows:

```
public class SomeAspect {
   public SomeAspect() {}

   public void setSomeIntValue(int val) {...}
```

```
   public void setMyAdvisor(org.jboss.aop.Advisor advisor) {...}
   public void setMyInstanceAdvisor(org.jboss.aop.InstanceAdvisor
 advisor) {...}
   public void setMyJoinpoint(org.jboss.aop.joinpoint.Joinpoint
 joinpoin) {...}
}
```

4.4. Aspect Factories

```
<aspect name="MyAspect" factory="org.jboss.AspectConfigFactory"
 scope="PER_CLASS">
     <some-arbitrary-xml>value</some-arbitrary-xml>
</aspect>
```

If you do not like the default Java Bean configuration for aspects, or want to delegate aspect creation to some other container, you can plug in your own factory class by specifying the `factory` attribute rather than the `class` attribute. Any arbitrary XML can be specified in the aspect XML declaration and it will be passed to the factory class. Factories must implement the `org.jboss.aop.advice.AspectFactory` interface.

5. interceptor

```
<interceptor class="org.jboss.MyInterceptor" scope="PER_VM"/>
<interceptor class="org.jboss.SomeInterceptor">
     <attribute name="SomeIntValue">55</attribute>
     <advisor-attribute name="MyAdvisor"/>
     <instance-advisor-attribute name="MyInstanceAdvisor"/>
     <joinpoint-attribute name="MyJoinpoint"/>
</interceptor>
<interceptor name="MyAspect"
 factory="org.jboss.InterceptorConfigFactory" scope="PER_CLASS">
  <some-arbitrary-xml>value</some-arbitrary-xml>
</interceptor>
```

Interceptors are defined in XML the same exact way as aspects are. No difference except the tag. If there is no `name` attribute defined, the name of the interceptor is the same as the `class` or `factory` attribute value.

6. bind

```
<bind pointcut="execution(void Foo->bar())">
      <interceptor-ref name="org.jboss.MyInterceptor/>
      <before name="beforeAdvice" aspect="org.jboss.MyAspect"/>
      <around name="aroundAdvice" aspect="org.jboss.MyAspect"/>
```

```
      <after name="afterAdvice" aspect="org.jboss.MyAspect"/>
      <throwing name="throwingAdvice" aspect="org.jboss.MyAspect"/>
      <finally name="finallyAdvice" aspect="org.jboss.MyAspect"/>
      <advice name="trace" aspect="org.jboss.MyAspect"/>
</bind>
```

In the above example, the `MyInterceptor` interceptor and several advice methods of the `MyAspect` class will be executed when the `Foo.bar` method is invoked.

bind
: `bind` tag is used to bind an advice of an aspect, or an interceptor to a specific joinpoint. The `pointcut` attribute is required and at least an advice or interceptor-ref definition.

interceptor-ref
: The `interceptor-ref` tag must reference an already existing `interceptor` XML definition. The name attribute should be the name of the interceptor you are referencing.

before, around, after, throwing and finally
: All these tags take a `name` attribute that should map to an advice of the specified type within the aspect class. The `aspect` attribute should be the name of the aspect definition.

advice
: The same as the previous, except for the fact that doesn't specify the type of the advice. This tag selects the default advice type, around, and is hence equivalent to the tag `around`.

7. stack

Stacks allow you to define a predefined set of advices/interceptors that you want to reference from within a `bind` element.

```
<stack name="stuff">
      <interceptor class="SimpleInterceptor1" scope="PER_VM"/>
      <advice name="trace" aspect="org.jboss.TracingAspect"/>
      <interceptor class="SimpleInterceptor3">
           <attribute name="size">55</attribute>
      </interceptor>
</stack>
```

After defining the stack you can then reference it from within a `bind` element.

```
<bind pointcut="execution(* POJO->*(..))">
       <stack-ref name="stuff"/>
</bind>
```

8. pointcut

The `pointcut` tag allows you to define a pointcut expression, name it and reference it within any binding you want. It is also useful to publish pointcuts into your applications to that others have a clear set of named integration points.

```
<pointcut name="publicMethods" expr="execution(public *
 *->*(..))"/>
<pointcut name="staticMethods" expr="execution(static *
 *->*(..))"/>
```

The above define two different pointcuts. One that matches all public methods, the other that matches the execution of all static methods. These two pointcuts can then be referenced within a `bind` element.

```
<bind pointcut="publicMethods AND staticMethods">
      <interceptor-ref name="tracing"/>
</bind>
```

9. introduction

9.1. Interface introductions

The `introduction` tag allows you to force an existing Java class to implement a particular defined interface.

```
<introduction class="org.acme.MyClass">
    <interfaces>java.io.Serializable</interfaces>
</introduction>
```

The above declaration says that the org.acme.MyClass class will be forced to implement java.io.Serializable. The `class` attribute can take wildcards but not boolean expressions. If you need more complex type expressions, you can use the `expr` attribute instead.

```
<introduction expr="has(* *->@test(..)) OR class(org.acme.*)">
    <interfaces>java.io.Serializable</interfaces>
</introduction>
```

The `expr` can be any type expression allowed in a `typedef` expression

9.2. Mixins

When introducing an interface you can also define a mixin class which will provide the implementation of that interface.

```
<introduction class="org.acme.MyClass">
      <mixin>
         <interfaces>
            java.io.Externalizable
         </interfaces>
         <class>org.acme.ExternalizableMixin</class>
         <construction>new
 org.acme.ExternalizableMixin(this)</construction>
      </mixin>
   </introduction>
```

interfaces
: defines the list of interfaces you are introducing

class
: The type of the mixin class.

construction
: The construction statement allows you to specify any Java code to create the mixin class. This code will be embedded directly in the class you are introducing to so `this` works in the construction statement.

10. annotation-introduction

Annotation introductions allow you to embed an annotation within a the class file of the class. You can introduce an annotation to a class, method, field, or constructor.

```
<annotation-introduction expr="constructor(POJO->new())">
      @org.jboss.complex (ch='a', string="hello world", flt=5.5,
 dbl=6.6, shrt=5, lng=6, \
      integer=7, bool=true, annotation=@single("hello"),
 array={"hello", "world"}, \
      clazz=java.lang.String)
</annotation-introduction>
```

The `expr` attribute takes method(), constructor(), class(), or field(). Within those you must define a valid expression for that construct. The following rules must be followed for the annotation declaration:

- Any annotation, Class or Enum referenced, MUST be fully qualified.

11. cflow-stack

Control flow is a runtime construct. It allows you to specify pointcut parameters revolving around the call stack of a Java program. You can do stuff like, if method A calls method B calls Method C calls Method D from Constructor A, trigger this advice.

In defining a control flow, you must first paint a picture of what the Java call stack should look like. This is the responsibility of the cflow-stack.

```
<cflow-stack name="recursive2">
      <called expr="void POJO->recursive(int)"/>
      <called expr="void POJO->recursive(int)"/>
      <not-called expr="void POJO->recursive(int)"/>
</cflow-stack>
```

A `cflow-stack` has a name and a bunch of `called` and `not-called` elements that define individual constructor or method calls with a Java call stack. The `expr` attribute must be a method or constructor expression. `called` states that the expr must be in the call stack. `not-called` states that there should not be any more of the expression within the stack. In the above example, the `cflow-stack` will be triggered if there are two and only two calls to the `recursive` method within the stack. Once the `cflow-stack` has been defined, it can then be referenced within a `bind` element through the `cflow` attribute. Boolean expressions are allowed here as well.

```
<bind pointcut="execution(void POJO->recursive(int))"
 cflow="recursive2 AND !cflow2">
      <interceptor class="SimpleInterceptor"/>
</bind>
```

12. typedef

```
<typedef name="jmx" expr="class(@org.jboss.jmx.@MBean) OR \
                          has(* *->org.jboss.jmx.@ManagedOperation)
 OR \
                          has(*
 *->org.jboss.jmx.@ManagedAttribute)"/>
```

`typedefs` allow you to define complex type expressions and then use then pointcut expressions. In the above example, we're defining a class that is tagged as @Mbean, or has a method tagged as @ManagedOperaion or @ManagedAttribute. The above typedef could then be used in a pointcut, introduction, or bind element

```
<pointcut name="stuff" expr="execution(* $typedef{jmx}->*(..))"/>
<introduction expr="class($typedef{jmx})">
```

13. dynamic-cflow

`dynamic-cflow` allows you to define code that will be executed that must be resolved true to trigger positive on a cflow test on an advice binding. The test happens dynamically at runtime and when combined with a pointcut expression allows you to

do runtime checks on whether a advice binding should run or not. Create a dynamic cflow class, by implementing the following interface.

```
package org.jboss.aop.pointcut;

import org.jboss.aop.joinpoint.Invocation;

/**
 * Dynamic cflow allows you to programmatically check to see if
 * you want to execute a given advice binding.
 *
 * @author
<a>Bill Burke</a>

 * @version $Revision: 79662 $
 *
 **/
public interface DynamicCFlow
{
   boolean shouldExecute(Invocation invocation);
}
```

You must declare it with XML so that it can be used in bind expressions.

```
<dynamic-cflow name="simple" class="org.jboss.SimpleDynamicCFlow"/>
```

You can then use it within a `bind`

```
<bind expr="execution(void Foo->bar())" cflow="simple">
```

14. prepare

The `prepare` tag allows you to define a pointcut expression. Any joinpoint that matches the expression will be aspectized and bytecode instrumented. This allows you to hotdeploy and bind aspects at runtime as well as to work with the per instance API that every aspectized class has. To prepare something, just define a pointcut expression that matches the joinpoint you want to instrument.

```
<prepare expr="execution(void Foo-bar())"/>
```

15. metadata

You can attach untyped metadata that is stored in `org.jboss.aop.metadata.SimpleMetaData structures` within the `org.jboss.aop.Advisor` class that manages each aspectized class. The XML

mapping has a section for each type of metadata. Class, method, constructor, field, and defaults for the whole shabang. Here's an example:

```
<metadata tag="testdata" class="org.jboss.test.POJO">
      <default>
         <some-data>default value</some-data>
      </default>
      <class>
         <data>class level</data>
      </class>
      <constructor expr="POJOConstructorTest()">
         <some-data>empty</some-data>
      </constructor>
      <method expr="void another(int, int)">
         <other-data>half</other-data>
      </method>
      <field name="somefield">
         <other-data>full</other-data>
      </field>
</metadata>
```

Any element can be defined under the class, default, method, field, and constructor tags. The name of these elements are used as attribute names in SimpleMetaData structures. The `tag` attribute is the name used to reference the metadata within the Advisor, or Invocation lookup mechanisms.

16. metadata-loader

```
<metadata-loader tag="security"
 class="org.jboss.aspects.security.SecurityClassMetaDataLoader"/>
```

If you need more complex XML mappings for untyped metadata, you can write your own metadata binding. The tag attribute is used to trigger the loader. The loader class must implement the `org.jboss.aop.metadata.ClassMetaDataLoader` interface.

```
public interface ClassMetaDataLoader
{
   public ClassMetaDataBinding importMetaData(Element element,
 String name,
                                              String tag, String
 classExpr) throws Exception;

   public void bind(ClassAdvisor advisor, ClassMetaDataBinding
 data,
                    CtMethod[] methods, CtField[] fields,
 CtConstructor[] constructors) \
                    throws Exception;
```

```
  public void bind(ClassAdvisor advisor, ClassMetaDataBinding
 data,
                   Method[] methods, Field[] fields, Constructor[]
 constructors) \
                   throws Exception;
}
```

Any arbitrary XML can be in the `metadata` element. The ClassMetaDataBinding.importMetaData method is responsible for parsing the element and building ClassMetaDataBinding structurs which are used in the precompiler and runtime bind steps. Look at the SecurityClassMetaDataLoader code shown above for a real concrete example.

17. precedence

Precedence allows you to impose an overall relative sorting order of your interceptors and advices.

```
         <precedence>
            <interceptor-ref name="org.acme.Interceptor"/>
            <advice aspect="org.acme.Aspect" name="advice1"/>
            <advice aspect="org.acme.Aspect" name="advice2"/>
         </precedence>
```

This says that when a joinpoint has both `org.acme.Interceptor` and `org.acme.Aspect.advice()` bound to it, `org.acme.Interceptor` must always be invoked before `org.acme.Aspect.advice1()` which must in turn be invoked before `org.acme.Aspect.advice2()`. The ordering of interceptors/advices that do not appear in a precedence is defined by their ordering for the individual bindings or intercerceptor stacks.

18. declare

You can declare checks to be enforced at instrumentation time. They take a pointcut and a message. If the pointcut is matched, the message is printed out.

18.1. declare-warning

```
   <declare-warning expr="class($instanceof{VehicleDAO}) \
            AND !has(public void *->save())">
         All VehicleDAO subclasses must override the save() method.
   </declare-warning>
```

The above declaration says that if any subclass of VehicleDAO does not implement a noargs save() method, a warning with the supplied message should be

logged. Your application will continue to be instrumented/run (since we are using `declare-warning` in this case).

18.2. declare-error

```
      <declare-error expr="call(* org.acme.businesslayer.*->*(..))
\
            AND within(org.acme.datalayer.*)">
      Data layer classes should not call up to the business layer
  </declare-error>
```

The above declaration says that if any classes in the datalayer call classes in the business layer of your application, an error should be thrown. Instumentation/execution of your application will stop.

Annotation Bindings

Annotations can be used as an alternative to XML for configuring classes for AOP.

1. @Aspect

To mark a class as an aspect you annotate it with the `@Aspect` annotation. Remember that a class to be used as an aspect does not need to inherit or implement anything special, but it must have an empty constuctor and contain one or more methods (advices) of the format:

```
public Object <any-method-name>(org.jboss.aop.joinpoint.Invocation)
```

The declaration of `org.jboss.aop.Aspect` is:

```
package org.jboss.aop;

import org.jboss.aop.advice.Scope;
import java.lang.annotation.ElementType;
import java.lang.annotation.Retention;
import java.lang.annotation.RetentionPolicy;
import java.lang.annotation.Target;


@Target({ElementType.TYPE}) @Retention(RetentionPolicy.RUNTIME)
        public @interface Aspect
{
   Scope scope() default Scope.PER_VM;
}
```

and Scope is:

```
package org.jboss.aop.advice;

public enum Scope
{
   PER_VM, PER_CLASS, PER_INSTANCE, PER_JOINPOINT
}
```

See *Section 4.2, "Scope"* for a description of the various scopes.

We use the @Aspect annotation as follows:

```
package com.mypackage;

import org.jboss.aop.Aspect;
import org.jboss.aop.advice.Scope;
import org.jboss.aop.joinpoint.Invocation;

@Aspect (scope = Scope.PER_VM)
public class MyAspect
{
   public Object myAdvice(Invocation invocation)
}
```

The name of the class (in this case `com.mypackage.MyAspect`) gets used as the internal name of the aspect. The equivalent using XML configuration would be:

```
<aop>
<aspect class="com.mypackage.MyAspect" scope="PER_VM"/>
</aop>
```

2. @InterceptorDef

To mark a class as an interceptor or an aspect factory you annotate it with the `@InterceptorDef` annotation. The class must either implement the `org.jboss.aop.advice.Interceptor` interface or the `org.jboss.aop.advice.AspectFactory` interface.

The declaration of `org.jboss.aop.InterceptorDef` is:

```
package org.jboss.aop;

@Target({ElementType.TYPE}) @Retention(RetentionPolicy.RUNTIME)
        public @interface Aspect
{
   Scope scope() default Scope.PER_VM;
}
```

The same `Scope` enum is used as for `Aspect`. The following examples use the @Bind annotation, which will be described in more detail below.

2.1. Interceptor Example

We use the `@InterceptorDef` annotation to mark an Interceptor as follows:

```
package com.mypackage;

import org.jboss.aop.Bind;
import org.jboss.aop.InterceptorDef;
import org.jboss.aop.advice.Interceptor;

@InterceptorDef (scope = Scope.PER_VM)
@Bind (pointcut="execution("* com.blah.Test->test(..)")
public class MyInterceptor implements Interceptor
{
   public Object invoke(Invocation invocation)throws Throwable
   {
      return invocation.invokeNext();
   }
}
```

The name of the class (in this case `com.mypackage.MyInterceptor`) gets used as the class name of the interceptor. The equivalent using XML configuration would be:

```
             <aop>
             <interceptor class="com.mypackage.MyInterceptor"
scope="PER_VM"/>
             </aop>
```

2.2. AspectFactory Example

The `@InterceptorDef` annotation is used to mark an AspectFactory as follows:

```
package com.mypackage;

import org.jboss.aop.advice.AspectFactory;

@InterceptorDef (scope=org.jboss.aop.advice.Scope.PER_VM)
@Bind (pointcut="execution("* com.blah.Test->test2(..)")
public class MyInterceptorFactory implements AspectFactory
{
   //Implemented methods left out for brevity
}
```

3. @PointcutDef

To define a named pointcut you annotate a field within an `@Aspect` or `@InterceptorDef` annotated class with `@PointcutDef`. `@PointcutDef` only applies to fields and is not recognised outside `@Aspect` or `@InterceptorDef` annotated classes.

The declaration of `org.jboss.aop.PointcutDef` is:

```
package org.jboss.aop;

@Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
public @interface PointcutDef
{
   String value();
}
```

`@PointcutDef` takes only one value, a valid pointcut expression. The name of the pointcut used internally and when yo want to reference it is:

```
<name of @Aspect/@InterceptorDef annotated class>.<name of
 @PointcutDef annotated field>
```

An example of an aspect class containing a named pointcut which it references from a bindng's pointcut expression:

```
   package com.mypackage;

   import org.jboss.aop.PointcutDef;
   import org.jboss.aop.pointcut.Pointcut;

   @Aspect (scope = Scope.PER_VM)
   public class MyAspect
   {
      @PointcutDef ("(execution(* org.blah.Foo->someMethod()) OR \
       execution(* org.blah.Foo->otherMethod()))")
      public static Pointcut fooMethods;

      public Object myAdvice(Invocation invocation)
      {
         return invocation.invokeNext();
      }
   }
```

```
```

It is worth noting that named pointcuts can be referenced in pointcut expressions outside the class they are declared in (if the annotated fields are declared public of course!).

Using XML configuration this would be:

```
            <aop>
            <aspect class="com.mypackage.MyAspect" scope="PER_VM"/>
            <pointcut
            name="com.mypackage.MyAspect.fooMethods"
            expr="(execution(* org.blah.Foo->someMethod()) OR \
                  execution(* org.blah.Foo->otherMethod()))"
      />
            </aop>
```

4. @Bind

To create a binding to an advice method from an aspect class, you annotate the advice method with `@Bind`. To create a binding to an Interceptor or AspectFactory, you annotate the class itself with `@Bind` since Interceptors only contain one advice (the `invoke()` method). The @Bind annotation will only be recognised in the situations just mentioned.

The declaration of `org.jboss.aop.Bind` is:

```
package org.jboss.aop;

@Target({ElementType.METHOD, ElementType.TYPE})
 @Retention(RetentionPolicy.RUNTIME)
public @interface Bind
{
  AdviceType type() default AdviceType.AROUND;
  String pointcut();
  String cflow() default "";
}
```

The `@Bind` annotation takes three parameters:

- `type`, valid values are `AdviceType.AROUND`, `AdviceType.BEFORE`, `AdviceType.AFTER`, `AdviceType.THROWING` and `AdviceType.FINALLY`. See *Chapter 4, Advices* for a description of the different advice types. If omitted, the default is an around advice.

- `pointcut`, which is a pointcut expression resolving to the joinpoints you want to bind an aspect/interceptor to
- `cflow`, which is optional. If defined it must resolve to the name of a defined cflow.)

In the case of a binding to an advice in an aspect class, the internal name of the binding becomes:

```
<name of the aspect class>.<the name of the advice method>
```

In the case of a binding to an `Interceptor` or `AspectFactory` implementation, the internal name of the binding becomes:

```
<name of the Interceptor/AspectFactory implementation class>
```

An example of a binding using an advice method in an aspect class:

```
   package com.mypackage;

   import org.jboss.aop.Bind;

   @Aspect (scope = Scope.PER_VM)
   public class MyAspect
   {
      @PointcutDef ("(execution(* org.blah.Foo->someMethod()) \
            OR execution(* org.blah.Foo->otherMethod()))")
      public static Pointcut fooMethods;

      @Bind (pointcut="com.mypackage.MyAspect.fooMethods")
      public Object myAdvice(Invocation invocation)
      {
         return invocation.invokeNext();
      }

      @Bind (pointcut="execution("* org.blah.Bar->someMethod())")
      public Object myAdvice(Invocation invocation)
      {
         return invocation.invokeNext();
      }

   }
```

The equivalent using XML configuration would be:

```
         <aop>
         <aspect class="com.mypackage.MyAspect" scope="PER_VM"/>
```

```
        <pointcut
        name="com.mypackage.MyAspect.fooMethods"
        expr="(execution("* org.blah.Foo->someMethod()) OR \
              execution("* org.blah.Foo->otherMethod()))"
     />
        <bind pointcut="com.mypackage.MyAspect.fooMethods">
        <advice name="myAdvice" aspect="com.mypackage.MyAspect">
        </bind>
        <bind pointcut="execution("* org.blah.Bar->someMethod())">
        <advice name="otherAdvice"
aspect="com.mypackage.MyAspect">
        </bind>
        </aop>
```

Revisiting the examples above in the @InterceptorDef section, now that we know what @Bind means, the equivalent using XML configuration would be:

```
          <aop>
          <interceptor class="com.mypackage.MyInterceptor"
scope="PER_VM"/>
          <interceptor
factory="com.mypackage.MyInterceptorFactory" scope="PER_VM"/>

          <bind pointcut="execution("* com.blah.Test->test2(..)">
          <interceptor-ref name="com.mypackage.MyInterceptor"/>
          </bind>
          <bind pointcut="execution("* com.blah.Test->test2(..)">
          <interceptor-ref
name="com.mypackage.MyInterceptorFactory"/>
          </bind>
          </aop>
```

5. @Introduction

Interface introductions can be done using the `@Introduction` annotation. Only fields within a class annotated with `@Aspect` or `@InterceptorDef` can be annotated with `@Introduction`.

The declaration of `org.jboss.aop.Introduction`:

```
  package org.jboss.aop;

  @Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
  public @interface Introduction
```

```
    {
       Class target() default java.lang.Class.class;
       String typeExpression() default "";
       Class[] interfaces();
    }
```

The parameters of `@Introduction` are:

- `target`, the name of the class we want to introduce an interface to.
- `typeExpression`, a type expression that should resolve to one or more classes we want to introduce an interface to.
- `interfaces`, an array of the interfaces we want to introduce

`target` or `typeExpression` has to be specified, but not both.

This is how to use this annotation:

```
package com.mypackage;

import org.jboss.aop.Introduction;

@Aspect (scope = Scope.PER_VM)
public class IntroAspect
{
   @Introduction (target=com.blah.SomeClass.class, \
         interfaces={java.io.Serializable.class})
   public static Object pojoNoInterfacesIntro;
}
```

This means make `com.blah.SomeClass.class` implement the `java.io.Serializable` interface. The equivalent configured via XML would be:

```
         <introduction class="com.blah.SomeClass.class">
         <interfaces>
      java.io.Serializable
         </interfaces>
         </introduction>
```

6. @Mixin

Sometimes when we want to introduce/force a new class to implement an interface, that interface introduces new methods to a class. The class needs to implement

these methods to be valid. In these cases a mixin class is used. The mixin class must implement the methods specified by the interface(s) and the main class can then implement these methods and delegate to the mixin class.

Mixins are created using the @Mixin annotation. Only methods within a class annotated with `@Aspect` or `@InterceptorDef` can be annotated with `@Mixin`. The annotated method has

- be public
- be static
- have an empty parameter list, or receive the target of introduction as parameter
- contain the logic to create the mixin class
- return an instance of the mixin class

The declaration of `org.jboss.aop.Mixin`:

```
   package org.jboss.aop;

   @Target({ElementType.METHOD})
 @Retention(RetentionPolicy.RUNTIME)
   public @interface Mixin
   {
      Class target() default java.lang.Class.class;
      String typeExpression() default "";
      Class[] interfaces();
      boolean isTransient() default true;
   }
```

The parameters of `@Mixin` are:

- `target`, the name of the class we want to introduce an interface to.
- `typeExpression`, a type expression that should resolve to one or more classes we want to introduce an interface to.
- `interfaces`, an array of the interfaces we want to introduce, implemented by the mixin class.
- `isTransient`. Internally AOP makes the main class keep a reference to the mixin class, and this sets if that reference should be transient or not. The default is true.

`target` or `typeExpression` has to be specified, but not both.

An example aspect using `@Mixin` follows:

```
  package com.mypackage;

  import org.jboss.aop.Mixin;
  import com.mypackage.POJO;

  @Aspect (scope=org.jboss.aop.advice.Scope.PER_VM)
  public class IntroductionAspect
  {
     @Mixin (target=com.mypackage.POJO.class,
interfaces={java.io.Externalizable.class})
     public static ExternalizableMixin
createExternalizableMixin(POJO pojo) {
         return new ExternalizableMixin(pojo);
     }
  }
```

Since this is slightly more complex than the previous examples we have seen, the `POJO` and `ExternalizableMixin` classes are included here.

```
  package com.mypackage;

  public class POJO
  {
     String stuff;
  }
```

```
  package com.mypackage;

  import java.io.Externalizable;
  import java.io.IOException;
  import java.io.ObjectInput;
  import java.io.ObjectOutput;

  public class ExternalizableMixin implements Externalizable
  {
     POJO pojo;

     public ExternalizableMixin(POJO pojo)
     {
        this.pojo = pojo;
     }

     public void readExternal(ObjectInput in) throws IOException,
ClassNotFoundException
     {
```

```
         pojo.stuff = in.readUTF();
      }

      public void writeExternal(ObjectOutput out) throws
 IOException
      {
         out.writeUTF(pojo.stuff);
      }
   }
```

This has the same effect as the following XML configuration:

```
            <introduction classs="com.mypackage.POJO">
            <mixin transient="true">
            <interfaces>
              java.io.Externalizable
            </interfaces>
            <class>com.mypackage.ExternalizableMixin</class>

 <construction>IntroductionAspect.createExternalizableMixin(this)</
construction>
            </mixin>
            </introduction>
```

7. @Prepare

To prepare a joinpoint or a set of joinpoints for DynamicAOP annotate a field with `@Prepare` in a class anotated with `@Aspect` or `@InterceptorDef`.

The declaration of `org.jboss.aop.Prepare` is:

```
   package org.jboss.aop;

   @Target({ElementType.FIELD, ElementType.TYPE})
 @Retention(RetentionPolicy.RUNTIME)
        public @interface Prepare {
       String value() default "";
   }
```

The single field `value` contains a pointcut expression matching one or more joinpoints.

To use `@Prepare` follow this example:

```
package com.mypackage;

import org.jboss.aop.Prepare;

@InterceptorDef (scope = Scope.PER_VM)
@Bind (pointcut="execution("* com.blah.Test->test(..)")
public class MyInterceptor2 implements Interceptor
{
   @Prepare ("all(com.blah.DynamicPOJO)")
   public static Pointcut dynamicPOJO;

   public Object invoke(Invocation invocation)throws Throwable
   {
      return invocation.invokeNext();
   }
}
```

Using XML configuration instead we would write:

```
         <prepare expr="all(com.blah.DynamicPOJO)"/>
```

This simple example used an `@InterceptorDef` class for a bit of variety in the examples, and to reiterate that `@Pointcut`, `@Introduction`, `@Mixin`, `@Prepare`, `@Typedef`, `@CFlow`, `@DynamicCFlow` and `@AnnotationIntroductionDef` can all be used both in `@InterceptorDef` annotated classes AND `@Aspect` annotated classes. Same for `@Bind`, but that is a special case as mentioned above.

7.1. @Prepare POJO

You can also annotate a POJO with @Prepare directly in cases where you are using Dynamic AOP, and the exact bindings are not known at instrumentation time. In this case you annotate the class itself. Here's how it is done:

```
package com.mypackage;

import org.jboss.aop.Prepare;

@Prepare ("all(this)")
public class MyDynamicPOJO implements Interceptor
{
   ...
}
```

```
```

`all(this)` means the same as `all(com.blah.MyDynamicPOJO)`, but the use of `all(this)` is recommended.

The examples just given equate to this XML

```
            <prepare expr="all(com.blah.MyDynamicPOJO)"/>
```

To summarise, when using @Prepare within an @Interceptor or @Aspect annotated class, you annotate a field within that class. When using @Prepare with a POJO you annotate the class itself.

8. @TypeDef

To use a typedef, you annotate a field with `@TypeDef` in a class anotated with `@Aspect` or `@InterceptorDef`.

The declaration of `org.jboss.aop.TypeDef`:

```
package org.jboss.aop;

@Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
public @interface TypeDef {
    String value();
}
```

The single `value` field takes a type expression that resolves to one or more classes. The name of the typedef used for reference and internally is:

```
<name of @Aspect/@InterceptorDef annotated class>.<name of @TypeDef
 annotated field>
```

Here's how to use it:

```
   package com.mypackage;

   import org.jboss.aop.TypeDef;
   import org.jboss.aop.pointcut.Typedef;
   @Aspect (scope=org.jboss.aop.advice.Scope.PER_VM)
   public class TypedefAspect
   {
      @TypeDef ("class(com.blah.POJO)")
```

```
      public static Typedef myTypedef;

       @Bind (pointcut="execution(* \

 $typedef{com.mypackage.TypedefAspect.myTypedef}-
>methodWithTypedef())")
       public Object typedefAdvice(Invocation invocation) throws
 Throwable
     {
        return invocation.invokeNext();
     }
   }
```

The equivalent using XML configuration would be:

```
           <aop>
           <aspect class="com.mypackage.TypedefAspect"
 scope="PER>VM"/>
           <typedef name="com.mypackage.TypedefAspect.myTypedef"
 expr="class(com.blah.POJO)"/>
           <bind
         pointcut="execution(* \

 $typedef{com.mypackage.TypedefAspect.myTypedef}-
>methodWithTypedef())"
           >
           <advice name="typedefAdvice"
 aspect="com.mypackage.TypedefAspect"/>
           </bind>
           </aop>
```

9. @CFlowDef

To create a CFlow stack, you annotate a field with `@CFlowDef` in a class anotated with `@Aspect` or `@InterceptorDef`. The declaration of `org.jboss.aop.CFlowStackDef` is:

```
   package org.jboss.aop;

   @Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
       public @interface CFlowStackDef
   {
      CFlowDef[] cflows();
   }
```

In turn the declaration of `org.jboss.aop.CFlowDef` is:

```
  package org.jboss.aop;

  public @interface CFlowDef {
      boolean called();
      String expr();
  }
```

The parameters of `@CFlowDef` are:

- `called`, whether the corresponding expr should appear in the stack trace or not.
- `expr`, a string matching stack a trace element

The name of the CFlowStackDef used for reference and internally is:

```
<name of @Aspect/@InterceptorDef annotated class>.<name of
 @CFlowStackDef annotated field>
```

CFlowStackDef is used like the following example:

```
  package com.mypackage;

  import org.jboss.aop.CFlowStackDef;
  import org.jboss.aop.pointcut.CFlowStack;

  @Aspect (scope=org.jboss.aop.advice.Scope.PER_VM)
  public class CFlowAspect
  {

     @CFlowStackDef (cflows={@CFlowDef(expr= "void
com.blah.POJO->cflowMethod1()", \
           called=false),  @CFlowDef(expr = "void
com.blah.POJO->cflowMethod2()", \
           called=true)})
     public static CFlowStack cfNot1And2Stack;

     @Bind (pointcut="execution(void
com.blah.POJO*->privMethod())", \
           cflow="com.mypackage.CFlowAspect.cfNot1And2Stack")
     public Object cflowAdvice(Invocation invocation) throws
Throwable
     {
        return invocation.invokeNext();
```

```
      }
   }
```

The above means the same as this XML:

```
            <aop>
            <cflow-stack
name="com.mypackage.CFlowAspect.cfNot1And2Stack">
            <called expr="void com.blah.POJO->cflowMethod1()"/>
            <not-called expr="void com.blah.POJO->cflowMethod2()"/>
            </cflow-stack>
            </aop>
```

10. @DynamicCFlowDef

To create a dynamic CFlow you annotate a class implementing `org.jboss.aop.pointcut.DynamicCFlow` with `@DynamicCFlowDef`. The declaration of `@org.jboss.aop.DynamicCFlowDef` is:

```
   package org.jboss.aop;

   @Target(ElementType.TYPE) @Retention(RetentionPolicy.RUNTIME)
   public @interface DynamicCFlowDef
   {
   }
```

Here is a @DynamicCFlow annotated class:

```
   package com.mypackage;

   import org.jboss.aop.DynamicCFlowDef;
   import org.jboss.aop.pointcut.DynamicCFlow;

   @DynamicCFlowDef
   public class MyDynamicCFlow implements DynamicCFlow
   {
      public static boolean execute = false;

      public boolean shouldExecute(Invocation invocation)
      {
         return execute;
      }
```

```
   }
```

The name of the `@DynamicCFlowDef` annotated class gets used as the name of the cflow for references.

To use the dynamic cflow we just defined:

```
  package com.mypackage;

  @Aspect (scope=org.jboss.aop.advice.Scope.PER_VM)
  public class CFlowAspect
  {
     @Bind (pointcut="execution(void
com.blah.POJO->someMethod())", \
           cflow="com.mypackage.MyDynamicCFlow")
     public Object cflowAdvice(Invocation invocation) throws
Throwable
     {
        return invocation.invokeNext();
     }
  }
```

11. @AnnotationIntroductionDef

You can introduce annotations by annotating a field with the `@AnnotationIntroductionDef` in a class anotated with `@Aspect` or `@InterceptorDef`. The declaration of `org.jboss.aop.AnnotationIntroductionDef` is:

```
  package org.jboss.aop;

  @Target (ElementType.FIELD) @Retention(RetentionPolicy.RUNTIME)
        public @interface AnnotationIntroductionDef
  {
     String expr();
     boolean invisible();
     String annotation();
  }
```

The parameters of `@AnnotationIntroductionDef` are:

- `expr`, pointcut matching the classes/constructors/methods/fields we want to annotate.

- `invisible`, if true: the annotation's retention is RetentionPolicy.CLASS; false: RetentionPolicy.RUNTIME
- `annotation`, the annotation we want to introduce.

The listings below make use of an annotation called `@com.mypackage.MyAnnotation`:

```
  package com.mypackage;
  public interface MyAnnotation
  {
     String string();
     int integer();
     boolean bool();
  }
```

What its parameters mean is not very important for our purpose.

The use of `@AnnotationIntroductionDef`:

```
  package com.mypackage;

  import org.jboss.aop.AnnotationIntroductionDef:
  import org.jboss.aop.introduction.AnnotationIntroduction;

  @.InterceptorDef (scope=org.jboss.aop.advice.Scope.PER_VM)
  @org.jboss.aop.Bind (pointcut="all(com.blah.SomePOJO)")
  public class IntroducedAnnotationInterceptor implements
Interceptor
  {
     @org.jboss.aop.AnnotationIntroductionDef \
           (expr="method(*
com.blah.SomePOJO->annotationIntroductionMethod())", \
            invisible=false, \
            annotation="@com.mypackage.MyAnnotation \
               (string='hello', integer=5, bool=true)")
     public static AnnotationIntroduction annotationIntroduction;

     public String getName()
     {
        return "IntroducedAnnotationInterceptor";
     }

     public Object invoke(Invocation invocation) throws Throwable
     {
        return invocation.invokeNext();
     }
```

```
   }
```

Note that the reference to `@com.mypackage.MyAnnotation` must use the fully qualified class name, and that the value for its string parameter uses single quotes.

The previous listings are the same as this XML configuration:

```
           <annotation-introduction
     expr="method(*
com.blah.SomePOJO->annotationIntroductionMethod())
     invisible="false"
           >
     @com.mypackage.MyAnnotation (string="hello", integer=5,
bool=true)
           </annotation-introduction>
```

12. @Precedence

You can declare precedence by annotating a class with `@Precedence`, and then annotate fields where the types are the various Interfaces/Aspects you want to sort. You annotate fields where the type is an interceptor with `@PrecedenceInterceptor`. When the type is an aspect class, you annotate the field with `@PrecedenceAdvice`. The definitions of org.jboss.aop.Precedence, org.jboss.aop.PrecedenceInterceptor and org.jboss.aop.PrecedenceAdvice are

```
   package org.jboss.aop;

   @Target({ElementType.TYPE}) @Retention(RetentionPolicy.RUNTIME)
   public @interface Precedence
   {
   }
```

```
   package org.jboss.aop;

   @Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
   public @interface PrecedenceInterceptor
   {
   }
```

```
```

```
package org.jboss.aop;

@Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
public @interface PrecedenceAdvice
{
   String value();
}
```

The `value()` attribute of `PrecedenceAdvice` is the name of the advice method to use.

The example shown below declares a relative sort order where `org.acme.Interceptor` must always be invoked before `org.acme.Aspect.advice1()` which must be invoked before `org.acme.Aspect.advice2()`:

```
import org.jboss.aop.Precedence;
import org.jboss.aop.PrecedenceAdvice;

@Precedence
public class MyPrecedence
{
   @PrecedenceInterceptor
   org.acme.Interceptor intercept;

   @PrecedenceAdvice ("advice1")
   org.acme.Aspect precAdvice1;

   @PrecedenceAdvice ("advice2")
   org.acme.Aspect precAdvice2;
}
```

The ordering of interceptors/advices defined via annotations that have no precedence defined, is arbitrary.

13. @DeclareError and @DeclareWarning

You can declare checks to be enforced at instrumentation time. They take a pointcut and a message. If the pointcut is matched, the message is printed out. To use this with annotations, annotate fields with `DeclareWarning` or `DeclareError` within a class annotated with `@Aspect` or `@InterceptorDef`. The definitions of `org.jboss.aop.DeclareError` and `org.jboss.aop.DeclareWarning` are:

```
package org.jboss.aop;
```

```
  @Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
  public @interface DeclareWarning
  {
     String expr();
     String msg();
  }
```

```
  package org.jboss.aop;

  @Target({ElementType.FIELD}) @Retention(RetentionPolicy.RUNTIME)
  public @interface DeclareError
  {
     String expr();
     String msg();
  }
```

For both: the expr() attribute is a pointcut expression that should not occur, and the msg() attribute is the message to print out if a match is found for the pointcut. If you use `DeclareWarning` instrumentation/your application will simply continue having printed the message you supplied. In the case of `DeclareError`, the message is logged and an error is thrown, causing instrumentation/your application to stop. Here is an example:

```
  import org.jboss.aop.Aspect;
  import org.jboss.aop.pointcut.Pointcut;
  import org.jboss.aop.DeclareError;
  import org.jboss.aop.DeclareWarning;

  @Aspect (scope=org.jboss.aop.advice.Scope.PER_VM)
  public class DeclareAspect
  {
     @DeclareWarning (expr="class($instanceof{VehicleDAO}) AND \
        !has(public void *->save())", \
        msg="All VehicleDAO subclasses must override the save()
method.")
     Pointcut warning;

     @DeclareError (expr="call(* org.acme.businesslayer.*->*(..))
\
        AND within(org.acme.datalayer.*)", \
        msg="Data layer classes should not call up to the business
layer")
     Pointcut error;
```

```
    }
```

Dynamic AOP

1. Hot Deployment

With JBoss AOP you can change advice and interceptor bindings at runtime. You can unregister existing bindings, and hot deploy new bindings if the given joinpoints have been instrumented. Hot-deploying within the JBoss application server is as easy as putting (or removing) a `*-aop.xml` file or `.aop` jar file within the deploy/ directory. There is also a runtime API for adding advice bindings at runtime. Getting an instance of `org.jboss.aop.AspectManager.instance()`, you can add your binding.

```
      org.jboss.aop.advice.AdviceBinding binding =
                                new
 AdviceBinding("execution(POJO->new(..))", null);
      binding.addInterceptor(SimpleInterceptor.class);
      AspectManager.instance().addBinding(binding);
```

First, you allocated an `AdviceBinding` passing in a pointcut expression. Then you add the interceptor via its class and then add the binding through the AspectManager. When the binding is added the AspectManager will iterate through ever loaded class to see if the pointcut expression matches any of the joinpoints within those classes.

2. Per Instance AOP

Any class that is instrumented by JBoss AOP, is forced to implement the `org.jboss.aop.Advised interface.`

```
public interface InstanceAdvised
{
   public InstanceAdvisor _getInstanceAdvisor();
   public void _setInstanceAdvisor(InstanceAdvisor newAdvisor);
}

public interface Advised extends InstanceAdvised
{
   public Advisor _getAdvisor();
}
```

The InstanceAdvisor is the interesting interface here. InstanceAdvisor allows you to insert Interceptors at the beginning or the end of the class's advice chain.

```
public interface InstanceAdvisor
```

```
{
   public void insertInterceptor(Interceptor interceptor);
   public void removeInterceptor(String name);
   public void appendInterceptor(Interceptor interceptor);

   public void insertInterceptorStack(String stackName);
   public void removeInterceptorStack(String name);
   public void appendInterceptorStack(String stackName);

   public SimpleMetaData getMetaData();

}
```

So, there are three advice chains that get executed consecutively in the same java call stack. Those interceptors that are added with the `insertInterceptor()` method for the given object instance are executed first. Next, those advices/interceptors that were bound using regular `bind`s. Finally, those interceptors added with the `appendInterceptor()` method to the object instance are executed. You can also reference `stack`s and insert/append full stacks into the pre/post chains.

Besides interceptors, you can also append untyped metadata to the object instance via the getMetaData() method.

3. Preparation

Dynamic AOP cannot be used unless the particular joinpoint has been instrumented. You can force intrumentation with the `prepare` functionality

4. Improved Instance API

As mentioned, you can add more aspects to a woven class using the `org.jboss.aop.InstanceAdvisor`. This API is limited to adding interceptors to the existing intereptor chains, so it is a bit limited.

The new default weaving mode introduced in JBoss AOP 2.0.0 still allows you access to the `InstanceAdvisor` interface, but also offers a fuller instance API, which allows you to add bindings, annotation overrides etc. via the normal dynamic AOP API. This is underdocumented, but for a full overview of the capabilites take a look at how `org.jboss.aop.AspectXmlLoader` interacts with `org.jboss.aop.AspectManager`. We are working on a new tidier API for the next version of JBoss AOP. Normally, for dynamic AOP you add things to the top level `AspectManager`, which means that all instances of all woven classes can be affected.

In JBoss AOP 2.0.0, each aspectized class has its own Domain. A domain is a sub-AspectManager. What is deployed in the main AspectManager is visible to the class's domain, but not vice versa. Furthermore each advised instance has its own Domain again which is a child of the class's domain. The Domain class is a sub-class

of the AspectManager, meaning you can add ANYTHING supported by JBoss AOP to it, you are not limited to just interceptors. In the following example we prepare all joinpoints of the POJO class and declare an aspect called `MyAspect`

```
  <!-- Weave in the hooks into our POJO class and add the
interceptors -->
  <aop>
     <aspect class="MyAspect"/>
     <prepare expr="all(POJO)"/>
  </aop>
```

```
  POJO pojo1 = new POJO();
  POJO pojo2 = new POJO();
```

```
  pojo1.someMethod();
```

At this stage, our `POJO` has the hooks woven in for AOP, but now bindings are deployed, so our call to `POJO.someMethod()` is not intercepted. Next let us add a binding to `POJO`'s class domain.

```
  //All woven classes implement the Advised interface
  Advised classAdvisor = ((Advised)pojo1);
  //Get the domain used by all instances of POJO
  AspectManager pojoDomain =
classAdvisor._getAdvisor().getManager();
  //Add a binding with an aspect for that class this is similar to
  AdviceBinding binding1 = new AdviceBinding("execution(*
POJO->someMethod*(..))", null);
  AspectDefinition myAspect =
AspectManager.instance().getAspectDefinition("MyAspect");
  binding1.addInterceptorFactory(new AdviceFactory(myAspect,
"intercept"));

  //Add the binding to POJO's domain
  pojoDomain.addBinding(binding1);

  pojo1.someMethod();
  pojo2.someMethod();
```

Now we have added a binding to `POJO`'s class Domain. Both calls to `someMethod()` get intercepted by MyAspect

```
  //Create an annotation introduction
  AnnotationIntroduction intro =
AnnotationIntroduction.createMethodAnnotationIntroduction(
        "* POJO->someMethod()",
        "@MyAnnotation",
        true);

  //Create another binding
  AdviceBinding binding2 = new AdviceBinding("execution(*
POJO->@MyAnnotation)", null);
  binding2.addInterceptor(MyInterceptor.class);

  //All woven instances have an instance advisor
  InstanceAdvisor instanceAdvisor1 =
((Advised)pojo1)._getInstanceAdvisor();

  //The instance advisor has its own domain
  Domain pojo1Domain = instanceAdvisor1.getDomain();

  //Add the annotation override and binding to the domain
  pojo1Domain.addAnnotationOverride(intro);
  pojo1Domain.addBinding(binding2);

  pojo1.someMethod();
  pojo2.someMethod();
```

We have added an annotation override and a new binding matching on that annotaton to `pojo1`'s domain, so when calling `pojo1.someMethod()` this gets intercecpted by `MyAspect` AND `MyInterceptor`. `pojo2.someMethod()` still gets intercepted by MyAspect only.

5. DynamicAOP with HotSwap

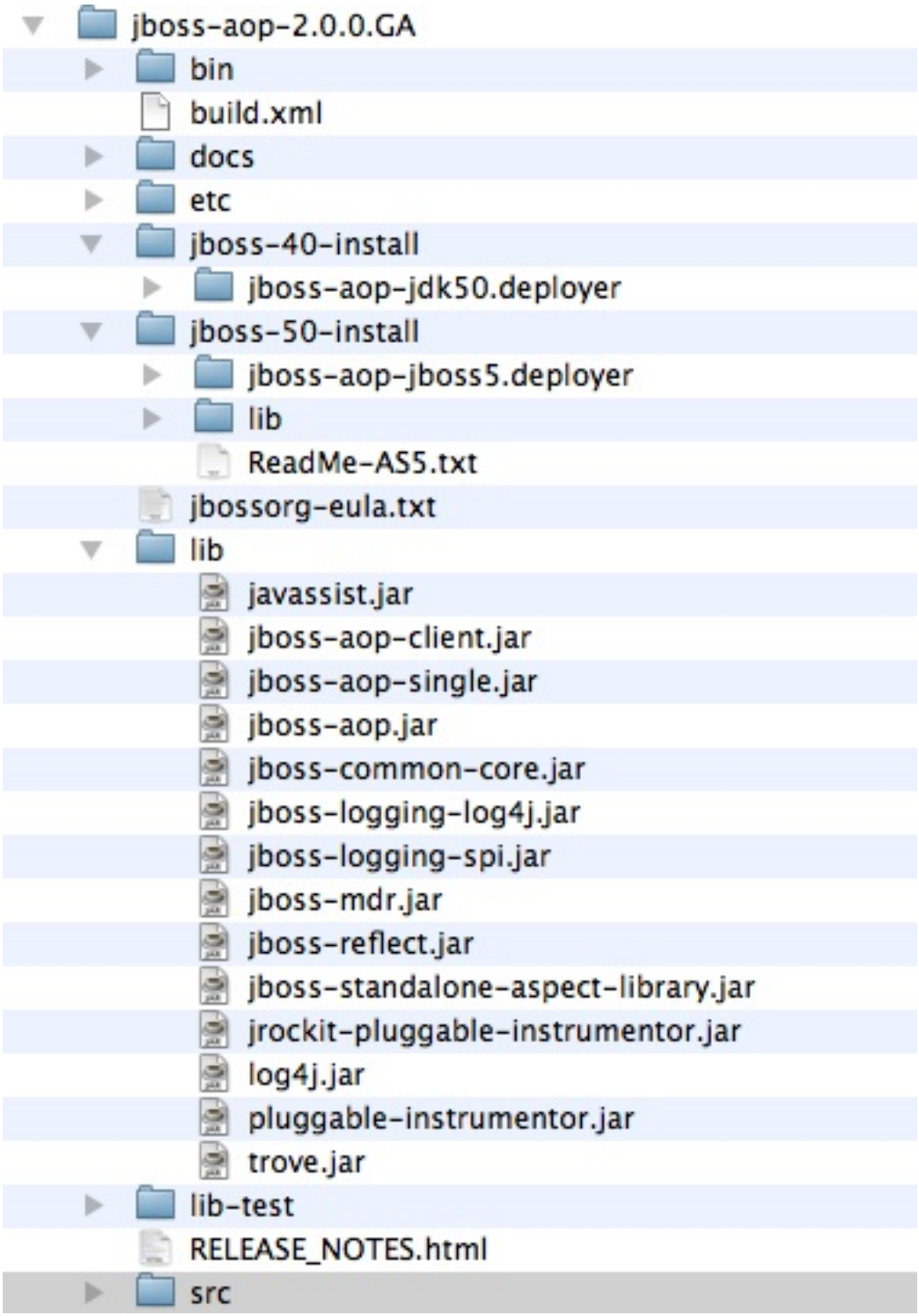
When running JBoss AOP with HotSwap, the dynamic AOP operations may result in the weaving of bytecodes. In this case, the flow control of joinpoints matched only by `prepare` expressions is not affected before any advices or interceptors are applied to them via dynamic aop. Only then, the joinpoint bytecodes will be weaved to start invoking the added advices and interceptors and, as a result, their flow control will be affected.

On the other hand, if HotSwap is disabled, the joinpoints matched by `prepare` expressions are completely instrumented and the flow control is affected before classes get loaded, even if no interceptors are applied to them with dynamic aop.

To learn how to enable HotSwap, refer to the "Running Aspectized Application" chapter.

Installing

This section defines how to install JBoss AOP standalone, within JBoss 4.0.x, JBoss 4.2.x and within JBoss 5.x



1. Installing Standalone

There's nothing really to install if you're running outside the JBoss application server. Just use the libraries under `lib/`.

2. Installing with JBoss 4.0.x and JBoss 4.2.x Application Server for JDK 5

DISCLAIMER: We no longer actively test against JBoss Application Server 4.0.x or 4.2.x. If there are any problems with the issues outlined below, please contact us on the JBoss AOP user forum at http://www.jboss.org.

To install JBoss AOP in JBoss 4.0.x or JBoss 4.2.x Application Server: with JDK 5, there is an ant build script to install into the application server. It lives in `jboss-40-install/jboss-aop-jdk50.deployer/build.xml`. Modify `jboss-40-install/jboss-aop-jdk50.deployer/jboss.properties` to point to the the root of your JBoss installation and specify the application server configuration you want to upgrade. These are the steps taken by the ant script:

1. Back up the existing `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer` to `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer.bak`
2. Copy the files from `jboss-40-install/jboss-aop-jdk50.deployer` over the files that already exist in your existing JBoss Application Server distribution under `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer`
3. In JBoss 4.0.4.GA and later, move `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer/javassist.jar` to `${jboss.home}/server/<config-name>/lib/javassist.jar`. Any existing javassist.jar in that location is copied to `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer.bak/lib/javassist.bak`
4. If you NOT upgrading from a previous AOP 2 distribution, open up `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer/jboss-aspect-library-jdk50.jar` and delete all classes and subpackages under `org.jboss.aop`. In AOP 2.0 we changed the packaging, these classes now exist inside `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer/jboss-aop-as4-deployer.jar`. Also,

we delete any files that also exist in `${jboss.home}/server/<config-name>/deploy/jboss-aop-jdk50.deployer/jboss-standalone-aspect-library.jar`

3. Installing with JBoss Application Server 5

JBoss AS 5 ships with AOP 2.0.0.GA. To upgrade to a newer AOP version, we have provided am an script to upgrade the server. It can be found at `jboss-50-install/build.xml`. Modifly `jboss-50-install` to point to the root of your JBoss installation, and specify the application server configuration you want to upgrade. These are the steps taken by the ant script:

1. Back up the existing `${jboss.home}/lib` and `${jboss.home}/server/<config-name>/deployers/jboss-aop-jboss5.deployer` folders.
2. Overwrite the `${jboss.home}/server/<config-name>/deployers/jboss-aop-jboss5.deployer` folder with the files from `jboss-50-install/jboss-aop-jboss5.deployer`.
3. Overwrite the `${jboss.home}/lib` folder with the files from `jboss-50-install/lib`.

Building and Compiling Aspectized Java

1. Instrumentation modes

JBoss AOP works by instrumenting the classes you want to run. This means that modifications to the bytecode are made in order to add extra information to the classes to hook into the AOP library. JBoss AOP allows for two types of instrumentation

- Precompiled - The classes are instrumented in a separate aop compilation step before they are run.
- Loadtime - The classes are instrumented when they are first loaded.

This chapter describes the steps you need to take to precompile your classes with the aop precompiler.

2. Ant Integration

JBoss AOP comes with an ant task that you can use for precompiling your classes with the aop precompiler. An example build.xml file is the basis for the explanation.

```
<?xml version="1.0" encoding="UTF-8"?>

<project default="compile" name="JBoss/AOP">
   <target name="prepare">
```

Define the source directory, and the directory to compile classes to.

```
        <property name="src.dir" value="PATH TO YOUR SOURCE DIR">
        <property name="classes.dir" value="PATH TO YOUR DIR FOR
 COMPILED CLASSES">
```

Define also the path of your JBoss AOP installation, as well as the path to the lib directory:

```
         <property name="jboss.aop.root" value="PATH TO JBOSS AOP
 HOME"/>
```

```
          <property name="jboss.aop.lib"
value="${jboss.aop.root}/lib"/>
```

Include the jboss-aop.jar and the jars it depends on in the classpath:

```
     <path id="classpath">
        <pathelement path="${jboss.aop.lib}/jboss-aop.jar"/>
        <pathelement path="${jboss.aop.lib}/javassist.jar"/>
        <pathelement path="${jboss.aop.lib}/trove.jar"/>
        <pathelement
path="${jboss.aop.lib}/jboss-common-core.jar"/>
        <pathelement
path="${jboss.aop.lib}/jboss-logging-spi.jar"/>
        <pathelement
path="${jboss.aop.lib}/jboss-logging-log4j.jar"/>
        <pathelement path="${jboss.aop.lib}/jboss-mdr.jar"/>
        <pathelement path="${jboss.aop.lib}/jboss-reflect.jar"/>
        <pathelement path="${jboss.aop.lib}/log4j.jar"/>
     </path>
```

As an alternative, you can use the single jar provided with JBoss AOP. This jar bundles all the libraries used by JBoss AOP in a single unit. To use this jar, just define:

```
     <path id="classpath">
        <pathelement
path="${jboss.aop.lib}/jboss-aop-single.jar"/>
     </path>
```

Now, define the `org.jboss.aop.ant.AopC` ant aop precompiler task:

```
     <taskdef name="aopc" classname="org.jboss.aop.ant.AopC"
        classpathref="jboss.aop.classpath"/>
     </target>
```

```
  <target name="compile" depends="prepare">
```

Compile the files (from the source directory to the compiled classes directory):

```
      <javac srcdir="${src.dir}"
         destdir="${classes.dir}"
         debug="on"
         deprecation="on"
         optimize="off"
         includes="**">
         <classpath refid="classpath"/>
      </javac>
```

Now use the ant aop precompiler task, it reads the files from the classes directory and weaves those classes, ovewriting them with the corresponding weaved version.

```
      <aopc compilerclasspathref="classpath" verbose="true">
         <classpath path="${classes.dir}"/>
         <src path="${classes.dir}"/>
         <include name="**/*.class"/>
         <aoppath path="jboss-aop.xml"/>
         <aopclasspath path="${classes.dir}"/>
      </aopc>
   </target>
</project>
```

The last tag, `aopclasspath`, must be used only if you used annotations to configure aspects, bindings, and the like. If this is the case and you are not using a jboss-aop.xml file, you can ommit the `aoppath` tag. You can also use both annotations and XML to configure aspects. In this case, you must declare both tags. The complete list of the parameters that `org.jboss.aop.ant.AopC` ant task takes follows:

- `compilerclasspath` or `compilerclasspathref` - These are interchangable, and represent the jars needed for the aop precompiler to work. The `compilerclasspath` version takes the paths of the jar files, and the `compilerclasspathref` version takes the name of a predefined ant path. They can be specified as attributes of `aopc`, as shown above. `compilerclasspath` can also be specified as a child element of `aopc`, in which case you can use all the normal ant functionality for paths (e.g. fileset).
- `classpath` or `classpathref` - Path to the compiled classes to be instrumented. The `classpath` version takes the path of the directory, and the `classpathref` version takes the name of a predefined ant path. They both be specified as attributes of `aopc`. `classpath` can also be specified as a child element of `aopc`, as shown above, in which case you can use all the normal ant functionality for paths

(e.g. fileset). The full classpath of the underlying java process will be classpath + compilerclasspath.

- `src` - A directory containing files to be transformed. You can use multiple src elements to specify more that one root directory for transformation.
- `include` - This is optional and it serves as a filter to pick out which files within `src` should be transformed. You can use wildcards within the `name` expression, and you can also use multiple `include` elements.
- `verbose` - Default is false. If true, verbose output is generated, which comes in handy for diagnosing unexpected results.
- `report` - Default is false. If true, the classes are not instrumented, but a report called `aop-report.xml` is generated which shows all classes that have been loaded that pertain to AOP, what interceptors and advices that are attached, and also what metadata that has been attached. One particularly useful thing is the unbounded section. It specifys all bindings that are not bound. It allows you to debug when you might have a typo in one of your XML deployment descriptors.

  Report generation works on the instrumented classes, so to get valid data in your report, you have to to make two passes with `aopc`. First you run `aopc` with `report="false"` to instrument the classes, and then you run `aopc` with `report="true"` to generate the report.
- `aoppath` - The path of the `*-aop.xml` file containing the xml configuration of your bindings. Files or Directories can be specified. If it is a directory, JBoss AOP will take all `aop.xml` files from that directory. This gets used for the `jboss.aop.path` optional system property which is described in the "Command Line" section.
  If you have more than one xml file, for example if you have both a "normal" `jboss-aop.xml` file, and a

  ```
  <aoppath>
  <pathelement path="jboss-aop.xml"/>
  <pathelement path="xmldir"/>
  </aoppath>
  ```
- `aopclasspath` - This should mirror your class path and contain all JARs/directories that may have annotated aspects (Ses Chapter "Annotated Bindings"). The AOPC compiler will browse each class file in this path to determine if any of them are annotationed with `@Aspect`. This gets used for the `jboss.aop.class.path` optional system property which is described in the "Command Line" section. If you have more than one jar file, you can specify these as follows:

  ```
  <aopclasspath>
  ```

```
                <pathelement path="aspects.jar"/>
                <pathelement path="foo.jar"/>
                </aopclasspath>
```

- `maxsrc` - The ant task expands any directories in `src` to list all class files, when creating the parameters for the java command that actually performs the compilation. On some operating systems there is a limit to the length of vaid command lines. The default value for `maxsrc` is 1000. If the total length of all the files used is greater than `maxsrc`, a temporary file listing the files to be transformed is used and passed in to the java command instead. If you have problems running the `aopc` task, try setting this value to a value smaller than 1000.

3. Command Line

To run the aop precompiler from the command line you need all the aop jars on your classpath, and the class files you are instrumenting must have everything they would need to run in the java classpath, including themselves, or the precompiler will not be able to run.

The `jboss.aop.path` optional system property points to XML files that contain your pointcut, advice bindings, and metadata definitions that the precompiler will use to instrument the .class files. The property can have one or files it points to delimited by the operating systems specific classpath delimiter (';' on windows, ':' on unix). Files or Directories can be specified. If it is a directory, JBoss AOP will take all `aop.xml` files from that directory.

The `jboss.aop.class.path` optional system property points to all JARs or directories that may have classes that are annotated as `@Aspect` (See Chapter "Annotated Bindings"). JBoss AOP will browse all classes in this path to see if they are annotated. The property can have one or files it points to delimited by the operating systems specific classpath delimiter (';' on windows, ':' on unix).

It is invoked as:

```
$java -classpath ... [-Djboss.aop.path=...]
 [-Djboss.aop.class.path=...] \
                    org.jboss.aop.standalone.Compiler <class files
 or directories>
```

In the /bin folder of the distribution we have provided batch/script files to make this easier. It includes all the aop libs for you, so you just have to worry about your files. The usage:

```
```

```
$ aopc <classpath> [-aoppath ...] [-aopclasspath ...] [-report]
 [-verbose] \
      <class files or directories>+
```

- `classpath` - path to your classes and any jars your code depends on

The other parameters are the same as above.

Running Aspectized Applications

This section will show you how to run JBoss AOP with standalone applications and how to run it integrated with the JBoss application server.

1. Loadtime, Compiletime and HotSwap Modes

There are 3 different modes to run your aspectized applications. Precompiled, loadtime or hotswap. JBoss AOP needs to weave your aspects into the classes which they aspectize. You can choose to use JBoss AOP's precompiler to accomplish this (Compiletime) or have this weavining happen at runtime either when the class is loaded (Loadtime) or after it (HotSwap).

Compiletime happens before you run your application. Compiletime weaving is done by using the JBoss AOP precompiler to weave in your aspects to existing .class files. The way it works is that you run the JBoss AOP precompiler on a set of .class files and those files will be modified based on what aspects you have defined. Compiletime weaving isn't always the best choice though. JSPs are a good instance where compiletime weaving may not be feasible. It is also perfectly reasonable to mix and match compile time and load time though. If you have load-time transformation enabled, precompiled aspects are not transformed when they are loaded and ignored by the classloader transformer.

Loadtime weaving offers the ultimate flexibility. JBoss AOP does not require a special classloader to do loadtime weaving, but there are some issues that you need to think about. The Java Virtual Machine actually has a simple standard mechanism of hooking in a class transformer through the `-javaagent`. JBoss AOP an additional load-time transformer that can hook into classloading via this standard mechanism.

Load-time weaving also has other serious side effects that you need to be aware of. JBoss AOP needs to do the same kinds of things that any standard Java profiling product needs to do. It needs to be able to process bytecode at runtime. This means that boot can end up being significantly slowed down because JBoss AOP has to do a lot of work before a class can be loaded. Once all classes are loaded though, load-time weaving has zero effect on the speed of your application. Besides boottime, load-time weaving has to create a lot of Javassist datastructure that represent the bytecode of a particular class. These datastructures consume a lot of memory. JBoss AOP does its best to flush and garbage collect these datastructures, but some must be kept in memory. We'll talk more about this later.

HotSwap weaving is a good choice if you need to enable aspects in runtime and don't want that the flow control of your classes be changed before that. When using this mode, your classes are instrumented a minimum necessary before getting

loaded, without affecting the flow control. If any joinpoint becomes intercepted in runtime due to a dynamic AOP operation, the affected classes are weaved, so that the added interceptors and aspects can be invoked. As the previous mode, hot swap contains some drawbacks that need to be considered.

2. Regular Java Applications

JBoss AOP does not require an application server to be used. Applications running JBoss AOP can be run standalone outside of an application server in any standard Java application. This section focuses on how to run JBoss AOP applications that don't run in the JBoss application server.

2.1. Precompiled instrumentation

Running a precompiled aop application is quite similar to running a normal java application. In addition to the classpath required for your application you need to specify the files required for aop, which are the files in the distribution's `lib/` folder.

As an alternative, you can replace all those jars by `jboss-aop-single.jar`, that bundles the libraries used by JBoss AOP with JBoss AOP class files in a single jar.

JBoss AOP finds XML configuration files in these two ways:

- You tell JBoss AOP where the XML files are. Set the `jboss.aop.path` system property. (You can specify multiple files or directories separated by ':' (*nix) or ';' (Windows), i.e. `-Djboss.aop.path=jboss-aop.xml;metadata-aop.xml`) If you specify a directory, all `aop.xml` files will be loaded from there as well.
- Let JBoss AOP figure out where XML files are. JBoss AOP will look for all XML files that match this pattern `/META-INF/jboss-aop.xml`. So, if you package your jars and put your JBoss AOP XML files within `/META-INF/jboss-aop.xml`, JBoss AOP will find these files.

If you are using annotated bindings (See Chapter "Annotated Bindings"), you must tell JBoss AOP which JARS or directories that may have annotated @Aspects.
To do this you must set the `jboss.aop.class.path` system property. (You can specify multiple jars or directories separated by ':' (*nix) or ';' (Windows), i.e. `-Djboss.aop.class.path=aspects.jar;classes`)

So to run a precompiled AOP application, where your jboss-aop.xml file is not part of a jar, you enter this at a command prompt:

```
$ java -cp=<classpath as described above> -Djboss.aop.path=<path to
 jboss-aop.xml> \
        -Djboss.aop.class.path=aspects.jar
        com.blah.MyMainClass
```

To run a precompiled AOP application, where your application contains a jar with a META-INF/jboss-aop.xml file, you would need to do this from the command-line:

```
$ java -cp=<classpath as described above> com.blah.MyMainClass
```

In the /bin folder of the distribution we have provided batch/script files to make this easier. It includes all the aop libs for you, so you just have to worry about your files. The usage:

```
$ run-precompiled classpath [-aoppath path_to_aop.xml]
 [-aopclasspath path_to_annotated] \
      com.blah.MyMainClass [args...]
```

If your application is not in a jar with a META-INF/jboss-aop.xml file, you must specify the path to your `*-aop.xml` files in the `-aoppath` parameter, and if your class comtains aspects configured via annotations (`@Aspect` etc.) you must pass in this classpath via the `-aopclasspath` parameter.

2.2. Loadtime

This section describes how to use loadtime instrumentation of classes with aop. The classes themselves are just compiled using Java, but are not precompiled with the aop precompiler. In the examples given if your classes are contained in a jar with a META-INF/jboss-aop.xml file, you would omit the `-Djboss.aop.path` system property.

The JVM has a pluggable way of defining a class transformer via the `java.lang.instrument` package. JBoss AOP uses this mechanism to weave aspects at class load time. Using loadtime weaving is really easy. All you have to do is define an additional standard switch on the Java command line. `-javaagent:jboss-aop.jar`. Here's how run an AOP application with loadtime instrumentation, where your jboss-aop.xml file is not part of a jar:

```
$ java -cp=<classpath as described above> -Djboss.aop.path=<path to
 jboss-aop.xml> \
      -javaagent:jboss-aop.jar com.blah.MyMainClass
```

And to run an AOP application with loadtime instrumentation, where your application contains a jar with a META-INF/jboss-aop.xml file:

```
$ java -cp=<classpath as described above> -javaagent:jboss-aop.jar
 \
      com.blah.MyMainClass
```

In the /bin folder of the distribution we have provided batch/script files to make this easier. It includes all the aop libs for you, so you just have to worry about your files. The usage:

```
$ run-load classpath [-aoppath path_to_aop.xml] [-aopclasspath
 path_to_annotated] \
      com.blah.MyMainClass [args...]
```

The parameters have the same meaning as for the run-precompiled scripts.

If you invoke the previous `java` examples with ant, by using the ant `java` task, make sure that you set `fork="true"` in the ant `java` task. Failure to do so, causes the `java` task to execute in the same VM as ant which is already running. This means that the special classloader used to do the loadtime transformations does not replace the standard one, so no instrumentation takes place.

2.2.1. Loadtime using JRockit

JRockit 5+ supports the "normal" -javaagent switch.

2.2.2. Improving Loadtime Performance

JBoss AOP needs to do the same kinds of things that any standard Java profiling product needs to do. It needs to be able to process bytecode at runtime before a class is loaded. JBoss AOP has to do a lot of work before a class can be loaded. This means that boot time can end up being significantly slowed down. Once all classes are loaded though, load-time weaving has zero effect on the speed of your application.

Besides boottime, load-time weaving has to create a lot of Javassist datastructures that represent the bytecode of a particular class. These datastructures consume a lot of memory. JBoss AOP does its best to flush and garbage collect these datastructures, but some must be kept in memory. This section focuses on how you can improve the performance of Loadtime weaving.

Increase the Java Heapspace
: In Java, when your application is getting close to eating up all of its memory/heapspace, the Java Garbage Collector starts to run more frequently

and aggressively. When the GC starts running more often the performance of your application will suffer. JBoss AOP does its best to balance bootup speed vs. memory consumption, but it does require loading bytecode into Javassist datastructures so it can analyze and transform a class. For speed purposes, the datastructures are cached thus leading to the extra memory consumption. Javassist structures of non-transformed classes are placed a SoftReference cache, so they are GC'd when memory is running low. Transformed classes, however, are locked in the cache. Transformed classes are help in memory, as they may effect pointcut matching on classes that haven't been loaded yet.

To increase your Heap size, use the standard `-Xmx` switch.

Filtering

Filtering probably has the greatest effect on overall boot-time speed. If you've ever worked with a Java profiling product before, you probably noticed that it has an option to filter classes that you are not interested in profiling. This can speed up performance of the tool. JBoss AOP has to analyze every class in the system to make sure it does not need to be transformed. THis is one reason why load-time weaving can be so slow. You can give JBoss AOP a lot of help by specifying sets of classes that do not need to be transformed.

To enable filtering, you can use the `jboss.aop.exclude` System Property. This System Property is a comma delimited list. The strings in the list can be package names and/or classnames. Packages/classes within this list will ignored by JBoss AOP. You can use the wildcard `*` in place of a classname, this will then exclude all classes. No other wildcards are supported.

```
                    java
-Djboss.aop.exclude=org.jboss,org.apache ...
```

There is also a mirror opposite of exclude. The System Property `jboss.aop.include` overrides any thing specified with exclude.

Include ignored annotations

To improve the startup time of JBoss AOP all invisible annotations (invisible annotations are all annotations that are not annotated with `@Retention(RetentionPolicy.RUNTIME)`) are ignored by default. To include them use the system property `jboss.aop.invisible.annotations` to add packages that will be included, or add "*" to include all.

```
                     java
-Djboss.aop.include.annotations=com.foo.bar,org.my.company
```

To include all:

```
java -Djboss.aop.include.annotations=*
```

Turn off optimizations

To increase overall runtime performance, JBoss AOP has to dynamically create a lot of extra code. If you turn off these optimizations, JBoss AOP can weave a bit quicker. There is a good chance, depending on your application that you will not even notice that these optimizations are turned off. See *Chapter 14, Instrumentation Modes* for how to switch between weaving modes.

Turn off pruning

JBoss AOP tries to aggressive prune cached Javassist structures. This may, may not have a tiny effect on performance. The `jboss.aop.prune` system property can be set to turn off pruning.

```
java -Djboss.aop.prune=false ...
```

-client/-server

Strangely enough, it seems that the -client VM switch is a little faster for JBoss AOP loadtime weaving that -server. If you are using the -server VM, trying switching to -client (the default).

Ignore

A way to completely ignore classes from being instrumented. This overrides whatever you have set up using the include/exclude filters. The system property is `jboss.aop.ignore`, and you can use wildcards in the classnames. As for include/exclude you may specify a comma separated list of class name patterns. This following example avoids instrumenting the cglib generated proxies for hibernate:

```
java
-Djboss.aop.ignore=*$$EnhancerByCGLIB$$*
```

2.3. HotSwap

The HotSwap feature allows bytecode of your classes to be weaved in runtime. This results in application flow control changes to your classes only when joinpoints become intercepted (to do this, use the dynamic aop funcionality provided by JBoss AOP). This is a mode to be considered when you want to assure the flow control of your classes will be kept intact until a binding or a interceptor is added.

This mode is currently provided through the `java.lang.instrument.Instrumentation` hot swap functionality, which is part of the JVMTI (Java Virtual Machine Tool Interface). So, you cannot run JBoss AOP in this mode when using a previous JDK version.

To enable HotSwap, you have to add an argument to the Java command line in a very similar way to the Loadtime mode: `-javaagent:jboss-aop.jar=-hotSwap`. The difference is that the `-hotSwap` argument was added to the agent parameter list.

This way, if your jboss-aop.xml file is contained in a jar file, run:

```
$ java -cp=<classpath as described above> -Djboss.aop.path=<path to
 jboss-aop.xml> \
  -javaagent:jboss-aop.jar=-hotSwap com.blah.MyMainClass
```

And if your jboss-aop.xml file is contained in a jar, run the following command line:

```
$ java -cp=<classpath as described above>
 -javaagent:jboss-aop.jar=-hotSwap \
  com.blah.MyMainClass
```

The `run-loadHotSwap` batch/script files contained in the /bin folder of the distribution are similar to the `run-load` ones, described in the previous subsection. All aop libs are included in these script files. To use them, run:

```
$ run-load classpath [-aoppath path_to_aop.xml] [-aopclasspath
 path_to_annotated] \
  com.blah.MyMainClass [args...]
```

When hotswap is enabled, the prunning of classes is turned off. Therefore, if you try to configure the jboss.aop.prune option as `true`, this setup will be ignored.

As with the Loadtime mode, the HotSwap mode results in a boot time delay. Besides this drawback, the execution of some dynamic aop operations may be slower than in the other modes, when classes need to be hot swapped. The available options to tune performance are the same as described in the "Improving Loadtime Performance" subsection, except the pruning of classes.

2.4. User-Defined ClassLoaders

In order to be compatible with JBoss AOP, the ClassLoader responsible for loading your application's classes must be able to find class files as resources. This means

that, given the name of a class that is in the classpath of your application, the methods below must all return the URL(s) of the corresponding class file(s):

```
public URL getResource(String name)
public Enumeration<URL> getResources(String name) throws
 IOException
public Enumeration<URL> getResourceAsStream(String name) throws
 IOException
```

Usually, there is no need to be concerned about this, as the ClassLoader implementations of Sun's JVM and JRockit follow the requirement above. On the other hand, if the application is being run with a user-defined ClassLoader, it is necessary to make sure the ClassLoader follows this important requirement.

3. JBoss Application Server

JBoss AOP is integrated with JBoss 4.0.1+ application server. The integration steps are different depending on what version of JBoss AS you are using and what JDK version you are using. It is also dependent on whether you want to use loadtime or compiletime instrumentation. JBoss 4.x comes with previous versions of JBoss AOP, which can be upgraded to AOP 2.0.x by using the ant scripts as explained in *Section 2, “Installing with JBoss 4.0.x and JBoss 4.2.x Application Server for JDK 5”*. JBoss 5 comes with AOP 2.0.x built in.

Based on what JDK you are on and what loadtime weaving option you want to you, you must configure JBoss AS differently.

3.1. Packaging AOP Applications

To deploy an AOP application in JBoss you need to package it. AOP is packaged similarly to SARs(MBeans). You can either deploy an XML file directly in the deploy/ directory with the signature *-aop.xml along with your package (this is how the base-aop.xml, included in the `jboss-aop.deployer` file works) or you can include it in the jar file containing your classes. If you include your xml file in your jar, it must have the file extension .aop and a jboss-aop.xml file must be contained in a META-INF directory, i.e. `META-INF/jboss-aop.xml`.

Note that in JBoss 5, you MUST specify the schema used, otherwise your information will not be parsed correctly. You do this by adding the `xmlns="urn:jboss:aop-beans:1:0` attribute to the root `aop` element, as shown here:

```
<aop xmlns="urn:jboss:aop-beans:1.0">
```

```
</aop>
```

If you want to create anything more than a non-trivial example, using the .aop jar files, you can make any top-level deployment contain a .aop file containing the xml binding configuration. That is you can have a .aop file in an .ear file, or a .aop file in a war file etc. The bindings specified in the `META-INF/jboss-aop.xml` file contained in the .aop file will affect all the classes in the whole war!

To pick up a .aop file in an .ear file, it must be listed in the `.ear/META-INF/application.xml` as a java module, e.g.:

```
<?xml version='1.0'  encoding='UTF-8'?>
<!DOCTYPE application PUBLIC '-//Sun Microsystems, Inc.//DTD J2EE
 Application 1.2//EN'

 'http://java.sun.com/j2ee/dtds/application_1_2.dtd'>

<application>
    <display-name>AOP in JBoss example</display-name>
    <module>
        <java>example.aop</java>
    </module>
    <module>
        <ejb>aopexampleejb.jar</ejb>
    </module>
    <module>
        <web>
           <web-uri>aopexample.war</web-uri>
          <context-root>/aopexample</context-root>
       </web>
   </module>
</application>
```

Note that in newer versions of JBoss (>= 4.0.5), the contents of the .ear file are deployed in the order they are listed in the application.xml. When using loadtime weaving the bindings listed in the example.aop file must be deployed before the classes being advised are deployed, so that the bindings exist in the system before the ejb, servlet etc. classes are loaded. This is acheived by listing the .aop file at the start of the application.xml. Older versions of JBoss did not have this issue since the contained .aop files were deployed before anything else, and this still holds true for other types of archives such as .sar and .war files.

3.2. The JBoss AspectManager Service

The AspectManager Service is installed in both JBoss 5 and JBoss 4.x.
It can be managed at run time using the JMX console which is found at `http://localhost:8080/jmx-console`. It is registered under the ObjectName `jboss.aop:service=AspectManager`. If you want to configure it on startup you need to edit some configuration files, which are different on JBoss 5 and JBoss 4.x, although the concepts are the same.

3.2.1. JBoss 5 AspectManager Service

In JBoss 5 the AspectManager Service is configured using a JBoss Microcontainer bean. The configuration file is `jboss-5.x.x.GA/server/xxx/conf/aop.xml`. The AspectManager Service is deployed with the following xml:

```
  <bean name="AspectManager"
class="org.jboss.aop.deployers.AspectManagerJDK5">
     ...

     <property name="jbossIntegration"><inject
bean="AOPJBossIntegration"/></property>

     <property name="enableLoadtimeWeaving">false</property>
     <!-- only relevant when EnableLoadtimeWeaving is true.
          When transformer is on, every loaded class gets
          transformed.  If AOP can't find the class, then it
          throws an exception.  Sometimes, classes may not have
          all the classes they reference.  So, the Suppressing
          is needed.  (i.e. Jboss cache in the default
configuration -->
     <property name="suppressTransformationErrors">true</property>
     <property name="prune">true</property>
     <property name="include">org.jboss.test.,
org.jboss.injbossaop.</property>
     <property name="exclude">org.jboss.</property>
     <!-- This avoids instrumentation of hibernate cglib enhanced
proxies
     <property name="ignore">*$$EnhancerByCGLIB$$*</property> -->
     <property name="optimized">true</property>
     <property name="verbose">false</property>
     <!--
        Available choices for this attribute are:
           org.jboss.aop.instrument.ClassicInstrumentor (default)
           org.jboss.aop.instrument.GeneratedAdvisorInstrumentor
      <property
name="instrumentor">org.jboss.aop.instrument.ClassicInstrumentor</
property>
```

```
      -->
          <!--
                By default the deployment of the aspects contained
in

../deployers/jboss-aop-jboss5.deployer/base-aspects.xml
                are not deployed. To turn on deployment uncomment
this property
          <property name="useBaseXml">true</property>
          -->
  </bean>
```

In later sections we will talk about changing the class of the AspectManager Service, to do this replace the contents of the `class` attribute of the `bean` element.

3.2.2. JBoss 4.x AspectManager Service

In JBoss 4.x the AspectManager Service is configured using a JBoss Microcontainer bean. The configuration file is `jboss-4.x.x.GA/server/default/deploy/jboss-aop-jdk50.deployer/META-INF/jboss-service.xml`. The AspectManager Service is deployed with the following xml:

```
  <mbean code="org.jboss.aop.deployment.AspectManagerServiceJDK5"
     name="jboss.aop:service=AspectManager">
     <attribute name="EnableLoadtimeWeaving">false</attribute>
     <!-- only relevant when EnableLoadtimeWeaving is true.
          When transformer is on, every loaded class gets
          transformed.  If AOP can't find the class, then it
          throws an exception.  Sometimes, classes may not have
          all the classes they reference.  So, the Suppressing
          is needed.  (i.e. Jboss cache in the default
configuration -->
     <attribute
name="SuppressTransformationErrors">true</attribute>
     <attribute name="Prune">true</attribute>
     <attribute name="Include">org.jboss.test,
org.jboss.injbossaop</attribute>
     <attribute name="Exclude">org.jboss.</attribute>
     <!-- This avoids instrumentation of hibernate cglib enhanced
proxies
     <attribute name="Ignore">*$$EnhancerByCGLIB$$*</attribute>
-->
     <attribute name="Optimized">true</attribute>
```

```
      <attribute name="Verbose">false</attribute>
      <depends optional-attribute-name="JBossIntegrationWrapper"
 proxy-
type="attribute">jboss.aop:service=JBoss4IntegrationWrapper</
depends>
      <!--
         Available choices for this attribute are:
            org.jboss.aop.instrument.ClassicInstrumentor (default)
            org.jboss.aop.instrument.GeneratedAdvisorInstrumentor
       <attribute
 name="Instrumentor">org.jboss.aop.instrument.ClassicInstrumentor</
attribute>
      -->
   </mbean>
```

In later sections we will talk about changing the class of the AspectManager Service, to do this replace the contents of the `code` attribute of the `mbean` element.

3.3. Loadtime transformation in JBoss AS Using Sun JDK

JBoss AS has special integration with JDK (from version 5.0 on) to do loadtime transformations. This section explains how to use it.

If you want to do load-time transformations with JBoss 5 and Sun JDK, these are the steps you must take.

- Set the `enableLoadtimeWeaving` attribute/property to true. By default, JBoss application server will not do load-time bytecode manipulation of AOP files unless this is set. If `suppressTransformationErrors` is `true` failed bytecode transformation will only give an error warning. This flag is needed because sometimes a JBoss deployment will not have all the classes a class references.
- Copy the `pluggable-instrumentor.jar` from the `lib/` directory of your JBoss AOP distribution to the `bin/` directory of your JBoss AOP application server installation.
- Next edit `run.sh` or `run.bat` (depending on what OS you're on) and add the following to the JAVA_OPTS environment variable:

```
set JAVA_OPTS=%JAVA_OPTS% -Dprogram.name=%PROGNAME%
 -javaagent:pluggable-instrumentor.jar
```

Note that the class of the AspectManager Service must be `org.jboss.aop.deployers.AspectManagerJDK5` on JBoss 5, or

`org.jboss.aop.deployment.AspectManagerServiceJDK5` as these are what work with the -javaagent weaver.

3.4. JBoss 5 and JRockit

JRockit also supports the -javaagent switch mentioned in *Section 3.3, "Loadtime transformation in JBoss AS Using Sun JDK"*. If you wish to use that, then the steps in *Section 3.3, "Loadtime transformation in JBoss AS Using Sun JDK"* are sufficient. However, JRockit also comes with its own framework for intercepting when classes are loaded, which might be faster than the -javaagent switch. If you wish to use this, there are three steps you must take.

If you want to do load-time transformations with JBoss 5 and JRockit using the special JRockit hooks, these are the steps you must take.

- Set the `enableLoadtimeWeaving` attribute/property to true. By default, JBoss application server will not do load-time bytecode manipulation of AOP files unless this is set. If `suppressTransformationErrors` is `true` failed bytecode transformation will only give an error warning. This flag is needed because sometimes a JBoss deployment will not have all the classes a class references.
- Copy the `jrockit-pluggable-instrumentor.jar` from the `lib/` directory of your JBoss AOP distribution to the `bin/` directory of your JBoss AOP application server installation.
- Next edit `run.sh` or `run.bat` (depending on what OS you're on) and add the following to the JAVA_OPTS and JBOSS_CLASSPATH environment variables:

```
# Setup JBoss sepecific properties
JAVA_OPTS="$JAVA_OPTS -Dprogram.name=$PROGNAME \

 -
Xmanagement:class=org.jboss.aop.hook.JRockitPluggableClassPreProcessor"
JBOSS_CLASSPATH="$JBOSS_CLASSPATH:jrockit-pluggable-
instrumentor.jar"
```

- Set the class of the AspectManager Service to be `org.jboss.aop.deployers.AspectManagerJRockit` on JBoss 5, or `org.jboss.aop.deployment.AspectManagerService` as these are what work with special hooks in JRockit.

3.5. Improving Loadtime Performance in a JBoss AS Environment

The same rules apply to JBoss AS for tuning loadtime weaving performance as standalone Java. See the previous chapter on tips and hints. YOU

CANNOT USE THE SAME SYSTEM PROPERTIES THOUGH! Switches like pruning, optimized, and include/exclude are configured through the jboss-aop.deployer/META-INF/jboss-service.xml file talked about earlier in this chapter. You should be able to figure out how to turn the switches on/off from the above documentation.

4. Scoping aop to the classloader

By default all deployments in JBoss are global to the whole application server. That means that any ear, sar, jar etc. that is put in the deploy directory can see the classes from any other deployed archive. Similarly, aop bindings are global to the whole virtual machine. This "global" visibility can be turned off per top-level deployment.

4.1. Deploying as part of a scoped classloader

How the following works may be changed in future versions of jboss-aop. If you deploy a .aop file as part of a scoped archive, the bindings etc. applied within the .aop/META-INF/jboss-aop.xml file will only apply to the classes within the scoped archive and not to anything else in the application server. Another alternative is to deploy -aop.xml files as part of a service archive (SAR). Again if the SAR is scoped, the bindings contained in the -aop.xml files will only apply to the contents of the SAR file. It is not currently possible to deploy a standalone -aop.xml file and have that attach to a scoped deployment. Standalone -aop.xml files will apply to classes in the whole application server.

4.2. Attaching to a scoped deployment

If you have an application using classloader isolation, as long as you have "prepared your classes" you can later attach a .aop file to that deployment. If we have a .ear file scoped using a jboss-app.xml file, with the scoped loader repository `jboss.test:service=scoped`:

```
<jboss-app>
  <loader-repository>
      jboss.test:service=scoped
  </loader-repository>
</jboss-app>
```

We can later deploy a .aop file containing aspects and configuration to attach that deployment to the scoped .ear. This is done using the `loader-repository` tag in the .aop files `META-INF/jboss-aop.xml` file.

```
<?xml version="1.0" encoding="UTF-8"?>
<aop>
   <loader-repository>jboss.test:service=scoped</loader-repository>
```

```
   <!-- Aspects and bindings -->
</aop>
```

This has the same effect as deploying the .aop file as part of the .ear as we saw previously, but allows you to hot deploy aspects into your scoped application.

Building JBoss AOP with Maven2

Since JBoss AOP requires either loadtime or compiletime weaving we need to customize maven a bit to make it do what we want. JBoss AOP provides plugins to make this weaving as easy as possible.

The JBoss AOP plugin is named jbossaop and is provided under the maven2 jboss.org repository. For the final releases use:

```
<repository>
   <id>maven.jboss.org</id>
   <name>JBoss Maven Repository</name>
   <url>http://repository.jboss.com/maven2</url>
</repository>
```

If you want to use the snapshot releases use:

```
<repository>
   <id>snapshots.jboss.org</id>
   <name>JBoss Maven Snapshot Repository</name>
   <url>http://snapshots.jboss.org/maven2</url>
</repository>
```

The jbossaop maven plugin will provide all the aop dependencies needed to weave and run. There is no need to include aop dependencies other than the plugin. NOTE: The version used in these examples may be obsolete, please check the latest release for the reference version instead of using the version in these examples.

1. AOP Compile with Maven2

The aop compile plugin is configured to run after the default maven compile phase has ended. By default it will try to find the jboss-aop.xml file in `src/main/resources/jboss-aop.xml`. It will also try to weave every class in `$project.build.outputDirectory` (usually target/classes). List of options:

- `aoppaths` - an array of possible jboss-aop.xml files. Default is `src/main/resources/jboss-aop.xml`
- `verbose` - if set to true it will provide debug information during the aop weaving. ' Default set to true.

- `suppress` - suppress when a class cannot be found that a class references. This may happen if code in a class references something and the class is not in the classpath. Default set to true.
- `noopt` - do not optimize the weaving. Default set to false.
- `report` - store the output to a file (`aop-report.xml`). Default set to false.
- `includeProjectDependency` - if set to true all project dependencies will also be included to the aop classpath. Only needed if a class inherits a class thats not defined in the current module. Default set to false.
- `classPath` - classpath, by default set to null. If its set to null it will use the plugin dependencies (and add project dependencies if `includeProjectDependency` is set) + the output build path. Do not change this if you are not sure.
- `aopClassPath` - load xml files that adds aspects to the manager. Do not change this if you are not sure. By default set to null.
- `includes` - an array of classes that will be weaved. Note that if this is specified just the classes thats specified here will be weaved. Default set to null.
- `properties` - a list of properties (name, value objects) that will be added as JVM properties. A small example:

```
<properties>
  <property>
    <name>log4j.configuration</name>
    <value>log4j.properties</value>
  </property>
</properties>
```

  This will add log4j.configuration as JVM properties like: -Dlog4j.configuration=log4j.properties.

There are a lot of options that can be set, but noone are mandatory (if they are mandatory they have a default value set). The average user would most likely only change `aoppaths`. A more complete example would look like:

```
<plugin>
  <groupId>org.jboss.maven.plugins</groupId>
  <artifactId>maven-jbossaop-plugin</artifactId>
  <version>1.0</version>
  <executions>
    <execution>
      <id>compile</id>
      <configuration>
      <!-- if you want to include dependencies from the current
 module
```

```
          (only needed if a class inherits a class thats not
 defined in this module
          -->
       <includeProjectDependency>true</includeProjectDependency>
       <aoppaths>
         <aoppath>src/main/resources/jboss-aop_test2.xml</aoppath>
         <!-- for a second jboss-aop.xml file
         <aoppath>src/main/resources/jboss-aop.xml</aoppath>
         -->
       </aoppaths>
       <!-- You can specify to only aopc a specific set of classes

       <includes>
         <include>POJO.class</include>
       </includes>
       -->
     </configuration>
     <goals>
       <goal>compile</goal>
     </goals>
   </execution>
  </executions>
</plugin>
```

2. AOP Compile tests with Maven2

The only difference between aop compiling tests and non-tests are the name of the plugin. The options are the same for tests and non-tests. A quick example:

```
<plugin>
  <groupId>org.jboss.maven.plugins</groupId>
  <artifactId>maven-jbossaop-plugin</artifactId>
  <version>1.0</version>
  <executions>
    <execution>
      <id>compile-test</id>
      <configuration>
        <aoppaths>

 <aoppath>src/main/resources/jboss-aop_testcase.xml</aoppath>
        </aoppaths>
      </configuration>
      <goals>
        <goal>compile-test</goal>
      </goals>
    </execution>
  </executions>
```

```
</plugin>
```

3. Running precompiled with Maven2

JBoss aop run plugin is configured to run after the package phase. There are less options here than for the compile step and they are very similar.

- `aoppaths` - an array of possible jboss-aop.xml files. Default is `src/main/resources/jboss-aop.xml`
- `includeProjectDependency` - if set to true all project dependencies will also be included to the aop classpath. Only needed if a class inherits a class thats not defined in the current module. Default set to false.
- `classPath` - classpath, by default set to null. If its set to null it will use the plugin dependencies (and add project dependencies if `includeProjectDependency` is set) + the output build path. Do not change this if you are not sure.
- `executable` - the java class that will be executed
- `properties` - a list of properties (name, value objects) that will be added as JVM properties. A small example:

```
<properties>
  <property>
    <name>log4j.configuration</name>
    <value>log4j.properties</value>
  </property>
</properties>
```

This will add log4j.configuration as JVM properties like: -Dlog4j.configuration=log4j.properties.

A small example using default jboss-aop.xml:

```
<plugin>
  <groupId>org.jboss.maven.plugins</groupId>
  <artifactId>maven-jbossaop-plugin</artifactId>
  <version>1.0.CR1</version>
  <executions>
    <execution>
      <id>run</id>
      <configuration>
        <executable>Foo</executable>
      </configuration>
      <goals>
        <goal>run</goal>
```

```
      </goals>
    </execution>
  </executions>
</plugin>
```

4. Running loadtime weaving with Maven2

Running a java application in loadtime weaving is almost identical to compile time (except that you dont need to precompile it first). The only change is that we need an option to say that we want to run it loadtime.

- `loadtime` - set it to true if you want loadtime weaving. Default is set to false.

A small example:

```
<plugin>
  <groupId>org.jboss.maven.plugins</groupId>
  <artifactId>maven-jbossaop-plugin</artifactId>
  <version>1.0.CR1</version>
  <executions>
    <execution>
      <id>run</id>
      <configuration>
        <aoppaths>

 <aoppath>src/main/resources/jboss-aop_testcase.xml</aoppath>
        </aoppaths>
        <loadtime>true</loadtime>
        <executable>Test</executable>
      </configuration>
      <goals>
        <goal>run</goal>
      </goals>
    </execution>
  </executions>
</plugin>
```

5. Running tests with Maven2

Running tests with aop is a different matter since the maven tests plugin is rather complex. But we can add the hooks we need to run it both compiletime and loadtime with the maven tests too. An example on how to run a test thats been aop compiled:

```
<plugin>
  <groupId>org.apache.maven.plugins</groupId>
  <artifactId>maven-surefire-plugin</artifactId>
```

```
  <version>2.4</version>
  <configuration>
    <forkMode>always</forkMode>
    <useSystemClassLoader>true</useSystemClassLoader>

 <argLine>-Djboss.aop.path=src/main/resources/jboss-
aop_testcase.xml</argLine>
  </configuration>
</plugin>
```

To run it loadtime we only need to add the javaagent option to argLine. Like this:

```
 <argLine>-javaagent:${settings.localRepository}/org/jboss/jboss-
aop/2.0.0.CR3/\
    jboss-aop-2.0.0.CR3.jar \

 -Djboss.aop.path=src/main/resources/jboss-aop_testcase.xml</
argLine>
```

- big thanks to henrik and finn for figuring out how to do this :) Note again that the versions used here are just for a reference and to provide as examples. Check the JBoss AOP homepage for the up-to-date versions.

Reflection and AOP

While AOP works fine for normal access to fields, methods and constructors, there are some problems with using the Reflection API for this using JBoss. The problems are:

- Intereptors/aspects bound to execution pointcuts for fields and constructors don't get invoked.
- Intereptors/aspects bound to caller pointcuts for methods and constructors don't get invoked.
- Reflection Methods such as `Class.getMethods()` and `Class.getField()` return extra JBoss AOP "plumbing" information.

1. Force interception via reflection

To address the issues with interceptors not being invoked when you use reflection, we have provided a reflection aspect. You bind it to a set of caller pointcuts, and it mounts the pre-defined interceptor/aspect chains. The jboss-aop.xml entries are:

```
  <aspect class="org.jboss.aop.reflection.ReflectionAspect"
scope="PER_VM"/>

  <bind pointcut="call(* java.lang.Class->newInstance())">
     <advice name="interceptNewInstance" \
        aspect="org.jboss.aop.reflection.ReflectionAspect"/>
  </bind>

  <bind pointcut="call(*
java.lang.reflect.Constructor->newInstance(java.lang.Object[]))">
     <advice name="interceptNewInstance" \
        aspect="org.jboss.aop.reflection.ReflectionAspect"/>
  </bind>

  <bind pointcut="call(*
java.lang.reflect.Method->invoke(java.lang.Object,
java.lang.Object[]))">
     <advice name="interceptMethodInvoke" \
        aspect="org.jboss.aop.reflection.ReflectionAspect"/>
  </bind>

  <bind pointcut="call(* java.lang.reflect.Field->get*(..))">
     <advice name="interceptFieldGet" \
        aspect="org.jboss.aop.reflection.ReflectionAspect"/>
  </bind>
```

```
<bind pointcut="call(* java.lang.reflect.Field->set*(..))">
   <advice name="interceptFieldSet" \
      aspect="org.jboss.aop.reflection.ReflectionAspect"/>
</bind>
```

The `ReflectionAspect` class provides a few hooks for you to override from a subclass if you like. These methods described below.

```
 protected Object interceptConstructor(
Invocation invocation,
Constructor constructor,
Object[] args)
throws Throwable;
```

Calls to `Class.newInstance()` and `Constructor.newInstance()` end up here. The default behavior is to mount any constructor execution or caller interceptor chains. If you want to override the behaviour, the parameters are:

- `invocation` - The invocation driving the chain of advices.
- `constructor` - The constructor being called
- `args` - the arguments being passed in to the constructor (in the case of Class.newInstance(), a zero-length array since it takes no parameters)

```
protected Object interceptFieldRead(
   Invocation invocation,
   Field field,
   Object instance)
   throws Throwable;
```

Calls to `Field.getXXX()` end up here. The default behavior is to mount any field read interceptor chains. If you want to override the behaviour, the parameters are:

- `invocation` - The invocation driving the chain of advices.
- `field` - The field being read
- `instance` - The instance from which we are reading a non-static field.

```
protected Object interceptFieldWrite(
   Invocation invocation,
```

```
      Field field,
      Object instance,
      Object arg)
      throws Throwable;
```

Calls to `Field.setXXX()` end up here. The default behavior is to mount any field write interceptor chains. If you want to override the behaviour, the parameters are:

- `invocation` - The invocation driving the chain of advices.
- `field` - The field being written
- `instance` - The instance on which we are writing a non-static field.
- `arg` - The value we are setting the field to

```
 protected Object interceptMethod(
Invocation invocation,
Method method,
Object instance,
Object[] args)
throws Throwable;
```

Calls to `Method.invoke()` end up here. The default behavior is to mount any method caller interceptor chains (method execution chains are handled correctly by default). If you want to override the behaviour, the parameters are:

- `invocation` - The invocation driving the chain of advices.
- `method` - The method being invoked
- `instance` - The instance on which we are invoking a non-static method.
- `args` - Values for the method arguments.

2. Clean results from reflection info methods

The `ReflectionAspect` also helps with getting rid of the JBoss AOP "plumbing" information. You bind it to a set of caller pointcuts, using the followingjboss-aop.xml entries :

```
  <bind pointcut="call(* java.lang.Class->getInterfaces())">
     <advice name="interceptGetInterfaces" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
```

```
  </bind>

  <bind pointcut="call(* java.lang.Class->getDeclaredMethods())">
     <advice name="interceptGetDeclaredMethods" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>

  <bind pointcut="call(* java.lang.Class->getDeclaredMethod(..))">
     <advice name="interceptGetDeclaredMethod" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>

  <bind pointcut="call(* java.lang.Class->getMethods())">
     <advice name="interceptGetMethods" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>

  <bind pointcut="call(* java.lang.Class->getMethod(..))">
     <advice name="interceptGetMethod" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>

  <bind pointcut="call(* java.lang.Class->getDeclaredFields())">
     <advice name="interceptGetDeclaredFields" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>

  <bind pointcut="call(* java.lang.Class->getDeclaredClasses())">
     <advice name="interceptGetDeclaredClasses" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>

  <bind pointcut="call(* java.lang.Class->getDeclaredField(..))">
     <advice name="interceptGetDeclaredField" \

aspect="org.jboss.test.aop.reflection.ReflectionAspectTester"/>
  </bind>
```

This way the calls to `Class.getMethods()` etc. only return information that is present in the "raw" class, by filtering out the stuff added to the class by JBoss AOP.

Interception of Array Element Access

This chapter will show you how to intercept access to the individual elements of an array. The concepts are similar to the interception we have seen previously, but a few configuration options are introduced. Array interception can currently only be configured via xml. There are three steps involved.

- Specifying which classes we want to replace access to arrays in
- Preparing the array fields in the target class
- Binding advices to array access

1. Replacing Array Access

To achieve array interception we need to replace all access to arrays within a selected set of classes. The `arrayreplacement` element is used for this. You can either specify a particular class using the `class` attribute or a class expression using the `expr` attribute:

```
<arrayreplacement class="org.acme.POJOWithArray"/>
<arrayreplacement expr="class(org.acme.*)"/>
```

2. Preparing Array Fields

If we want to intercept an array's elements, that array field needs to be woven, using either a `prepare` or a `bind` expression. If that field is within a class picked out by an `arrayreplacement` expression it gets all the hooks for arrayreplacement to take place. The following xml along with the previous `arrayreplacement` weaves `org.acme.POJOWithArray.ints` for array element interception.

```
<prepare expr="field(int[] org.acme.POJOWithArray->ints)"/>
```

3. Binding Advices to array element access

To bind advices to the access of array elements, you use a `arraybind` element. It binds advices to all arrays woven for array access. You can use the `type` attribute to specify if you want the interception to take place when setting elements in the array, getting elements from the array, or both. Valid values for the `type` attribute are: `READ_WRITE`, `READ_ONLY` and `WRITE_ONLY`. An example is shown below:

```
<interceptor class="org.acme.TestInterceptor"/>
<arraybind type="READ_ONLY">
   <interceptor-ref name="org.acme.TestInterceptor"/>
</arraybind>
```

`arraybind` currently only supports `interceptor-ref` and `advice` as child elements. `before`, `after`, `throwing` and `finally` are not yet supported for array interception. for arrays.

4. Invocation types for array element access interception

Writing aspects for array element interception is more or less the same as for any other joinpoint. However, array element interception comes with its own hierarchy of `Invocation` clases. Which one of these is used depends on what is being itercepted. The hierarchy is shown below (all the classes live in the `org.jboss.aop.array` package):

```
ArrayElementInvocation
-ArrayElementReadInvocation
--BooleanArrayElementReadInvocation  -Element read from a boolean[]
--ByteArrayElementReadInvocation     -Element read from a byte[]
--CharArrayElementReadInvocation     -Element read from a char[]
--DoubleArrayElementReadInvocation   -Element read from a double[]
--FloatArrayElementReadInvocation    -Element read from a float[]
--IntArrayElementReadInvocation      -Element read from a int[]
--LongArrayElementReadInvocation     -Element read from a long[]
--ObjectArrayElementReadInvocation   -Element read from a Object[],
 String[] etc.
--ShortArrayElementReadInvocation    -Element read from a shore[]
-ArrayElementWriteInvocation
--BooleanArrayElementWriteInvocation -Element written to a
 boolean[]
```

```
--ByteArrayElementWriteInvocation    -Element written to a byte[]
--CharArrayElementWriteInvocation    -Element written to a char[]
--DoubleArrayElementWriteInvocation  -Element written to a double[]
--FloatArrayElementWriteInvocation   -Element written to a float[]
--IntArrayElementWriteInvocation     -Element written to a int[]
--LongArrayElementWriteInvocation    -Element written to a long[]
--ObjectArrayElementWriteInvocation  -Element written to a
 Object[], String[] etc.
--ShortArrayElementWriteInvocation   -Element written to a short[]
```

The write invocation classes allow you access to the value the element is being set to. `ArrayElementReadInvocation` defines a method to get hold of the value being set:

```
public abstract Object getValue();
```

The sub-classes override this value, and also define a more fine-grained value to avoid using the wrapper classes where appropriate, as shown in the following methods from `DoubleArrayElementWriteInvocation`:

```
public Object getValue()
{
   return new Double(value);
}

public double getDoubleValue()
{
   return value;
}
```

When reading an array element the invocation's return value contains the value read. For all array invocations you can get the index of the element being accessed by calling `ArrayElementInvocation.getIndex()`.

Instrumentation Modes

Since it's inception JBoss AOP has introduced different modes of weaving. While the base functionality is the same, the weaving mode introduced in JBoss AOP 2.0.0 allows for more functionality. This chapter will explain a bit about the pros and cons of the different weaving modes, and what functionalities are offered.

1. Classic Weaving

This original weaving mode offers the full basic functionality, and comes in two flavours: 'non-optimized' and 'optimized'.

1.1. Non-optimized

This is the original weaving mode. It generates a minimum amount of woven code, only modyfying the target joinpoints. However, the the invocation classes end up calling the target joinpoint using reflection. Hence it will have minimum overhead at weaving time, but incur the extra cost of calling via reflection at runtime.

To use not-optimized classic weaving at compile-time, you need to specify the following parameters to the `aopc` ant task.

- `optimized` - false
- `jboss.aop.instrumentor` - org.jboss.aop.instrument.ClassicInstrumentor

An example is shown in the following build.xml snippet. Only the relevant parts are shown.

```
<aopc optimized="false" compilerclasspathref="...">
   <sysproperty key="jboss.aop.instrumentor" \
      value="org.jboss.aop.instrument.ClassicInstrumentor"/>
   ...
</aopc>
```

To turn this weaving mode on when using load-time weaving, you need to specify the same flags as system properties when running your woven application. Here is an example:

```
java -Djboss.aop.optimized=false \

-
```

```
Djboss.aop.instrumentor=org.jboss.aop.instrument.ClassicInstrumentor
 \
      [other aop and classpath settings] MyClass
```

1.2. Optimized

This is a development of the original weaving mode. Like the non-optimized flavour, it modifies the target joinpoints, but in addition it generates an invocation class per woven joinpoint, which calls the target joinpoint normally, avoiding the cost of calling via reflection.

To use optimized classic weaving at compile-time, you need to specify the following parameters to the `aopc` ant task.

- `optimized` - true
- `jboss.aop.instrumentor` - org.jboss.aop.instrument.ClassicInstrumentor

An example is shown in the following build.xml snippet. Only the relevant parts are shown.

```
   <aopc optimized="true" compilerclasspathref="...">
      <sysproperty key="jboss.aop.instrumentor" \
         value="org.jboss.aop.instrument.ClassicInstrumentor"/>
      ...
   </aopc>
```

To turn this weaving mode on when using load-time weaving, you need to specify the same flags as system properties when running your woven application. Here is an example:

```
   java -Djboss.aop.optimized=true \

 -
Djboss.aop.instrumentor=org.jboss.aop.instrument.ClassicInstrumentor
 \
      [other aop and classpath settings] MyClass
```

2. Generated Advisor Weaving

This is the weaving mode that is used by default in JBoss AOP 2.0.x. In addition to generating the invocation classes, it also generates the 'advisors'. These contain

the internal book-keeping code that keeps track of the advice chains for the varoius woven joinpoints). At runtime, this means that there is less overhead of looking things up. This mode also allows for some new features in JBoss AOP 2.0.x.

This weaving mode is used by default, so you don't have to specify any extra parameters. This may change in future, so for completeness the parameter you would to pass in to the `aopc` ant task is.

- `jboss.aop.instrumentor` - org.jboss.aop.instrument.GeneratedAdvisorInstrumentor

An example is shown in the following build.xml snippet. Only the relevant parts are shown.

```
   <aopc optimized="true" compilerclasspathref="...">
      <sysproperty key="jboss.aop.instrumentor" \

 value="org.jboss.aop.instrument.GeneratedAdvisorInstrumentor"/>
      ...
   </aopc>
```

Similarly, for load-time weaving, the default is to use this weaving mode. If you were to need to turn it one you would pass in the `GeneratedAdvisorInstrumentor` when starting the JVM:

```
   java
 -
Djboss.aop.instrumentor=org.jboss.aop.instrument.GeneratedAdvisorInstrumentor
 \
      [other aop and classpath settings] MyClass
```

Now we will look at some of the features that are available using this weaving mode.

2.1. Lightweight Aspects

The use of the before, after, after-throwing and finally advices as mentioned in *Section 2, "Before/After/After-Throwing/Finally Advices"* is only supported in this weaving mode.

2.2. Improved Instance API

The improved instance api mentioned in *Section 4, "Improved Instance API"* is only available in this weaving mode.

2.3. Chain Overriding of Inherited Methods

This will be explained with an example. Consider the following case:

```
public class Base{
   void test(){}
}

public class Child{
}

public class ChildTest{
   void test(){}
}
```

```
<aop>
   <prepare expr="execution(* POJO->test())"/>
   <bind pointcut="execution(* Base->test())">
      <interceptor class="BaseInterceptor"/>
   </bind>
   <bind pointcut="execution(* Child*->test())">
      <interceptor class="ChildInterceptor"/>
   </bind>
</aop>
```

```
Base base = new Base();                  //1
Child child = new Child();               //2
ChildTest childTest = new ChildTest();   //3

base.test();                             //4
child.test();                            //5
childTest.test();                        //6
```

With the "old" weaving we needed an exact match on methods for advices to get bound, meaning that:

- Call 4 would get intercepted by BaseInterceptor

- Call 5 would get intercepted by BaseInterceptor
- Call 6 would get intercepted by ChildInterceptor

The discrepancy is between calls 5 and 6, we get different behaviour depending on if we have overridden the method or are just inheriting it, which in turn means we have to have some in-depth knowledge about our hierarchy of classes and who overrides/inherits what in order to have predictable interception.

The new weaving model matches differently, and treats inherited methods the same as overridden methods, so:

- Call 4 would get intercepted by BaseInterceptor
- Call 5 would get intercepted by ChildInterceptor
- Call 6 would get intercepted by ChildInterceptor

Note that for this to work, the parent method *MUST* be woven. In the previous example `Base.test()` has been prepared.