Red Hat JBoss Data Grid 6.4 Developer Guide

For use with Red Hat JBoss Data Grid 6.4

Misha Husnain Ali Gemma Sheldon Rakesh Ghatvisave

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Misha Husnain Ali
Red Hat Engineering Content Services
mhusnain@redhat.com

Gemma Sheldon
Red Hat Engineering Content Services
gsheldon@redhat.com

Rakesh Ghatvisave
Red Hat Engineering Content Services
rghatvis@redhat.com

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Abstract

An advanced guide intended for developers using Red Hat JBoss Data Grid 6.4

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Preface

Part I. Programmable APIs

Red Hat JBoss Data Grid provides the following programmable APIs:

- Cache
- Batching
- Grouping
- Persistence (formerly CacheStore)
- ConfigurationBuilder
- Externalizable
- Notification (also known as the Listener API because it deals with Notifications and Listeners)

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Chapter 1. The Cache API

The Cache interface provides simple methods for the addition, retrieval and removal of entries, which includes atomic mechanisms exposed by the JDK's **`ConcurrentMap`** interface. How entries are stored depends on the cache mode in use. For example, an entry may be replicated to a remote node or an entry may be looked up in a cache store.

The Cache API is used in the same manner as the JDK Map API for basic tasks. This simplifies the process of migrating from Map-based, simple in-memory caches to Red Hat JBoss Data Grid's cache.

Note

This API is not available in JBoss Data Grid's Remote Client-Server Mode

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1.1. Using the ConfigurationBuilder API to Configure the Cache API

Red Hat JBoss Data Grid uses a ConfigurationBuilder API to configure caches.

Caches are configured programmatically using the ***`ConfigurationBuilder`*** helper object.

The following is an example of a synchronously replicated cache configured programmatically using the ConfigurationBuilder API:

Procedure 1.1. Programmatic Cache Configuration

```
Configuration c = new
ConfigurationBuilder().clustering().cacheMode(CacheMode.REPL_SYNC).build
();

String newCacheName = "repl";
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

1. In the first line of the configuration, a new cache configuration object (named **`c`**) is created using the **`ConfigurationBuilder`**. Configuration **`c`** is assigned the default values for all cache configuration options except the cache mode, which is overridden and set to synchronous replication (**`REPL_SYNC`**).
2. In the second line of the configuration, a new variable (of type **`String`**) is created and assigned the value **`repl`**.
3. In the third line of the configuration, the cache manager is used to define a named cache configuration for itself. This named cache configuration is called **`repl`** and its configuration is based on the configuration provided for cache configuration **`c`** in the first line.
4. In the fourth line of the configuration, the cache manager is used to obtain a reference to the unique instance of the **`repl`** that is held by the cache manager. This cache instance is now ready to be used to perform operations to store and retrieve data.

Note

JBoss EAP includes its own underlying JMX. This can cause a collision when using the sample code with JBoss EAP and display an error such as **`org.infinispan.jmx.JmxDomainConflictException: Domain already registered org.infinispan`**.

To avoid this, configure global configuration as follows:

```
GlobalConfiguration glob = new GlobalConfigurationBuilder()
 .clusteredDefault()
        .globalJmxStatistics()
          .allowDuplicateDomains(true)
          .enable()
        .build();
```

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1.2. Per-Invocation Flags

Per-invocation flags can be used with data grids in Red Hat JBoss Data Grid to specify behavior for each cache call. Per-invocation flags facilitate the implementation of potentially time saving optimizations.

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1.2.1. Per-Invocation Flag Functions

The **`putForExternalRead()`** method in Red Hat JBoss Data Grid's Cache API uses flags internally. This method can load a JBoss Data Grid cache with data loaded from an external resource. To improve the efficiency of this call, JBoss Data Grid calls a normal **`put`** operation passing the following flags:

- The **`ZERO_LOCK_ACQUISITION_TIMEOUT`** flag: JBoss Data Grid uses an almost zero lock acquisition time when loading data from an external source into a cache.
- The **`FAIL_SILENTLY`** flag: If the locks cannot be acquired, JBoss Data Grid fails silently without throwing any lock acquisition exceptions.
- The **`FORCE_ASYNCHRONOUS`** flag: If clustered, the cache replicates asynchronously, irrespective of the cache mode set. As a result, a response from other nodes is not required.

Combining the flags above significantly increases the efficiency of the operation. The basis for this efficiency is that **`putForExternalRead`** calls of this type are used because the client can retrieve the required data from a persistent store if the data cannot be found in memory. If the client encounters a cache miss, it retries the operation.

For a detailed list of all flags available for JBoss Data Grid are available in the JBoss Data Grid API Documentation here: https://access.redhat.com/documentation/en-US/Red_Hat_JBoss_Data_Grid/6.4/html/API_Documentation/files/api/org/infinispan/context/Flag.html

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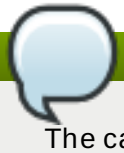
1.2.2. Configure Per-Invocation Flags

To use per-invocation flags in Red Hat JBoss Data Grid, add the required flags to the advanced cache via the **`withFlags()`** method call.

Example 1.1. Configuring Per-Invocation Flags

```
Cache cache = ...
 cache.getAdvancedCache()
    .withFlags(Flag.SKIP_CACHE_STORE, Flag.CACHE_MODE_LOCAL)
    .put("local", "only");
```



Note

The called flags only remain active for the duration of the cache operation. To use the same flags in multiple invocations within the same transaction, use the **`withFlags()`** method for each invocation. If the cache operation must be replicated onto another node, the flags are also carried over to the remote nodes.

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1.2.3. Per-Invocation Flags Example

In a use case for Red Hat JBoss Data Grid, where a write operation, such as **`put()`**, must not return the previous value, the ***`IGNORE_RETURN_VALUES`*** flag is used. This flag prevents a remote lookup (to get the previous value) in a distributed environment, which in turn prevents the retrieval of the undesired, potential, previous value. Additionally, if the cache is configured with a cache loader, this flag prevents the previous value from being loaded from its cache store.

Example 1.2. Using the *`IGNORE_RETURN_VALUES`* Flag

```
Cache cache = ...
 cache.getAdvancedCache()
    .withFlags(Flag.IGNORE_RETURN_VALUES)
    .put("local", "only")
```

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1.3. The AdvancedCache Interface

Red Hat JBoss Data Grid offers an **`AdvancedCache`** interface, geared towards extending JBoss Data Grid, in addition to its simple Cache Interface. The **`AdvancedCache`** Interface can:

- Inject custom interceptors
- Access certain internal components
- Apply flags to alter the behavior of certain cache methods

The following code snippet presents an example of how to obtain an **AdvancedCache**:

```
AdvancedCache advancedCache = cache.getAdvancedCache();
```

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1.3.1. Flag Usage with the AdvancedCache Interface

Flags, when applied to certain cache methods in Red Hat JBoss Data Grid, alter the behavior of the target method. Use **AdvancedCache.withFlags()** to apply any number of flags to a cache invocation.

Example 1.3. Applying Flags to a Cache Invocation

```
advancedCache.withFlags(Flag.CACHE_MODE_LOCAL, Flag.SKIP_LOCKING)
   .withFlags(Flag.FORCE_SYNCHRONOUS)
   .put("hello", "world");
```

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1.3.2. Custom Interceptors and the AdvancedCache Interface

The **AdvancedCache** Interface provides a mechanism that allows advanced developers to attach custom interceptors. Custom interceptors can alter the behavior of the Cache API methods and the **AdvacedCache** Interface can be used to attach such interceptors programmatically at run time.

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1.3.3. Limitations of Map Methods

Specific Map methods, such as **size()**, **values()**, **keySet()** and **entrySet()**, can be used with certain limitations with Red Hat JBoss Data Grid as they are unreliable. These methods do not acquire locks (global or local) and concurrent modification, additions and removals are excluded from consideration in these calls. Furthermore, the listed methods are only operational on the local cache and do not provide a global view of state.

If the listed methods acted globally, it would result in a significant impact on performance and would produce a scalability bottleneck. As a result, it is recommended that these methods are used for informational and debugging purposes only.

Performance Concerns

From Red Hat JBoss Data Grid 6.3 onwards, the map methods **size()**, **values()**, **keySet()**, and **entrySet()** include entries in the cache loader by default whereas previously these methods only included the local data container. The underlying cache loader directly affects the performance of these commands. As an example, when using a database, these methods run a complete scan of the table where data is stored which can result in slower processing. Use ***Cache.getAdvancedCache().withFlags(Flag.SKIP_CACHE_LOAD).values()*** to maintain the old behavior and not loading from the cache loader which would avoid the slower performance.

Changes to the size() Method (Embedded Caches)

In JBoss Data Grid 6.3 the **Cache#size()** method returned only the number of entries on the local

node, ignoring other nodes for clustered caches and including any expired entries. While the default behavior has not been changed in JBoss Data Grid 6.4, accurate results can be enabled for bulk operations, including **size()**, by setting the ***infinispan.accurate.bulk.ops*** system property to true. In this mode of operation, the result returned by the **size()** method is affected by the flags ***org.infinispan.context.Flag#CACHE_MODE_LOCAL***, to force it to return the number of entries present on the local node, and ***org.infinispan.context.Flag#SKIP_CACHE_LOAD***, to ignore any passivated entries.

Changes to the size() Method (Remote Caches)

In JBoss Data Grid 6.3, the Hot Rod **size()** method obtained the size of a cache by invoking the **STATS** operation and using the returned ***numberOfEntries*** statistic. This statistic is not an accurate measurement of the number of entries in a cache because it does not take into account expired and passivated entries and it is only local to the node that responded to the operation. As an additional result, when security was enabled, the client would need the **ADMIN** permission instead of the more appropriate **BULK_READ**.

In JBoss Data Grid 6.4 the Hot Rod protocol has been enhanced with a dedicated **SIZE** operation, and the clients have been updated to use this operation for the **size()** method. The JBoss Data Grid server will need to be started with the ***infinispan.accurate.bulk.ops*** system property set to **true** so that size can be computed accurately.

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1.3.4. Custom Interceptors

Custom interceptors can be added to Red Hat JBoss Data Grid declaratively or programmatically. Custom interceptors extend JBoss Data Grid by allowing it to influence or respond to cache modifications. Examples of such cache modifications are the addition, removal or updating of elements or transactions.

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1.3.4.1. Custom Interceptor Design

To design a custom interceptor in Red Hat JBoss Data Grid, adhere to the following guidelines:

- A custom interceptor must extend the **CommandInterceptor**.
- A custom interceptor must declare a public, empty constructor to allow for instantiation.
- A custom interceptor must have JavaBean style setters defined for any property that is defined through the **property** element.

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1.3.4.2. Adding Custom Interceptors Declaratively

Each named cache in Red Hat JBoss Data Grid has its own interceptor stack. As a result, custom interceptors can be added on a per named cache basis.

A custom interceptor can be added using XML. Use the following procedure to add custom interceptors.

Procedure 1.2. Adding Custom Interceptors

```
<namedCache name="cacheWithCustomInterceptors">
```

```
   <customInterceptors>
      <interceptor position="FIRST"
class="com.mycompany.CustomInterceptor1">
         <properties>
            <property name="attributeOne" value="value1" />
            <property name="attributeTwo" value="value2" />
         </properties>
      </interceptor>
      <interceptor position="LAST"
class="com.mycompany.CustomInterceptor2"/>
      <interceptor index="3" class="com.mycompany.CustomInterceptor1"/>
      <interceptor before="org.infinispan.interceptors.CallInterceptor"
class="com.mycompany.CustomInterceptor2"/>
      <interceptor after="org.infinispan.interceptors.CallInterceptor"
class="com.mycompany.CustomInterceptor1"/>
   </customInterceptors>
</namedCache>
```

1. **Define Custom Interceptors**

   All custom interceptors must extend org.infinispan.interceptors.base.BaseCustomInterceptor.

2. **Define the Position of the New Custom Interceptor**

   Interceptors must have a defined position. These options are mutually exclusive, meaning an interceptor cannot have both a position attribute and index attribute. Valid options are:

   A. **via Position Attribute**

   - **`FIRST`** - Specifies that the new interceptor is placed first in the chain.
   - **`LAST`** - Specifies that the new interceptor is placed last in the chain.
   - **`OTHER_THAN_FIRST_OR_LAST`** - Specifies that the new interceptor can be placed anywhere except first or last in the chain.

   B. **via Index Attribute**

   - The **`index`** identifies the position of this interceptor in the chain, with 0 being the first position.
   - The **`after`** method places the new interceptor directly after the instance of the named interceptor specified via its fully qualified class name.
   - The **`before`** method places the new interceptor directly before the instance of the named interceptor specified via its fully qualified class name.

   C. **Define Interceptor Properties**

   Define specific interceptor properties.

3. **Apply Other Custom Interceptors**

   In this example, the next custom interceptor is called CustomInterceptor2.

Note

Custom interceptors with the position **`OTHER_THAN_FIRST_OR_LAST`** may cause the CacheManager to fail.

Note

This configuration is only valid for JBoss Data Grid's Library Mode.

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1.3.4.3. Adding Custom Interceptors Programmatically

To add a custom interceptor programmatically in Red Hat JBoss Data Grid, first obtain a reference to the **`AdvancedCache`**.

Example 1.4. Obtain a Reference to the AdvancedCache

```
CacheManager cm = getCacheManager();
Cache aCache = cm.getCache("aName");
AdvancedCache advCache = aCache.getAdvancedCache();
```

Then use an ***`addInterceptor()`*** method to add the interceptor.

Example 1.5. Add the Interceptor

```
advCache.addInterceptor(new MyInterceptor(), 0);
```

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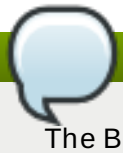
Chapter 2. The Batching API

The Batching API is used when the Red Hat JBoss Data Grid cluster is the sole participant in a transaction. However, Java Transaction API (JTA) transactions (which use the Transaction Manager) are used when multiple systems are participants in the transaction.



Note

The Batching API cannot be used in JBoss Data Grid's Remote Client-Server mode.

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2.1. About Java Transaction API

Red Hat JBoss Data Grid supports configuring, use of, and participation in Java Transaction API (JTA) compliant transactions.

JBoss Data Grid does the following for each cache operation:

1. First, it retrieves the transactions currently associated with the thread.
2. If not already done, it registers an **`XAResource`** with the transaction manager to receive notifications when a transaction is committed or rolled back.

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2.2. Batching and the Java Transaction API (JTA)

In Red Hat JBoss Data Grid, the batching functionality initiates a JTA transaction in the back end, causing all invocations within the scope to be associated with it. For this purpose, the batching functionality uses a simple Transaction Manager implementation at the back end. As a result, the following behavior is observed:

1. Locks acquired during an invocation are retained until the transaction commits or rolls back.
2. All changes are replicated in a batch on all nodes in the cluster as part of the transaction commit process. Ensuring that multiple changes occur within the single transaction, the replication traffic remains lower and improves performance.
3. When using synchronous replication or invalidation, a replication or invalidation failure causes the transaction to roll back.
4. When a cache is transactional and a cache loader is present, the cache loader is not enlisted in the cache's transaction. This results in potential inconsistencies at the cache loader level when the transaction applies the in-memory state but (partially) fails to apply the changes to the store.
5. All configurations related to a transaction apply for batching as well.

Example 2.1. Configuring a Transaction that Applies for Batching

```
<transaction syncRollbackPhase="false"
      syncCommitPhase="false"
      useEagerLocking="true"
      eagerLockSingleNode="true" />
```

The configuration attributes can be used for both transactions and batching, using different values.

Note

Batching functionality and JTA transactions are only supported in JBoss Data Grid's Library Mode.

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2.3. Using the Batching API

2.3.1. Enable the Batching API (Remote Client-Server Mode)

Red Hat JBoss Data Grid's Batching API uses the JBoss Enterprise Application Platform syntax to enable invocation batching in your cache configuration.

Example 2.2. Enable Invocation Batching

```
<distributed-cache name="default" batching="true" statistics="true">
 <!-- Additional configuration information here -->
</distributed-cache>
```

In JBoss Data Grid, invocation batching is disabled by default and batching can be used without a defined Transaction Manager.

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2.3.2. Configure the Batching API

To use the Batching API, enable invocation batching in the cache configuration.

XML Configuration

To configure the Batching API in the XML file, the **`transactionMode`** must be **`TRANSACTIONAL`** to enable **`invocationBatching`**:

```
<transaction transactionMode="TRANSACTIONAL">
<invocationBatching enabled="true" />
```

Programmatic Configuration

To configure the Batching API programmatically use:

```
Configuration c = new
ConfigurationBuilder().invocationBatching().enable().build();
```

In Red Hat JBoss Data Grid, invocation batching is disabled by default and batching can be used without a defined Transaction Manager.

Note

Programmatic configurations can only be used with JBoss Data Grid's Library mode.

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2.3.3. Use the Batching API

After the cache is configured to use batching, call **`startBatch()`** and **`endBatch()`** on the cache as follows to use batching:

```
Cache cache = cacheManager.getCache();
```

Example 2.3. Without Using Batch

```
cache.put("key", "value");
```

When the **`cache.put(key, value);`** line executes, the values are replaced immediately.

Example 2.4. Using Batch

```
cache.startBatch();
cache.put("k1", "value");
cache.put("k2", "value");
cache.put("k3", "value");
cache.endBatch(true);
cache.startBatch();
cache.put("k1", "value");
cache.put("k2", "value");
cache.put("k3", "value");
cache.endBatch(false);
```

When the line **`cache.endBatch(true);`** executes, all modifications made since the batch started are replicated.

When the line **`cache.endBatch(false);`** executes, changes made in the batch are discarded.

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2.3.4. Batching API Usage Example

A simple use case that illustrates the Batching API usage is one that involves transferring money between two bank accounts.

Example 2.5. Batching API Usage Example

Red Hat JBoss Data Grid is used for a transaction that involves transferring money from one bank account to another. If both the source and destination bank accounts are located within JBoss Data Grid, a Batching API is used for this transaction. However, if one account is located within JBoss Data Grid and the other in a database, distributed transactions are required for the transaction.

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Chapter 3. The Grouping API

The Grouping API can relocate groups of entries to a specified node or to a node selected using the hash of the group.

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3.1. Grouping API Operations

Normally, Red Hat JBoss Data Grid uses the hash of a specific key to determine an entry's destination node. However, when the Grouping API is used, a hash of the group associated with the key is used instead of the hash of the key to determine the destination node.

Each node can use an algorithm to determine the owner of each key. This removes the need to pass metadata (and metadata updates) about the location of entries between nodes. This approach is beneficial because:

- Every node can determine which node owns a particular key without expensive metadata updates across nodes.
- Redundancy is improved because ownership information does not need to be replicated if a node fails.

When using the Grouping API, each node must be able to calculate the owner of an entry. As a result, the group cannot be specified manually and must be either:

- Intrinsic to the entry, which means it was generated by the key class.
- Extrinsic to the entry, which means it was generated by an external function.

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3.2. Grouping API Use Case

This feature allows logically related data to be stored on a single node. For example, if the cache contains user information, the information for all users in a single location can be stored on a single node.

The benefit of this approach is that when seeking specific (logically related) data, the Distributed Executor task is directed to run only on the relevant node rather than across all nodes in the cluster. Such directed operations result in optimized performance.

> **Example 3.1. Grouping API Example**
>
> Acme, Inc. is a home appliance company with over one hundred offices worldwide. Some offices house employees from various departments, while certain locations are occupied exclusively by the employees of one or two departments. The Human Resources (HR) department has employees in Bangkok, London, Chicago, Nice and Venice.
>
> Acme, Inc. uses Red Hat JBoss Data Grid's Grouping API to ensure that all the employee records for the HR department are moved to a single node (Node AB) in the cache. As a result, when attempting to retrieve a record for a HR employee, the **`DistributedExecutor`** only checks node AB and quickly and easily retrieves the required employee records.

Storing related entries on a single node as illustrated optimizes the data access and prevents time and resource wastage by seeking information on a single node (or a small subset of nodes) instead of all the nodes in the cluster.

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3.3. Configure the Grouping API

Use the following steps to configure the Grouping API:

1. Enable groups using either the declarative or programmatic method.
2. Specify either an intrinsic or extrinsic group. For more information about these group types, see Section 3.1, “Grouping API Operations”
3. Register all specified groupers.

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3.3.1. Enable Groups

The first step to set up the Grouping API is to enable groups. In Red Hat JBoss Data Grid, groups are enabled declaratively or programmatically as follows:

Example 3.2. Declaratively Enable Groups

Use the following configuration to enable groups using XML:

```
<clustering>
  <hash>
     <groups enabled="true" />
  </hash>
</clustering>
```

Example 3.3. Programmatically Enable Groups

Use the following to enable groups programmatically:

```
Configuration c = new
ConfigurationBuilder().clustering().hash().groups().enabled().build();
```

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3.3.2. Specify an Intrinsic Group

Use an intrinsic group with the Grouping API if:

- the key class definition can be altered, that is if it is not part of an unmodifiable library.
- if the key class is not concerned with the determination of a key/value pair group.

Use the **@Group** annotation in the relevant method to specify an intrinsic group. The group must always be a String, as illustrated in the example:

Example 3.4. Specifying an Intrinsic Group Example

```
class User {

   <!-- Additional configuration information here -->
   String office;
   <!-- Additional configuration information here -->

   public int hashCode()) {
      // Defines the hash for the key, normally used to determine
location
      <!-- Additional configuration information here -->
   }

   // Override the location by specifying a group, all keys in the same
   // group end up with the same owner
   @Group
   String getOffice() {
      return office;
   }

}
```

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3.3.3. Specify an Extrinsic Group

Specify an extrinsic group for the Grouping API if:

- the key class definition cannot be altered, that is if it is part of an unmodifiable library.
- if the key class is concerned with the determination of a key/value pair group.

An extrinsic group is specified using an implementation of the **Grouper** interface. This interface uses the **computeGroup** method to return the group.

In the process of specifying an extrinsic group, the **Grouper** interface acts as an interceptor by passing the computed value to **computeGroup**. If the **@Group** annotation is used, the group using it is passed to the first **Grouper**. As a result, using an intrinsic group provides even greater control.

Example 3.5. Specifying an Extrinsic Group Example

The following is an example that consists of a simple **Grouper** that uses the key class to extract the group from a key using a pattern. Any group information specified on the key class is ignored in such a situation.

```
public class KXGrouper implements Grouper<String> {

   // A pattern that can extract from a "kX" (e.g. k1, k2) style key
   // The pattern requires a String key, of length 2, where the first
```

```
character is
   // "k" and the second character is a digit. We take that digit, and
perform
   // modular arithmetic on it to assign it to group "1" or group "2".

   private static Pattern kPattern = Pattern.compile("(^k)(\\d)$");

    public String computeGroup(String key, String group) {
        Matcher matcher = kPattern.matcher(key);
        if (matcher.matches()) {
            String g = Integer.parseInt(matcher.group(2)) % 2 + "";
            return g;
        } else
            return null;
    }

    public Class<String> getKeyType() {
        return String.class;
    }

}
```

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3.3.4. Register Groupers

After creation, each grouper must be registered to be used.

Example 3.6. Declaratively Register a Grouper

```
<clustering>
  <hash>
     <groups enabled="true">
        <grouper class="com.acme.KXGrouper" />
     </groups>
  </hash>
</clustering>
```

Example 3.7. Programmatically Register a Grouper

```
Configuration c = new
ConfigurationBuilder().clustering().hash().groups().addGrouper(new
KXGrouper()).enabled().build();
```

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Chapter 4. The Persistence SPI

In Red Hat JBoss Data Grid, persistence can configure external (persistent) storage engines. These storage engines complement JBoss Data Grid's default in-memory storage.

Persistent external storage provides several benefits:

- Memory is volatile and a cache store can increase the life span of the information in the cache, which results in improved durability.
- Using persistent external stores as a caching layer between an application and a custom storage engine provides improved Write-Through functionality.
- Using a combination of eviction and passivation, only the frequently required information is stored in-memory and other data is stored in the external storage.

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4.1. Persistence SPI Benefits

The Red Hat JBoss Data Grid implementation of the Persistence SPI offers the following benefits:

- Alignment with JSR-107 (http://jcp.org/en/jsr/detail?id=107). JBoss Data Grid's **`CacheWriter`** and **`CacheLoader`** interfaces are similar to the JSR-107 writer and reader. As a result, alignment with JSR-107 provides improved portability for stores across JCache-compliant vendors.
- Simplified transaction integration. JBoss Data Grid handles locking automatically and so implementations do not have to coordinate concurrent access to the store. Depending on the locking mode, concurrent writes on the same key may not occur. However, implementors expect operations on the store to originate from multiple threads and add the implementation code accordingly.
- Reduced serialization, resulting in reduced CPU usage. The new SPI exposes stored entries in a serialized format. If an entry is fetched from persistent storage to be sent remotely, it does not need to be deserialized (when reading from the store) and then serialized again (when writing to the wire). Instead, the entry is written to the wire in the serialized format as fetched from the storage.

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4.2. Programmatically Configure the Persistence SPI

The following is a sample programmatic configuration for a Single File Store using the Persistence SPI:

Example 4.1. Configure the Single File Store via the Persistence SPI

```
ConfigurationBuilder builder = new ConfigurationBuilder();
   builder.persistence()
          .passivation(false)
          .addSingleFileStore()
             .preload(true)
             .shared(false)
             .fetchPersistentState(true)
             .ignoreModifications(false)
```

```
            .purgeOnStartup(false)
            .location(System.getProperty("java.io.tmpdir"))
            .async()
               .enabled(true)
               .threadPoolSize(5)
            .singleton()
               .enabled(true)
               .pushStateWhenCoordinator(true)
               .pushStateTimeout(20000);
```

Note

Programmatic configurations can only be used with Red Hat JBoss Data Grid's Library mode.

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Chapter 5. The ConfigurationBuilder API

The ConfigurationBuilder API is a programmatic configuration API in Red Hat JBoss Data Grid.

The ConfigurationBuilder API is designed to assist with:

- Chain coding of configuration options in order to make the coding process more efficient
- Improve the readability of the configuration

In JBoss Data Grid, the ConfigurationBuilder API is also used to enable CacheLoaders and configure both global and cache level operations.

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5.1. Using the ConfigurationBuilder API

5.1.1. Programmatically Create a CacheManager and Replicated Cache

Programmatic configuration in Red Hat JBoss Data Grid almost exclusively involves the ConfigurationBuilder API and the CacheManager. The following is an example of a programmatic CacheManager configuration:

Procedure 5.1. Configure the CacheManager Programmatically

```
EmbeddedCacheManager manager = new DefaultCacheManager("my-config-
file.xml");
Cache defaultCache = manager.getCache();
Configuration c = new
ConfigurationBuilder().clustering().cacheMode(CacheMode.REPL_SYNC)
.build();

String newCacheName = "repl";
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

1. Create a CacheManager as a starting point in an XML file. If required, this CacheManager can be programmed in runtime to the specification that meets the requirements of the use case.
2. Create a new synchronously replicated cache programmatically.
    a. Create a new configuration object instance using the ConfigurationBuilder helper object:

    In the first line of the configuration, a new cache configuration object (named **c**) is created using the **ConfigurationBuilder**. Configuration **c** is assigned the default values for all cache configuration options except the cache mode, which is overridden and set to synchronous replication (**REPL_SYNC**).

    b. Define or register the configuration with a manager:

    In the third line of the configuration, the cache manager is used to define a named cache configuration for itself. This named cache configuration is called **repl** and its configuration is based on the configuration provided for cache configuration **c** in the first line.

c. In the fourth line of the configuration, the cache manager is used to obtain a reference to the unique instance of the **repl** that is held by the cache manager. This cache instance is now ready to be used to perform operations to store and retrieve data.

Note

Programmatic configurations can only be used with JBoss Data Grid's Library mode.

Report a bug

5.1.2. Create a Customized Cache Using the Default Named Cache

The default cache configuration (or any customized configuration) can serve as a starting point to create a new cache.

As an example, if the **infinispan-config-file.xml** specifies the configuration for a replicated cache as a default and a distributed cache with a customized lifespan value is required. The required distributed cache must retain all aspects of the default cache specified in the **infinispan-config-file.xml** file except the mentioned aspects.

Procedure 5.2. Customize the Default Cache

```
EmbeddedCacheManager manager = new DefaultCacheManager("infinispan-
config-file.xml");
Configuration dcc = cacheManager.getDefaultCacheConfiguration();
Configuration c = new ConfigurationBuilder().read(dcc).clustering()
 .cacheMode(CacheMode.DIST_SYNC).l1().lifespan(60000L).enable()
 .build();
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

1. Read an instance of a default Configuration object to get the default configuration:
2. Use the ConfigurationBuilder to construct and modify the cache mode and L1 cache lifespan on a new configuration object:
3. Register/define your cache configuration with a cache manager, where cacheName is name of cache specified in **infinispan-config-file.xml**:
4. Get default cache with custom configuration changes.

Report a bug

5.1.3. Create a Customized Cache Using a Non-Default Named Cache

A situation can arise where a new customized cache must be created using a named cache that is not the default. The steps to accomplish this are similar to those used when using the default named cache for this purpose.

The difference in approach is due to taking a named cache called **replicatedCache** as the base instead of the default cache.

Procedure 5.3. Creating a Customized Cache Using a Non-Default Named Cache

```
EmbeddedCacheManager manager = new DefaultCacheManager("infinispan-
config-file.xml");
Configuration rc =
cacheManager.getCacheConfiguration("replicatedCache");
Configuration c = new ConfigurationBuilder().read(rc).clustering()
 .cacheMode(CacheMode.DIST_SYNC).l1().lifespan(60000L).enable()
 .build();
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

1. Read the **`replicatedCache`** to get the default configuration.
2. Use the ConfigurationBuilder to construct and modify the desired configuration on a new configuration object.
3. Register/define your cache configuration with a cache manager where *newCacheName* is the name of cache specified in **`infinispan-config-file.xml`**
4. Get a ***`newCacheName`*** cache with custom configuration changes.

Report a bug

5.1.4. Using the Configuration Builder to Create Caches Programmatically

As an alternative to using an xml file with default cache values to create a new cache, use the ConfigurationBuilder API to create a new cache without any XML files. The ConfigurationBuilder API is intended to provide ease of use when creating chained code for configuration options.

The following new configuration is valid for global and cache level configuration. GlobalConfiguration objects are constructed using GlobalConfigurationBuilder while Configuration objects are built using ConfigurationBuilder.

Report a bug

5.1.5. Global Configuration Examples

5.1.5.1. Globally Configure the Transport Layer

A commonly used configuration option is to configure the transport layer. This informs Red Hat JBoss Data Grid how a node will discover other nodes:

Example 5.1. Configuring the Transport Layer

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .globalJmxStatistics().enable()
  .build();
```

Report a bug

5.1.5.2. Globally Configure the Cache Manager Name

The following sample configuration allows you to use options from the global JMX statistics level to configure the name for a cache manager. This name distinguishes a particular cache manager from other cache managers on the same system.

Example 5.2. Configuring the Cache Manager Name

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .globalJmxStatistics()
    .cacheManagerName("SalesCacheManager")
    .mBeanServerLookup(new JBossMBeanServerLookup())
    .enable()
  .build();
```

Report a bug

5.1.5.3. Globally Customize Thread Pool Executors

Some Red Hat JBoss Data Grid features are powered by a group of thread pool executors. These executors can be customized at the global level as follows:

Example 5.3. Customize Thread Pool Executors

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .replicationQueueScheduledExecutor()
    .factory(new DefaultScheduledExecutorFactory())
    .addProperty("threadNamePrefix", "RQThread")
  .build();
```

Report a bug

5.1.6. Cache Level Configuration Examples

5.1.6.1. Cache Level Configuration for the Cluster Mode

The following configuration allows the use of options such as the cluster mode for the cache at the cache level rather than globally:

Example 5.4. Configure Cluster Mode at Cache Level

```
Configuration config = new ConfigurationBuilder()
  .clustering()
    .cacheMode(CacheMode.DIST_SYNC)
    .sync()
    .l1().lifespan(25000L).enable()
    .hash().numOwners(3)
  .build();
```

Report a bug

5.1.6.2. Cache Level Eviction and Expiration Configuration

Use the following configuration to configure expiration or eviction options for a cache at the cache level:

Example 5.5. Configuring Expiration and Eviction at the Cache Level

```
Configuration config = new ConfigurationBuilder()
           .eviction()

.maxEntries(20000).strategy(EvictionStrategy.LIRS).expiration()
             .wakeUpInterval(5000L)
             .maxIdle(120000L)
           .build();
```

Report a bug

5.1.6.3. Cache Level Configuration for JTA Transactions

To interact with a cache for JTA transaction configuration, configure the transaction layer and optionally customize the locking settings. For transactional caches, it is recommended to enable transaction recovery to deal with unfinished transactions. Additionally, it is recommended that JMX management and statistics gathering is also enabled.

Example 5.6. Configuring JTA Transactions at Cache Level

```
Configuration config = new ConfigurationBuilder()
  .locking()

.concurrencyLevel(10000).isolationLevel(IsolationLevel.REPEATABLE_READ)

.lockAcquisitionTimeout(12000L).useLockStriping(false).writeSkewCheck(tr
ue)
  .transaction()
    .transactionManagerLookup(new GenericTransactionManagerLookup())
  .recovery().enable()
  .jmxStatistics().enable()
  .build();
```

Report a bug

5.1.6.4. Cache Level Configuration Using Chained Persistent Stores

The following configuration can be used to configure one or more chained persistent stores at the cache level:

Example 5.7. Configuring Chained Persistent Stores at Cache Level

```
Configuration conf = new ConfigurationBuilder()
          .persistence()
```

```
            .passivation(false)
            .addSingleFileStore()
               .location("/tmp/firstDir")
         .persistence()
            .passivation(false)
            .addSingleFileStore()
               .location("/tmp/secondDir")
         .build();
```

Report a bug

5.1.6.5. Cache Level Configuration for Advanced Externalizers

An advanced option such as a cache level configuration for advanced externalizers can also be configured programmatically as follows:

Example 5.8. Configuring Advanced Externalizers at Cache Level

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .serialization()
    .addAdvancedExternalizer(new PersonExternalizer())
    .addAdvancedExternalizer(999, new AddressExternalizer())
  .build();
```

Report a bug

Chapter 6. The Externalizable API

An **`Externalizer`** is a class that can:

- Marshall a given object type to a byte array.
- Unmarshall the contents of a byte array into an instance of the object type.

Externalizers are used by Red Hat JBoss Data Grid and allow users to specify how their object types are serialized. The marshalling infrastructure used in JBoss Data Grid builds upon JBoss Marshalling and provides efficient payload delivery and allows the stream to be cached. The stream caching allows data to be accessed multiple times, whereas normally a stream can only be read once.

The Externalizable interface uses and extends serialization. This interface is used to control serialization and deserialization in JBoss Data Grid.

Report a bug

6.1. Customize Externalizers

As a default in Red Hat JBoss Data Grid, all objects used in a distributed or replicated cache must be serilizable. The default Java serialization mechanism can result in network and performance inefficiency. Additional concerns include serialization versioning and backwards compatibility.

For enhanced throughput, performance or to enforce specific object compatibility, use a customized externalizer. Customized externalizers for JBoss Data Grid can be used in one of two ways:

- Use an Externalizable Interface. For details, see Chapter 6, *The Externalizable API*.
- Use an advanced externalizer.

Report a bug

6.2. Annotating Objects for Marshalling Using @SerializeWith

Objects can be marshalled by providing an Externalizer implementation for the type that needs to be marshalled or unmarshalled, then annotating the marshalled type class with **`@SerializeWith`** indicating the Externalizer class to use.

Example 6.1. Using the @SerializeWith Annotation

```
import org.infinispan.commons.marshall.Externalizer;
import org.infinispan.commons.marshall.SerializeWith;

@SerializeWith(Person.PersonExternalizer.class)
public class Person {

   final String name;
   final int age;

   public Person(String name, int age) {
      this.name = name;
      this.age = age;
```

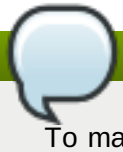
```
   }

   public static class PersonExternalizer implements
Externalizer<Person> {
      @Override
      public void writeObject(ObjectOutput output, Person person)
            throws IOException {
         output.writeObject(person.name);
         output.writeInt(person.age);
      }

      @Override
      public Person readObject(ObjectInput input)
            throws IOException, ClassNotFoundException {
         return new Person((String) input.readObject(),
input.readInt());
      }
   }
}
```

In the provided example, the object has been defined as marshallable due to the **`@SerializeWith`** annotation. JBoss Marshalling will therefore marshall the object using the Externalizer class passed.

This method of defining externalizers is user friendly, however it has the following disadvantages:

- The payload sizes generated using this method are not the most efficient. This is due to some constraints in the model, such as support for different versions of the same class, or the need to marshall the Externalizer class.
- This model requires the marshalled class to be annotated with **`@SerializeWith`**, however an Externalizer may need to be provided for a class for which source code is not available, or for any other constraints, it cannot be modified.
- Annotations used in this model may be limiting for framework developers or service providers that attempt to abstract lower level details, such as the marshalling layer, away from the user.

Advanced Externalizers are available for users affected by these disadvantages.



Note

To make Externalizer implementations easier to code and more typesafe, define type <t> as the type of object that is being marshalled or unmarshalled.

Report a bug

6.3. Using an Advanced Externalizer

Using a customized advanced externalizer helps optimize performance in Red Hat JBoss Data Grid.

1. Define and implement the **`readObject()`** and **`writeObject()`** methods.
2. Link externalizers with marshaller classes.
3. Register the advanced externalizer.

Report a bug

6.3.1. Implement the Methods

To use advanced externalizers, define and implement the **`readObject()`** and **`writeObject()`** methods. The following is a sample definition:

Example 6.2. Define and Implement the Methods

```
import org.infinispan.commons.marshall.AdvancedExternalizer;

public class Person {

   final String name;
   final int age;

   public Person(String name, int age) {
      this.name = name;
      this.age = age;
   }

   public static class PersonExternalizer implements
AdvancedExternalizer<Person> {
      @Override
      public void writeObject(ObjectOutput output, Person person)
            throws IOException {
         output.writeObject(person.name);
         output.writeInt(person.age);
      }

      @Override
      public Person readObject(ObjectInput input)
            throws IOException, ClassNotFoundException {
         return new Person((String) input.readObject(),
input.readInt());
      }

      @Override
      public Set<Class<? extends Person>> getTypeClasses() {
         return Util.<Class<? extends Person>>asSet(Person.class);
      }

      @Override
      public Integer getId() {
         return 2345;
      }
   }
}
```

Note

This method does not require annotated user classes. As a result, this method is valid for classes where the source code is not available or cannot be modified.

Report a bug

6.3.2. Link Externalizers with Marshaller Classes

Use an implementation of **`getTypeClasses()`** to discover the classes that this externalizer can marshall and to link the **`readObject()`** and **`writeObject()`** classes.

The following is a sample implementation:

```
import org.infinispan.util.Util;
<!-- Additional configuration information here -->
@Override
public Set<Class<? extends ReplicableCommand>> getTypeClasses() {
  return Util.asSet(LockControlCommand.class, GetKeyValueCommand.class,
      ClusteredGetCommand.class, MultipleRpcCommand.class,
      SingleRpcCommand.class, CommitCommand.class,
      PrepareCommand.class, RollbackCommand.class,
      ClearCommand.class, EvictCommand.class,
      InvalidateCommand.class, InvalidateL1Command.class,
      PutKeyValueCommand.class, PutMapCommand.class,
      RemoveCommand.class, ReplaceCommand.class);
}
```

In the provided sample, the **`ReplicableCommandExternalizer`** indicates that it can externalize several command types. This sample marshalls all commands that extend the **`ReplicableCommand`** interface but the framework only supports class equality comparison so it is not possible to indicate that the classes marshalled are all children of a particular class or interface.

In some cases, the class to be externalized is private and therefore the class instance is not accessible. In such a situation, look up the class with the provided fully qualified class name and pass it back. An example of this is as follows:

```
@Override
public Set<Class<? extends List>> getTypeClasses() {
 return Util.<Class<? extends List>>asSet(
       Util.<List>loadClass("java.util.Collections$SingletonList",
null));
}
```

Report a bug

6.3.3. Register the Advanced Externalizer (Declaratively)

After the advanced externalizer is set up, register it for use with Red Hat JBoss Data Grid. This registration is done declaratively (via XML) as follows:

Procedure 6.1. Register the Advanced Externalizer

```
<infinispan>
    <global>
        <serialization>
            <advancedExternalizers>
                <advancedExternalizer
externalizerClass="org.infinispan.marshall.AdvancedExternalizerTest$IdVia
AnnotationObj$Externalizer"/>
            </advancedExternalizers>
        </serialization>
    </global>
</infinispan>
```

1. Add the **`global`** element to the **`infinispan`** element.
2. Add the **`serialization`** element to the **`global`** element.
3. Add the **`advancedExternalizers`** element to add information about the new advanced externalizer.
4. Define the externalizer class using the ***`externalizerClass`*** attributes. Replace the *$IdViaAnnotationObj* and *$AdvancedExternalizer* values as required.

Report a bug

6.3.4. Register the Advanced Externalizer (Programmatically)

After the advanced externalizer is set up, register it for use with Red Hat JBoss Data Grid. This registration is done programmatically as follows:

Example 6.3. Registering the Advanced Externalizer Programmatically

```
GlobalConfigurationBuilder builder = ...
builder.serialization()
   .addAdvancedExternalizer(new Person.PersonExternalizer());
```

Enter the desired information for the GlobalConfigurationBuilder in the first line.

Report a bug

6.3.5. Register Multiple Externalizers

Alternatively, register multiple advanced externalizers because **`GlobalConfiguration.addExternalizer()`** accepts ***`varargs`***. Before registering the new externalizers, ensure that their IDs are already defined using the **`@Marshalls`** annotation.

Example 6.4. Registering Multiple Externalizers

```
builder.serialization()
   .addAdvancedExternalizer(new Person.PersonExternalizer(),
                            new Address.AddressExternalizer());
```

Report a bug

6.4. Custom Externalizer ID Values

Advanced externalizers can be assigned custom IDs if desired. Some ID ranges are reserved for other modules or frameworks and must be avoided:

Table 6.1. Reserved Externalizer ID Ranges

ID Range	Reserved For
1000-1099	The Infinispan Tree Module
1100-1199	Red Hat JBoss Data Grid Server modules
1200-1299	Hibernate Infinispan Second Level Cache
1300-1399	JBoss Data Grid Lucene Directory
1400-1499	Hibernate OGM
1500-1599	Hibernate Search
1600-1699	Infinispan Query Module
1700-1799	Infinispan Remote Query Module

Report a bug

6.4.1. Customize the Externalizer ID (Declaratively)

Customize the advanced externalizer ID declaratively (via XML) as follows:

Procedure 6.2. Customizing the Externalizer ID (Declaratively)

```
<infinispan>
  <global>
    <serialization>
      <advancedExternalizers>
       <advancedExternalizer id="$ID"
externalizerClass="org.infinispan.marshall.AdvancedExternalizerTest$IdVia
ConfigObj$Externalizer"/>
       </advancedExternalizers>
    </serialization>
  </global>
</infinispan>
```

1. Add the **`global`** element to the **`infinispan`** element.
2. Add the **`serialization`** element to the **`global`** element.
3. Add the **`advancedExternalizer`** element to add information about the new advanced externalizer.
4. Define the externalizer ID using the ***`id`*** attribute. Ensure that the selected ID is not from the range of IDs reserved for other modules.
5. Define the externalizer class using the ***`externalizerClass`*** attribute. Replace the *$IdViaAnnotationObj* and *$AdvancedExternalizer* values as required.

Report a bug

6.4.2. Customize the Externalizer ID (Programmatically)

Use the following configuration to programmatically assign a specific ID to the externalizer:

Example 6.5. Assign an ID to the Externalizer

```
GlobalConfiguration globalConfiguration = new
GlobalConfigurationBuilder()
            .serialization()
               .addAdvancedExternalizer($ID, new
Person.PersonExternalizer())
            .build();
```

Replace the *$ID* with the desired ID.

Report a bug

Chapter 7. The Notification/Listener API

Red Hat JBoss Data Grid provides a listener API that provides notifications for events as they occur. Clients can choose to register with the listener API for relevant notifications. This annotation-driven API operates on cache-level events and cache manager-level events.

Report a bug

7.1. Listener Example

The following example defines a listener in Red Hat JBoss Data Grid that prints some information each time a new entry is added to the cache:

Example 7.1. Configuring a Listener

```
@Listener
public class PrintWhenAdded {
  @CacheEntryCreated
  public void print(CacheEntryCreatedEvent event) {
    System.out.println("New entry " + event.getKey() + " created in
the cache");
  }
}
```

Report a bug

7.2. Cache Entry Modified Listener Configuration

In a cache entry modified listener event, The ***`getValue()`*** method's behavior is specific to whether the callback is triggered before or after the actual operation has been performed. For example, if **`event.isPre()`** is true, then **`event.getValue()`** would return the old value, prior to modification. If **`event.isPre()`** is false, then **`event.getValue()`** would return new value. If the event is creating and inserting a new entry, the old value would be null. For more information about ***`isPre()`***, see the Red Hat JBoss Data Grid *API Documentation*'s listing for the **`org.infinispan.notifications.cachelistener.event`** package.

Listeners can only be configured programmatically by using the methods exposed by the Listenable and FilteringListenable interfaces (which the Cache object implements).

Report a bug

7.3. Listener Notifications

Each cache event triggers a notification that is dispatched to listeners. A listener is a simple POJO annotated with **`@Listener`**. A Listenable is an interface that denotes that the implementation can have listeners attached to it. Each listener is registered using methods defined in the Listenable.

A listener can be attached to both the cache and Cache Manager to allow them to receive cache-level or cache manager-level notifications.

Report a bug

7.3.1. About Cache-level Notifications

In Red Hat JBoss Data Grid, cache-level events occur on a per-cache basis, and are global and cluster-wide. Examples of cache-level events include the addition, removal and modification of entries, which trigger notifications to listeners registered on the relevant cache.

Report a bug

7.3.2. Cache Manager-level Notifications

Examples of events that occur in Red Hat JBoss Data Grid at the cache manager-level are:

- Nodes joining or leaving a cluster;
- The starting and stopping of caches

Cache manager-level events are located globally and used cluster-wide, but are restricted to events within caches created by a single cache manager.

Report a bug

7.3.3. About Synchronous and Asynchronous Notifications

By default, notifications in Red Hat JBoss Data Grid are dispatched in the same thread that generates the event. Therefore the listener must be written in a way that does not block or prevent the thread's progression.

Alternatively, the listener can be annotated as asynchronous, which dispatches notifications in a separate thread and prevents blocking the operations of the original thread.

Annotate listeners using the following:

```
@Listener (sync = false)
public class MyAsyncListener { .... }
```

Use the ***<asyncListenerExecutor/>*** element in the configuration file to tune the thread pool that is used to dispatch asynchronous notifications.

Report a bug

7.4. Modifying Cache Entries

After the cache entry has been created, the cache entry can be modified programmatically.

Report a bug

7.4.1. Cache Entry Modified Listener Configuration

In a cache entry modified listener event, The ***`getValue()`*** method's behavior is specific to whether the callback is triggered before or after the actual operation has been performed. For example, if **`event.isPre()`** is true, then **`event.getValue()`** would return the old value, prior to modification. If **`event.isPre()`** is false, then **`event.getValue()`** would return new value. If the event is creating and inserting a new entry, the old value would be null. For more information about ***`isPre()`***, see the Red Hat JBoss Data Grid *API Documentation*'s listing for the **`org.infinispan.notifications.cachelistener.event`** package.

Listeners can only be configured programmatically by using the methods exposed by the Listenable and FilteringListenable interfaces (which the Cache object implements).

Report a bug

7.4.2. Cache Entry Modified Listener Example

The following example defines a listener in Red Hat JBoss Data Grid that prints some information each time a cache entry is modified:

Example 7.2. Modified Listener

```
@Listener
public class PrintWhenModified {
    @CacheEntryModified
    public void print(CacheEntryModifiedEvent event) {
        System.out.println("Cache entry modified. Details = " +
event");
       }
    }
```

Report a bug

7.5. Clustered Listeners

Clustered listeners allow listeners to be used in a distributed cache configuration. In a distributed cache environment, registered local listeners are only notified of events that are local to the node where the event has occurred. Clustered listeners resolve this issue by allowing a single listener to receive any write notification that occurs in the cluster, regardless of where the event occurred. As a result, clustered listeners perform slower than non-clustered listeners, which only provide event notifications for the node on which the event occurs.

When using clustered listeners, client applications are notified when an entry is added, updated, or deleted in a particular cache. The event is cluster-wide so that client applications can access the event regardless of the node on which the application resides or connects with.

The event will always be triggered on the node where the listener was registered, while disregarding where the cache update originated.

Note

Expiry events are not notified.

Report a bug

7.5.1. Configuring Clustered Listeners

In the following use case, listener stores events as it receives them.

Procedure 7.1. Clustered Listener Configuration

```
@Listener(clustered = true)
  protected static class ClusterListener {
     List<CacheEntryEvent> events = Collections.synchronizedList(new
ArrayList<CacheEntryEvent>());

     @CacheEntryCreated
     @CacheEntryModified
     @CacheEntryRemoved
     public void onCacheEvent(CacheEntryEvent event) {
        log.debugf("Adding new cluster event %s", event);
        events.add(event);
     }
  }

  public void addClusterListener(Cache<?, ?> cache) {
     ClusterListener clusterListener = new ClusterListener();
     cache.addListener(clusterListener);
  }
```

1. Clustered listeners are enabled by annotating the **`@Listener`** class with **`clustered=true`**.
2. The following methods are annotated to allow client applications to be notified when entries are added, modified, or removed.
   - **`@CacheEntryCreated`**
   - **`@CacheEntryModified`**
   - **`@CacheEntryRemoved`**
3. The listener is registered with a cache, with the option of passing on a filter or converter.

The following limitations occur when using clustered listeners, that do not apply to non-clustered listeners:

- A cluster listener can only listen to entries that are created, modified, or removed. No other events are listened to by a clustered listener.
- Only post events are sent to a clustered listener, pre events are ignored.

Report a bug

7.5.2. The Cache Listener API

Clustered listeners can be added on top of the existing **`@CacheListener API`** via the **`addListener`** method.

Example 7.3. The Cache Listener API

```
cache.addListener(Object listener, Filter filter, Converter converter);

public @interface Listener {
  boolean clustered() default false;
  boolean includeCurrentState() default false;
  boolean sync() default true;
}
```

```
interface CacheEventFilter<K,V> {
  public boolean accept(K key, V oldValue, Metadata oldMetadata, V
newValue, Metadata newMetadata, EventType eventType);
}

interface CacheEventConvertor<K,V,C> {
  public C convert(K key, V oldValue, Metadata oldMetadata, V
newValue, Metadata newMetadata, EventType eventType);
}
```

The Cache API

The local or clustered listener can be registered with the **`cache.addListener`** method, and is active until one of the following events occur.

- The listener is explicitly unregistered by invoking **`cache.removeListener`**.
- The node on which the listener was registered crashes.

Listener Annotation

The listener annotation is enhanced with two attributes:

- **`clustered()`**:This attribute defines whether the annotated listener is clustered or not. Note that clustered listeners can only be notified for **`@CacheEntryRemoved`**, **`@CacheEntryCreated`**, and **`@CacheEntryModified`** events. This attribute is false by default.
- **`includeCurrentState()`**: This attribute applies to clustered listeners only, and is false by default. When set to **`true`**, the entire existing state within the cluster is evaluated. When being registered, a listener will immediately be sent a **`CacheCreatedEvent`** for every entry in the cache.

`oldValue` and `oldMetadata`

The **`oldValue`** and **`oldMetadata`** values are extra methods on the accept method of **`CacheEventFilter`** and **`CacheEventConverter`** classes. They values are provided to any listener, including local listeners. For more information about these values, see the *JBoss Data Grid API Documentation*.

`EventType`

The **`EventType`** includes the type of event, whether it was a retry, and if it was a pre or post event.

When using clustered listeners, the order in which the cache is updated is reflected in the sequence of notifications received.

The clustered listener does not guarantee that an event is sent only once. The listener implementation must be idempotent in order to prevent situations where the same event is sent more than once. Implementors can expect singularity to be honored for stable clusters and outside of the time span in which synthetic events are generated as a result of **`includeCurrentState`**.

Report a bug

7.5.3. Clustered Listener Example

The following use case demonstrates a listener that wants to know when orders are generated that have a destination of New York, NY. The listener requires a Filter that filters all orders that come in and out of New York. The listener also requires a Converter as it does not require the entire order, only the date it is to be delivered.

Example 7.4. Use Case: Filtering and Converting the New York orders

```
class CityStateFilter implements CacheEventFilter<String, Order> {
   private final String state;
   private final String city;

   public boolean accept(String orderId, Order oldOrder, Metadata
oldMetadata, Order newOrder, Metadata newMetadata, EventType
eventType) {
      switch (eventType.getType()) {
         // Only send update if the order is going to our city
         case Type.CACHE_ENTRY_CREATED:
            return city.equals(newOrder.getCity()) &&
state.equals(newOrder.getState());
         // Only send update if our order has changed from our city to
elsewhere or if is now going to our city
         case Type.CACHE_ENTRY_MODIFIED:
            if (city.equals(oldOrder.getCity()) &&
state.equals(oldOrder.getState())) {
               // If old city matches then we have to compare if new
order is no longer going to our city
               return !city.equals(newOrder.getCity()) ||
!state.equals(newOrder.getState());
            } else {
               // If the old city doesn't match ours then only send
update if new update does match ours
               return city.equals(newOrder.getCity()) &&
state.equals(newOrder.getState());
            }
         // On remove we have to send update if our order was
originally going to city
         case Type.CACHE_ENTRY_REMOVED:
            return city.equals(oldOrder.getCity()) &&
state.equals(oldOrder.getState());
      }
   }
}

class OrderDateConverter implements CacheEventConverter<String, Order,
Date> {
   private final String state;
   private final String city;

   public Date convert(String orderId, Order oldValue, Metadata
oldMetadata, Order newValue, Metadata newMetadata, EventType
eventType) {
      // If remove we do not care about date - this tells listener to
remove its data
      if (eventType.isRemove()) {
         return null;
```

```
      } else if (eventType.isModification()) {
         if (state.equals(newOrder.getState()) &&
city.equals(newOrder.getCity()) {
            // If it is a modification meaning the destination has
changed to ours then we allow it
            return newOrder.getDate();
         } else {
            // If destination is no longer our city it means it was
changed from us so send null
            return null;
         }
      } else {
         // This was a create so we always send date
         return newOrder.getDate();
      }
   }
}
```

Report a bug

7.5.4. Optimized Cache Filter Converter

The example provided in Section 7.5.3, “Clustered Listener Example” could use the optimized **`CacheEventFilterConverter`**, in order to perform the filtering and converting of results into one step.

The **`CacheEventFilterConverter`** is an optimization that allows the event filter and conversion to be performed in one step. This can be used when an event filter and converter are most efficiently used as the same object, composing the filtering and conversion in the same method. This can only be used in situations where your conversion will not return a null value. To convert a null value, use the **`CacheEventFilter`** and the **`CacheEventConverter`** interfaces independently.

The following is an example of the New York orders use case using the **`CacheEventFilterConverter`**:

Example 7.5. CacheEventFilterConverter

```
class OrderDateFilterConverter extends
AbstractCacheEventFilterConverter<String, Order, Date> {
   private final String state;
   private final String city;

   public Date filterAndConvert(String orderId, Order oldValue,
Metadata oldMetadata, Order newValue, Metadata newMetadata, EventType
eventType) {
      // Remove if the date is not required - this tells listener to
remove its data
      if (eventType.isRemove()) {
         return null;
      } else if (eventType.isModification()) {
         if (state.equals(newOrder.getState()) &&
city.equals(newOrder.getCity()) {
            // If it is a modification meaning the destination has
changed to ours then we allow it
```

```
            return newOrder.getDate();
         } else {
            // If destination is no longer our city it means it was
changed from us so send null
            return null;
         }
      } else {
         // This was a create so we always send date
         return newOrder.getDate();
      }
   }
}
```

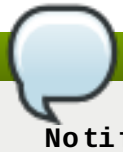
When registering the listener, provide the **`FilterConverter`** as both arguments to the filter and converter:

```
OrderDateFilterConverter filterConverter = new
OrderDateFilterConverter("NY", "New York");
cache.addListener(listener, filterConveter, filterConverter);
```

Report a bug

7.6. NotifyingFutures

Methods in Red Hat JBoss Data Grid do not return Java Development Kit (JDK) **`Futures`**, but a sub-interface known as a **`NotifyingFuture`**. Unlike a JDK **`Future`**, a listener can be attached to a **`NotifyingFuture`** to notify the user about a completed future.



Note

`NotifyingFutures` are only available in JBoss Data Grid Library mode.

Report a bug

7.6.1. NotifyingFutures Example

The following is an example depicting how to use **`NotifyingFutures`** in Red Hat JBoss Data Grid:

Example 7.6. Configuring NotifyingFutures

```
FutureListener futureListener = new FutureListener() {

public void futureDone(Future future) {
      try {
         future.get();
      } catch (Exception e) {
         // Future did not complete successfully
         System.out.println("Help!");
      }
```

```
   }
};

cache.putAsync("key", "value").attachListener(futureListener);
```

Report a bug

7.7. Remote Event Listeners (Hot Rod)

Event listeners allow Red Hat JBoss Data Grid Hot Rod servers to be able to notify remote clients of events such as **`CacheEntryCreated`**, **`CacheEntryModified`**, and **`CacheEntryRemoved`**. Clients can choose whether or not to listen to these events to avoid flooding connected clients. This assumes that clients maintain persistent connections to the servers.

Client listeners for remote events can be added similarly to clustered listeners in library mode. The following example demonstrates a remote client listener that prints out each event it receives.

Example 7.7. Event Print Listener

```
import org.infinispan.client.hotrod.annotation.*;
import org.infinispan.client.hotrod.event.*;

@ClientListener
public class EventLogListener {

   @ClientCacheEntryCreated
   public void handleCreatedEvent(ClientCacheEntryCreatedEvent e) {
      System.out.println(e);
   }

   @ClientCacheEntryModified
   public void handleModifiedEvent(ClientCacheEntryModifiedEvent e) {
      System.out.println(e);
   }

   @ClientCacheEntryRemoved
   public void handleRemovedEvent(ClientCacheEntryRemovedEvent e) {
      System.out.println(e);
   }

}
```

- **`ClientCacheEntryCreatedEvent`** and **`ClientCacheEntryModifiedEvent`** instances provide information on the key and version of the entry. This version can be used to invoke conditional operations on the server, such a **`replaceWithVersion`** or **`removeWithVersion`**.
- **`ClientCacheEntryRemovedEvent`** events are only sent when the remove operation succeeds. If a remove operation is invoked and no entry is found or there are no entries to remove, no event is generated. If users require remove events regardless of whether or not they are successful, a customized event logic can be created.
- All client cache entry created, modified, and removed events provide a **`boolean`**

isCommandRetried() method that will return **true** if the write command that caused it has to be retried due to a topology change. This indicates that the event has been duplicated or that another event was dropped and replaced, such as where a Modified event replaced a Created event.

Important

Remote event listeners are available for the Hot Rod Java client only.

Warning

Remote event listeners is a Technology Preview feature and is therefore not supported in JBoss Data Grid 6.4.

Report a bug

7.7.1. Adding and Removing Event Listeners

Registering and Event Listener with the Server

The following example registers the Event Print Listener with the server. See Example 7.7, “Event Print Listener”.

Example 7.8. Adding an Event Listener

```
RemoteCache<Integer, String> cache = rcm.getCache();
cache.addClientListener(new EventLogListener();
```

Removing a Client Event Listener

A client event listener can be removed as follows

Example 7.9. Removing an Event Listener

```
EventLogListener listener = ...
cache.removeClientListener(listener);
```

Report a bug

7.7.2. Remote Event Client Listener Example

The following procedure demonstrates the steps required to configure a remote client listener to interact with the remote cache via Hot Rod.

Procedure 7.2. Configuring Remote Event Listeners

1. **Download the Red Hat JBoss Data Grid Server distribution from the Red Hat Customer Portal**

   The latest Red Hat JBoss Data Grid distribution includes the Hot Rod server with which the client will communicate.

2. **Start the server**

   Start the JBoss Data Grid server by using the following command from the root of the server.

   ```
   $ ./bin/standalone.sh
   ```

3. **Write an application to interact with the Hot Rod server**

   A. **Maven users**

   Create an application with the following dependency, changing the version to **`6.4.0-Final-redhat-1`** or better.

   ```
   <dependency>
     <groupId>org.infinispan</groupId>
     <artifactId>infinispan-remote</artifactId>
     <version>${infinispan.version}</version>
   </dependency>
   ```

   B. Non-Maven users, adjust according to your chosen build tool or download the distribution containing all JBoss Data Grid jars.

4. **Write the client application**

   The following demonstrates a simple remote event listener that logs all events received.

   ```
   import org.infinispan.client.hotrod.annotation.*;
   import org.infinispan.client.hotrod.event.*;


   @ClientListener
   public class EventLogListener {


    @ClientCacheEntryCreated
    @ClientCacheEntryModified
    @ClientCacheEntryRemoved
    public void handleRemoteEvent(ClientEvent event) {
      System.out.println(event);
     }


   }
   ```

5. **Use the remote event listener to execute operations against the remote cache**

The following example demonstrates a simple main java class, which adds the remote event listener and executes some operations against the remote cache.

```
import org.infinispan.client.hotrod.*;


RemoteCacheManager rcm = new RemoteCacheManager();
RemoteCache<Integer, String> cache = rcm.getCache();
EventLogListener listener = new EventLogListener();
try {
 cache.addClientListener(listener);
 cache.put(1, "one");
 cache.put(1, "new-one");
 cache.remove(1);
} finally {
 cache.removeClientListener(listener);
}
```

Result

Once executed, the console output should appear similar to the following:

```
ClientCacheEntryCreatedEvent(key=1,dataVersion=1)
ClientCacheEntryModifiedEvent(key=1,dataVersion=2)
ClientCacheEntryRemovedEvent(key=1)
```

The output indicates that by default, events come with the key and the internal data version associated with current value. The actual value is not sent back to the client for performance reasons. Receiving remote events has a performance impact, which is increased with cache size, as more operations are executed. To avoid inundating Hot Rod clients, filter remote events on the server side, or customize the event contents.

Report a bug

7.7.3. Filtering Remote Events

To prevent clients being inundated with events, Red Hat JBoss Data Grid Hot Rod remote events can be filtered by providing key/value filter factories that create instances that filter which events are sent to clients, and how these filters can act on client provided information.

Sending events to remote clients has a performance cost, which increases with the number of clients with registered remote listeners. The performance impact also increases with the number of modifications that are executed against the cache.

The performance cost can be reduced by filtering the events being sent on the server side. Custom code can be used to exclude certain events from being broadcast to the remote clients to improve performance.

Filtering can be based on either key or value information, or based on cache entry metadata. To enable filtering, a cache event filter factory that produces filter instances must be created. The following is a sample implementation that filters key “2” out of the events sent to clients.

Example 7.10. KeyValueFilter

```
package sample;

import java.io.Serializable;
import org.infinispan.filter.*;
import org.infinispan.metadata.*;

@NamedFactory(name = "basic-filter-factory")
public class BasicKeyValueFilterFactory implements
KeyValueFilterFactory {
  @Override public KeyValueFilter<Integer, String>
getKeyValueFilter(final Object[] params) {
    return new BasicKeyValueFilter();
  }

    static class BasicKeyValueFilter implements KeyValueFilter<Integer,
String>, Serializable {
      @Override public boolean accept(Integer key, String value,
Metadata metadata) {
        return !"2".equals(key);
      }
    }
}
```

In order to register a listener with this key value filter factory, the factory must be given a unique name, and the Hot Rod server must be plugged with the name and the cache event filter factory instance.

Report a bug

7.7.3.1. Custom Filters for Remote Events

Custom filters can improve performance by excluding certain event information from being broadcast to the remote clients.

Note

The deployment of custom code into the server is now supported in Red Hat JBoss Data Grid 6.4.

To plug the JBoss Data Grid Server with a custom filter use the following procedure:

Procedure 7.3. Using a Custom Filter

1. Create a **JAR** file with the filter implementation within it. Each factory must have a name assigned to it via the **`org.infinispan.filter.NamedFactory`** annotation. The example uses a **`KeyValueFilterFactory`**.
2. Create a **`META-INF/services/org.infinispan.notifications.filter.KeyValueFilterFactory`** file within the **JAR** file, and within it write the fully qualified class name of the filter class implementation.

3. Deploy the **JAR** file in the JBoss Data Grid Server.

Once the server is plugged with the filter, add a remote client listener that will use the filter. The following example extends the EventLogListener implementation provided in Remote Event Client Listener Example (See Section 7.7.2, "Remote Event Client Listener Example"), and overrides the **`@ClientListener`** annotation to indicate the filter factory to use with the listener.

Example 7.11. Add Filter Factory to the Listener

```
@org.infinispan.client.hotrod.annotation.ClientListener(filterFactoryNa
me = "basic-filter-factory")
public class BasicFilteredEventLogListener extends EventLogListener {}
```

The listener can now be added via the RemoteCacheAPI. The following example demonstrates this, and executes some operations against the remote cache.

Example 7.12. Register the Listener with the Server

```
import org.infinispan.client.hotrod.*;

RemoteCacheManager rcm = new RemoteCacheManager();
RemoteCache<Integer, String> cache = rcm.getCache();
BasicFilteredEventLogListener listener = new
BasicFilteredEventLogListener();
try {
  cache.addClientListener(listener);
  cache.putIfAbsent(1, "one");
  cache.replace(1, "new-one");
  cache.putIfAbsent(2, "two");
  cache.replace(2, "new-two");
  cache.putIfAbsent(3, "three");
  cache.replace(3, "new-three");
  cache.remove(1);
  cache.remove(2);
  cache.remove(3);
} finally {
  cache.removeClientListener(listener);
}
```

The system output shows that the client receives events for all keys except those that have been filtered.

Result

The following demonstrates the resulting system output from the provided example.

```
ClientCacheEntryCreatedEvent(key=1,dataVersion=1)
ClientCacheEntryModifiedEvent(key=1,dataVersion=2)
ClientCacheEntryCreatedEvent(key=3,dataVersion=5)
ClientCacheEntryModifiedEvent(key=3,dataVersion=6)
```

```
ClientCacheEntryRemovedEvent(key=1)
ClientCacheEntryRemovedEvent(key=3)
```

Important

Filter instances must be marshallable when they are deployed in a cluster in order for filtering to occur where the event is generated, even if the event is generated in a different node to where the listener is registered. To make them marshallable, either make them extend Serializable, Externalizable, or provide a custom Externalizer.

Report a bug

7.7.3.2. Enhanced Filter Factories

When adding client listeners, users can provide parameters to the filter factory in order to generate different filter instances with different behaviors from a single filter factory based on client-side information.

The following configuration demonstrates how to enhance the filter factory so that it can filter dynamically based on the key provided when adding the listener, rather than filtering on a statically given key.

Example 7.13. Configuring an Enhanced Filter Factory

```
package sample;

import java.io.Serializable;
import org.infinispan.filter.*;
import org.infinispan.metadata.*;


@NamedFactory(name = "basic-filter-factory")
public class BasicKeyValueFilterFactory implements
KeyValueFilterFactory {
  @Override public KeyValueFilter<Integer, String>
getKeyValueFilter(final Object[] params) {
    return new BasicKeyValueFilter(params);
}

  static class BasicKeyValueFilter implements KeyValueFilter<Integer,
String>, Serializable {
    private final Object[] params;
    public BasicKeyValueFilter(Object[] params) { this.params = params;
}
    @Override public boolean accept(Integer key, String value,
Metadata metadata) {
      return !params[0].equals(key);
    }
  }
}
```

The filter can now filter by “3” instead of “2”:

Example 7.14. Running an Enhanced Filter Factory

```
import org.infinispan.client.hotrod.*;

RemoteCacheManager rcm = new RemoteCacheManager();
RemoteCache<Integer, String> cache = rcm.getCache();
BasicFilteredEventLogListener listener = new
BasicFilteredEventLogListener();
try {
  cache.addClientListener(listener, new Object[]{3}, null); // <-
Filter parameter passed
  cache.putIfAbsent(1, "one");
  cache.replace(1, "new-one");
  cache.putIfAbsent(2, "two");
  cache.replace(2, "new-two");
  cache.putIfAbsent(3, "three");
  cache.replace(3, "new-three");
  cache.remove(1);
  cache.remove(2);
  cache.remove(3);
} finally {
  cache.removeClientListener(listener);
}
```

Result

The provided example results in the following output:

```
ClientCacheEntryCreatedEvent(key=1,dataVersion=1)
ClientCacheEntryModifiedEvent(key=1,dataVersion=2)
ClientCacheEntryCreatedEvent(key=2,dataVersion=3)
ClientCacheEntryModifiedEvent(key=2,dataVersion=4)
ClientCacheEntryRemovedEvent(key=1)
ClientCacheEntryRemovedEvent(key=2)
```

The amount of information sent to clients can be further reduced or increased by customizing remote events.

Report a bug

7.7.4. Customizing Remote Events

In Red Hat JBoss Data Grid, Hot Rod remote events can be customized to contain the information required to be sent to a client. By default, events contain only a basic set of information, such as a key and type of event, in order to avoid overloading the client, and to reduce the cost of sending them.

Note

The deployment of custom code into the server is now supported in Red Hat JBoss Data Grid 6.4.

The information included in these events can be customized to contain more information, such as values, or contain even less information. Customization is done via **CacheEventConverter** instances, which are created by implementing a **CacheEventConverterFactory** class. Each factory must have a name associated to it via the **@NamedFactory** annotation.

To plug the JBoss Data Grid Server with an event converter use the following procedure:

Procedure 7.4. Using a Converter

1. Create a **JAR** file with the converter implementation within it. Each factory must have a name assigned to it via the **org.infinispan.filter.NamedFactory** annotation.
2. Create a **META-INF/services/org.infinispan.notifications.filter.CacheEventConverterFactory** file within the **JAR** file and within it, write the fully qualified class name of the converter class implementation.
3. Deploy the **JAR** file in the JBoss Data Grid Server.

Converters can also act on client provided information, allowing converter instances to customize events based on the information provided when the listener was added. The API allows converter parameters to be passed in when the listener is added.

Report a bug

7.7.4.1. Adding a Converter

When a listener is added, the name of a converter factory can be provided to use with the listener. When the listener is added, the server looks up the factory and invokes the **getConverter** method to get a **org.infinispan.filter.Converter** class instance to customize events server side.

The following example demonstrates sending custom events containing value information to remote clients for a cache of Integers and Strings. The converter generates a new custom event, which includes the value as well as the key in the event. The custom event has a bigger event payload compared with default events, however if combined with filtering, it can reduce bandwidth cost.

Example 7.15. Sending Custom Events

```
import org.infinispan.filter.*;

@NamedFactory(name = "value-added-converter-factory")
class ValueAddedConverterFactory implements ConverterFactory {
  public Converter<Integer, String, ValueAddedEvent>
getConverter(final Object[] params) {
    return new ValueAddedConverter();
  }

  static class ValueAddedConverter implements Converter<Integer,
String, ValueAddedEvent> {
```

```
    public ValueAddedEvent convert(Integer key, String value, Metadata
metadata) {
      return new ValueAddedEvent(key, value);
    }
  }
}

// Must be Serializable or Externalizable.
class ValueAddedEvent implements Serializable {
    final Integer key;
    final String value;
    ValueAddedEvent(Integer key, String value) {
      this.key = key;
      this.value = value;
    }
}
```

Report a bug

7.7.4.2. Lightweight Events

Other converter implementations are able to send back events that contain no key or event type information, resulting in extremely lightweight events at the expense of having rich information provided by the event.

In order to plug the server with this converter, deploy the converter factory and associated converter class within a **JAR** file including a service definition inside the **META-INF/services/org.infinispan.filter.ConverterFactory** file as follows:

```
sample.ValueAddedConverterFactor
```

The client listener must then be linked with the converter factory by adding the factory name to the **@ClientListener** annotation.

```
@ClientListener(converterFactoryName = "value-added-converter-factory")
public class CustomEventLogListener { ... }
```

Report a bug

7.7.4.3. Dynamic Converter Instances

Dynamic converter instances convert based on parameters provided when the listener is registered. Converters use the parameters received by the converter factories to enable this option. For example:

Example 7.16. Dynamic Converter

```
import
org.infinispan.notifications.cachelistener.filter.CacheEventConverterFa
ctory;
import
```

```
org.infinispan.notifications.cachelistener.filter.CacheEventConverter;

class DynamicCacheEventConverterFactory implements
CacheEventConverterFactory {
   public CacheEventConverter<Integer, String, CustomEvent>
getConverter(final Object[] params) {
      return new DynamicCacheEventConverter(params);
   }
}

// Serializable, Externalizable or marshallable with Infinispan
Externalizers needed when running in a cluster
class DynamicCacheEventConverter implements
CacheEventConverter<Integer, String, CustomEvent>, Serializable {
   final Object[] params;

   DynamicCacheEventConverter(Object[] params) {
      this.params = params;
   }

   public CustomEvent convert(Integer key, String value, Metadata
metadata, String prevValue, Metadata prevMetadata, EventType
eventType) {
      // If the key matches a key given via parameter, only send the
key information
      if (params[0].equals(key))
         return new ValueAddedEvent(key, null);

      return new ValueAddedEvent(key, value);
   }
}
```

The dynamic parameters required to do the conversion are provided when the listener is registered:

```
RemoteCache<Integer, String> cache = rcm.getCache();
cache.addClientListener(new EventLogListener(), null, new Object[]{1});
```

Report a bug

7.7.4.4. Adding a Remote Client Listener for Custom Events

Implementing a listener for custom events is slightly different to other remote events, as they involve non-default events. The same annotations are used as in other remote client listener implementations, but the callbacks receive instances of **`ClientCacheEntryCustomEvent<T>`**, where **`T`** is the type of custom event we are sending from the server. For example:

Example 7.17. Custom Event Listener Implementation

```
import org.infinispan.client.hotrod.annotation.*;
import org.infinispan.client.hotrod.event.*;

@ClientListener(converterFactoryName = "value-added-converter-
```

```
factory")
public class CustomEventLogListener {

    @ClientCacheEntryCreated
    @ClientCacheEntryModified
    @ClientCacheEntryRemoved
    public void
handleRemoteEvent(ClientCacheEntryCustomEvent<ValueAddedEvent> {
        System.out.println(event);
    }
}
```

To use the remote event listener to execute operations against the remote cache, write a simple main Java class, which adds the remote event listener and executes some operations against the remote cache. For example:

Example 7.18. Execute Operations against the Remote Cache

```
import org.infinispan.client.hotrod.*;

RemoteCacheManager rcm = new RemoteCacheManager();
RemoteCache<Integer, String> cache = rcm.getCache();
CustomEventLogListener listener = new CustomEventLogListener();
try {
  cache.addClientListener(listener);
  cache.put(1, "one");
  cache.put(1, "new-one");
  cache.remove(1);
} finally {
  cache.removeClientListener(listener);
}
```

Result

Once executed, the console output should appear similar to the following:

```
 ClientCacheEntryCustomEvent(eventData=ValueAddedEvent{key=1,
value='one'}, eventType=CLIENT_CACHE_ENTRY_CREATED)
ClientCacheEntryCustomEvent(eventData=ValueAddedEvent{key=1, value='ne-
wone'}, eventType=CLIENT_CACHE_ENTRY_MODIFIED)
ClientCacheEntryCustomEvent(eventData=ValueAddedEvent{key=1,
value='null'}, eventType=CLIENT_CACHE_ENTRY_REMOVED
```

Important

Converter instances must be marshallable when they are deployed in a cluster in order for conversion to occur where the event is generated, even if the event is generated in a different node to where the listener is registered. To make them marshallable, either make them extend Serializable, Externalizable, or provide a custom Externalizer for them. Both client and server need to be aware of any custom event type and be able to marshall it in order to facilitate both server and client writing against type safe APIs. On the client side, this is done by an optional marshaller configurable via the RemoteCacheManager. On the server side, this is done by a marshaller added to the Hot Rod server configuration.

Report a bug

7.7.5. Event Marshalling

When filtering or customizing events, the KeyValueFilter and Converter instances must be marshallable. As the client listener is installed in a cluster, the filter and/or converter instances are sent to other nodes in the cluster in order for filtering and conversion to occur where the event originates, improving efficiency. These classes can be made marshallable by having them extend Serializable or by providing and registering a custom Externalizer.

Note

The deployment of custom code into the server is now supported in Red Hat JBoss Data Grid 6.4.

To deploy a Marshaller instance server-side, use a similar method to that used for filtering and customized events.

Procedure 7.5. Deploying a Marshaller

1. Create a **JAR** file with the converter implementation within it. Each factory must have a name assigned to it via the **`org.infinispan.filter.NamedFactory`** annotation.
2. Create a **`META-INF/services/org.infinispan.commons.marshall.Marshaller`** file within the **JAR** file and within it, write the fully qualified class name of the marshaller class implementation
3. Deploy the **JAR** file in the Red Hat JBoss Data Grid Server

The Marshaller can be deployed either in a separate jar, or in the same jar as the CacheEventConverter, and/or CacheEventFilter instances.

Note

Only the deployment of a single Marshaller instance is supported. If multiple marshaller instances are deployed, warning messages will be displayed as a reminder indicating which marshaller instance will be used.

Report a bug

7.7.6. Remote Event Clustering and Failover

When a client adds a remote listener, it is installed in a single node in the cluster, which is in charge of sending events back to the client for all affected operations that occur cluster-wide.

In a clustered environment, when a node containing the listener goes down, the Hot Rod client implementation transparently fails over the client listener registration to a different node. This may result in a gap in event consumption, which can be solved using one of the following solutions.

State Delivery

The **`@ClientListener`** annotation has an optional ***`includeCurrentState`*** parameter, which when enabled, has the server send **`CacheEntryCreatedEvent`** event instances for all existing cache entries to the client. This allows clients to recompute their state or computation in the event the Hot Rod client transparently fails over registered listeners. The performance of the ***`includeCurrentState`*** parameter is impacted by the cache size, and therefore it is disabled by default.

@ClientCacheFailover

Rather than relying on receiving state, users can define a method with the **`@ClientCacheFailover`** annotation, which receives ***`ClientCacheFailoverEvent`*** parameter inside the client listener implementation. If the node where a Hot Rod client has registered a client listener fails, the Hot Rod client detects it transparently, and fails over all listeners registered in the node that failed to another node.

During this failover, the client may miss some events. To avoid this, the ***`includeCurrentState`*** parameter can be set to true. Alternatively, Hot Rod clients can be made aware of failover events by adding a callback handler. This callback method is an efficient solution to handling cluster topology changes affecting client listeners.

Example 7.19. @ClientCacheFailove

```
import org.infinispan.client.hotrod.annotation.*;
import org.infinispan.client.hotrod.event.*;

@ClientListener
public class EventLogListener {
// ...

    @ClientCacheFailover
    public void handleFailover(ClientCacheFailoverEvent e) {
      // Deal with client failover, e.g. clear a near cache.
    }
}
```

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Part II. Securing Data in Red Hat JBoss Data Grid

In Red Hat JBoss Data Grid, data security can be implemented in the following ways:

Role-based Access Control

JBoss Data Grid features role-based access control for operations on designated secured caches. Roles can be assigned to users who access your application, with roles mapped to permissions for cache and cache-manager operations. Only authenticated users are able to perform the operations that are authorized for their role.

In Library mode, data is secured via role-based access control for CacheManagers and Caches, with authentication delegated to the container or application. In Remote Client-Server mode, JBoss Data Grid is secured by passing identity tokens from the Hot Rod client to the server, and role-based access control of Caches and CacheManagers.

Node Authentication and Authorization

Node-level security requires new nodes or merging partitions to authenticate before joining a cluster. Only authenticated nodes that are authorized to join the cluster are permitted to do so. This provides data protection by preventing authorized servers from storing your data.

Encrypted Communications Within the Cluster

JBoss Data Grid increases data security by supporting encrypted communications between the nodes in a cluster by using a user-specified cryptography algorithm, as supported by Java Cryptography Architecture (JCA).

JBoss Data Grid also provides audit logging for operations, and the ability to encrypt communication between the Hot Rod Client and Server using Transport Layer Security (TLS/SSL).

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Chapter 8. Red Hat JBoss Data Grid Security: Authorization and Authentication

8.1. Red Hat JBoss Data Grid Security: Authorization and Authentication

Red Hat JBoss Data Grid is able to perform authorization on CacheManagers and Caches. JBoss Data Grid authorization is built on standard security features available in a JDK, such as JAAS and the SecurityManager.

If an application attempts to interact with a secured CacheManager and Cache, it must provide an identity which JBoss Data Grid's security layer can validate against a set of required roles and permissions. Once validated, the client is issued a token for subsequent operations. Where access is denied, an exception indicating a security violation is thrown.

When a cache has been configured for with authorization, retrieving it returns an instance of **`SecureCache`**. **`SecureCache`** is a simple wrapper around a cache, which checks whether the "current user" has the permissions required to perform an operation. The "current user" is a Subject associated with the **`AccessControlContext`**.

JBoss Data Grid maps Principals names to roles, which in turn, represent one or more permissions. The following diagram represents these relationships:

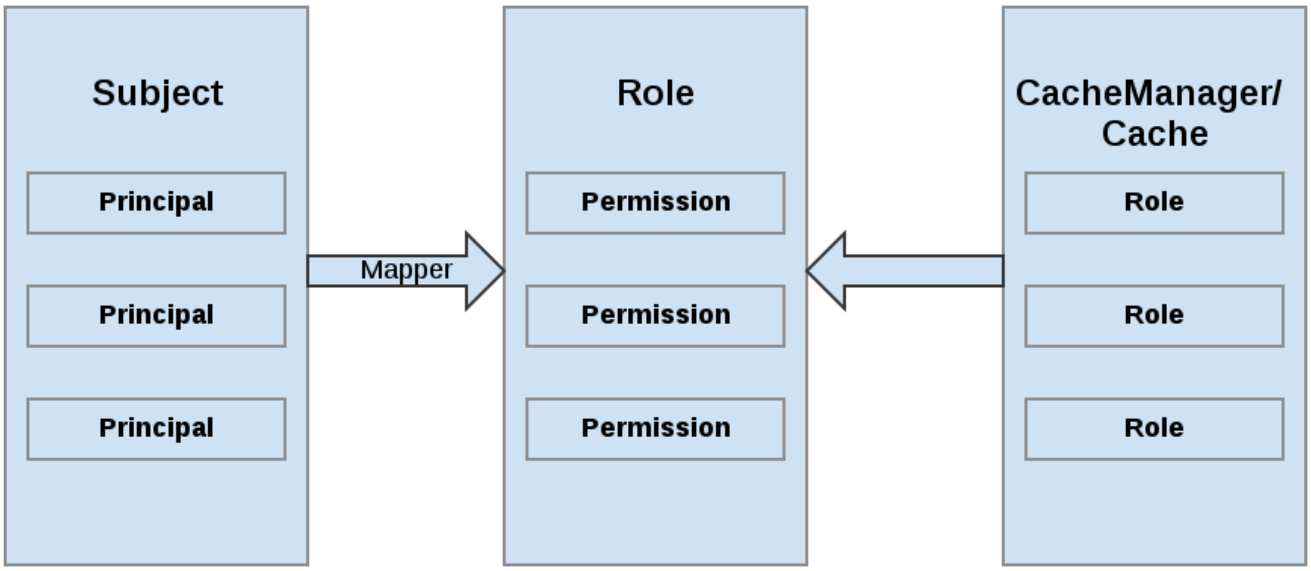

Figure 8.1. Roles and Permissions Mapping

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8.2. Permissions

Access to a CacheManager or a Cache is controlled using a set of required permissions. Permissions control the type of action that is performed on the CacheManager or Cache, rather than the type of data being manipulated. Some of these permissions can apply to specifically name entities, such as a named cache. Different types of permissions are available depending on the entity.

Table 8.1. CacheManager Permissions

Permission	Function	Description
CONFIGURATION	defineConfiguration	Whether a new cache configuration can be defined.
LISTEN	addListener	Whether listeners can be registered against a cache manager.
LIFECYCLE	stop, start	Whether the cache manager can be stopped or started respectively.
ALL		A convenience permission which includes all of the above.

Table 8.2. Cache Permissions

Permission	Function	Description
READ	get, contains	Whether entries can be retrieved from the cache.
WRITE	put, putIfAbsent, replace, remove, evict	Whether data can be written/replaced/removed/evicted from the cache.
EXEC	distexec, mapreduce	Whether code execution can be run against the cache.
LISTEN	addListener	Whether listeners can be registered against a cache.
BULK_READ	keySet, values, entrySet,query	Whether bulk retrieve operations can be executed.
BULK_WRITE	clear, putAll	Whether bulk write operations can be executed.
LIFECYCLE	start, stop	Whether a cache can be started / stopped.
ADMIN	getVersion, addInterceptor*, removeInterceptor, getInterceptorChain, getEvictionManager, getComponentRegistry, getDistributionManager, getAuthorizationManager, evict, getRpcManager, getCacheConfiguration, getCacheManager, getInvocationContextContainer, setAvailability, getDataContainer, getStats, getXAResource	Whether access to the underlying components/internal structures is allowed.
ALL		A convenience permission which includes all of the above.
ALL_READ		Combines READ and BULK_READ.
ALL_WRITE		Combines WRITE and BULK_WRITE.

Note

Some permissions may need to be combined with others in order to be useful. For example, EXEC with READ or with WRITE.

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8.3. Role Mapping

In order to convert the Principals in a Subject into a set of roles used for authorization, a **`PrincipalRoleMapper`** must be specified in the global configuration. Red Hat JBoss Data Grid ships with three mappers, and also allows you to provide a custom mapper.

Table 8.3. Mappers

Mapper Name	Java	XML	Description
IdentityRoleMapper	org.infinispan.security.impl.IdentityRoleMapper	<identity-role-mapper />	Uses the Principal name as the role name.
CommonNameRoleMapper	org.infinispan.security.impl.CommonRoleMapper	<common-name-role-mapper />	If the Principal name is a Distinguished Name (DN), this mapper extracts the Common Name (CN) and uses it as a role name. For example the DN **`cn=managers,ou=people,dc=example,dc=com`** will be mapped to the role **`managers`**.
ClusterRoleMapper	org.infinispan.security.impl.ClusterRoleMapper	<cluster-role-mapper />	Uses the **`ClusterRegistry`** to store principal to role mappings. This allows the use of the CLI's **`GRANT`** and **`DENY`** commands to add/remove roles to a Principal.
Custom Role Mapper		<custom-role-mapper class="a.b.c" />	Supply the fully-qualified class name of an implementation of **`org.infinispan.security.impl.PrincipalRoleMapper`**

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8.4. Configuring Authentication and Role Mapping using JBoss EAP Login Modules

When using Red Hat JBoss EAP log in module for querying roles from LDAP, you must implement your own mapping of Principals to Roles, as JBoss EAP uses its own custom classes. The following example demonstrates how to map a principal obtained from JBoss EAP login module to a role. It maps user principal name to a role, performing a similar action to the **`IdentityRoleMapper`**:

Example 8.1. Mapping a Principal from JBoss EAP's Login Module

```
public class SimplePrincipalGroupRoleMapper implements
PrincipalRoleMapper {
   @Override
   public Set<String> principalToRoles(Principal principal) {
      if (principal instanceof SimpleGroup) {
         Enumeration<Principal> members = ((SimpleGroup)
principal).members();
         if (members.hasMoreElements()) {
            Set<String> roles = new HashSet<String>();
            while (members.hasMoreElements()) {
               Principal innerPrincipal = members.nextElement();
               if (innerPrincipal instanceof SimplePrincipal) {
                  SimplePrincipal sp = (SimplePrincipal)
innerPrincipal;
                  roles.add(sp.getName());
               }
            }
            return roles;
         }
      }
      return null;
   }
}
```

Example 8.2. Example of JBoss EAP LDAP login module configuration

```
 <security-domain name="ispn-secure" cache-type="default">
                  <authentication>
                     <login-module
code="org.jboss.security.auth.spi.LdapLoginModule" flag="required">
                        <module-option
name="java.naming.factory.initial"
value="com.sun.jndi.ldap.LdapCtxFactory"/>
                        <module-option name="java.naming.provider.url"
value="ldap://localhost:389"/>
                        <module-option
name="java.naming.security.authentication" value="simple"/>
                        <module-option name="principalDNPrefix"
value="uid="/>
                        <module-option name="principalDNSuffix"
value=",ou=People,dc=infinispan,dc=org"/>
                        <module-option name="rolesCtxDN"
value="ou=Roles,dc=infinispan,dc=org"/>
                        <module-option name="uidAttributeID"
value="member"/>
                        <module-option name="matchOnUserDN"
```

```
value="true"/>
                        <module-option name="roleAttributeID"
value="cn"/>
                        <module-option name="roleAttributeIsDN"
value="false"/>
                        <module-option name="searchScope"
value="ONELEVEL_SCOPE"/>
                    </login-module>
                </authentication>
            </security-domain>
```

Example 8.3. Example of JBoss EAP Login Module Configuration

```
<security-domain name="krb-admin" cache-type="default">
                    <authentication>
                        <login-module code="Kerberos" flag="required">
                            <module-option name="useKeyTab"
value="true"/>
                            <module-option name="principal"
value="admin@INFINISPAN.ORG"/>
                            <module-option name="keyTab"
value="${basedir}/keytab/admin.keytab"/>
                        </login-module>
                    </authentication>
                </security-domain>
```

When using GSSAPI authentication, this would typically involve using LDAP for role mapping, with JBoss EAP server authenticating itself to the LDAP server via GSSAPI. For more information on how to configure this, see the *JBoss EAP Administration and Configuration Guide*.

Important

For information about how to configure JBoss EAP login modules, see the *JBoss EAP Administration and Configuration Guide* and see the Red Hat Directory Server *Administration Guide* how to configure LDAP server, and specify users and their role mapping.

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8.5. Configuring Red Hat JBoss Data Grid for Authorization

Authorization is configured at two levels: the cache container (CacheManager), and at the single cache.

CacheManager

The following is an example configuration for authorization at the CacheManager level:

Example 8.4. CacheManager Authorization (Declarative Configuration)

```
<cache-container name="local" default-cache="default">
        <security>
           <authorization>
             <identity-role-mapper />
             <role name="admin" permissions="ALL"/>
             <role name="reader" permissions="READ"/>
             <role name="writer" permissions="WRITE"/>
             <role name="supervisor" permissions="ALL_READ ALL_WRITE"/>
           </authorization>
        </security>
</cache-container>
```

Each cache container determines:

- whether to use authorization.
- a class which will map principals to a set of roles.
- a set of named roles and the permissions they represent.

You can choose to use only a subset of the roles defined at the container level.

Roles

Roles for each cache can be defined as follows:

Example 8.5. Defining Roles

```
<local-cache name="secured">
            <security>
                <authorization roles="admin reader writer
supervisor"/>
            </security>
        </local-cache>
```

Programmatic CacheManager Authorization (Library Mode)

The following example shows how to set up the same authorization parameters for Library mode using programmatic configuration:

Example 8.6. CacheManager Authorization Programmatic Configuration

```
GlobalConfigurationBuilder global = new GlobalConfigurationBuilder();
  global
     .security()
        .authorization()
           .principalRoleMapper(new IdentityRoleMapper())
           .role("admin")
              .permission(CachePermission.ALL)
           .role("supervisor")
              .permission(CachePermission.EXEC)
              .permission(CachePermission.READ)
```

```
            .permission(CachePermission.WRITE)
         .role("reader")
            .permission(CachePermission.READ);
ConfigurationBuilder config = new ConfigurationBuilder();
config
   .security()
      .enable()
      .authorization()
         .role("admin")
         .role("supervisor")
         .role("reader");
```

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8.6. Data Security for Library Mode

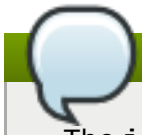
8.6.1. Subject and Principal Classes

To authorize access to resources, applications must first authenticate the request's source. The JAAS framework defines the term subject to represent a request's source. The **`Subject`** class is the central class in JAAS. A **`Subject`** represents information for a single entity, such as a person or service. It encompasses the entity's principals, public credentials, and private credentials. The JAAS APIs use the existing Java 2 **`java.security.Principal`** interface to represent a principal, which is a typed name.

During the authentication process, a subject is populated with associated identities, or principals. A subject may have many principals. For example, a person may have a name principal (John Doe), a social security number principal (123-45-6789), and a user name principal (johnd), all of which help distinguish the subject from other subjects. To retrieve the principals associated with a subject, two methods are available:

```
public Set getPrincipals() {...}
public Set getPrincipals(Class c) {...}
```

`getPrincipals()` returns all principals contained in the subject. **`getPrincipals(Class c)`** returns only those principals that are instances of class **`c`** or one of its subclasses. An empty set is returned if the subject has no matching principals.



Note

The **`java.security.acl.Group`** interface is a sub-interface of **`java.security.Principal`**, so an instance in the principals set may represent a logical grouping of other principals or groups of principals.

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8.6.2. Obtaining a Subject

In order to use a secured cache in Library mode, you must obtain a **`javax.security.auth.Subject`**. The Subject represents information for a single cache entity, such as a person or a service.

Red Hat JBoss Data Grid allows a JAAS Subject to be obtained either by using your container's features, or by using a third-party library.

In JBoss containers, this can be done using the following:

```
Subject subject = SecurityContextAssociation.getSubject();
```

The Subject must be populated with a set of Principals, which represent the user and groups it belongs to in your security domain, for example, an LDAP or Active Directory.

The Java EE API allows retrieval of a container-set Principal through the following methods:

- Servlets: **`ServletRequest.getUserPrincipal()`**
- EJBs: **`EJBContext.getCallerPrincipal()`**
- MessageDrivenBeans: **`MessageDrivenContext.getCallerPrincipal()`**

The **`mapper`** is then used to identify the principals associated with the Subject and convert them into roles that correspond to those you have defined at the container level.

A Principal is only one of the components of a Subject, which is retrieved from the **`java.security.AccessControlContext`**. Either the container sets the Subject on the **`AccessControlContext`**, or the user must map the Principal to an appropriate Subject before wrapping the call to the JBoss Data Grid API using a **`Security.doAs()`** method.

Once a Subject has been obtained, the cache can be interacted with in the context of a PrivilegedAction.

Example 8.7. Obtaining a Subject

```
import org.infinispan.security.Security;

Security.doAs(subject, new PrivilegedExceptionAction<Void>() {
public Void run() throws Exception {
    cache.put("key", "value");
}
});
```

The **`Security.doAs()`** method is in place of the typical Subject.doAs() method. Unless the **`AccessControlContext`** must be modified for reasons specific to your application's security model, using **`Security.doAs()`** provides a performance advantage.

To obtain the current Subject, use **`Security.getSubject();`**, which will retrieve the Subject from either the JBoss Data Grid context, or from the **`AccessControlContext`**.

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8.6.3. Subject Authentication

Subject Authentication requires a JAAS login. The login process consists of the following points:

1. An application instantiates a **`LoginContext`** and passes in the name of the login configuration and a **`CallbackHandler`** to populate the **`Callback`** objects, as required by the configuration **`LoginModule`**s.

2. The **LoginContext** consults a **Configuration** to load all the **LoginModules** included in the named login configuration. If no such named configuration exists the **other** configuration is used as a default.
3. The application invokes the **LoginContext.login** method.
4. The login method invokes all the loaded **LoginModule**s. As each **LoginModule** attempts to authenticate the subject, it invokes the handle method on the associated **CallbackHandler** to obtain the information required for the authentication process. The required information is passed to the handle method in the form of an array of **Callback** objects. Upon success, the **LoginModule**s associate relevant principals and credentials with the subject.
5. The **LoginContext** returns the authentication status to the application. Success is represented by a return from the login method. Failure is represented through a LoginException being thrown by the login method.
6. If authentication succeeds, the application retrieves the authenticated subject using the **LoginContext.getSubject** method.
7. After the scope of the subject authentication is complete, all principals and related information associated with the subject by the **login** method can be removed by invoking the **LoginContext.logout** method.

The **LoginContext** class provides the basic methods for authenticating subjects and offers a way to develop an application that is independent of the underlying authentication technology. The **LoginContext** consults a **Configuration** to determine the authentication services configured for a particular application. **LoginModule** classes represent the authentication services. Therefore, you can plug different login modules into an application without changing the application itself. The following code shows the steps required by an application to authenticate a subject.

```
CallbackHandler handler = new MyHandler();
LoginContext lc = new LoginContext("some-config", handler);

try {
    lc.login();
    Subject subject = lc.getSubject();
} catch(LoginException e) {
    System.out.println("authentication failed");
    e.printStackTrace();
}

// Perform work as authenticated Subject
// ...

// Scope of work complete, logout to remove authentication info
try {
    lc.logout();
} catch(LoginException e) {
    System.out.println("logout failed");
    e.printStackTrace();
}

// A sample MyHandler class
class MyHandler
    implements CallbackHandler
{
```

```
    public void handle(Callback[] callbacks) throws
        IOException, UnsupportedCallbackException
    {
        for (int i = 0; i < callbacks.length; i++) {
            if (callbacks[i] instanceof NameCallback) {
                NameCallback nc = (NameCallback)callbacks[i];
                nc.setName(username);
            } else if (callbacks[i] instanceof PasswordCallback) {
                PasswordCallback pc = (PasswordCallback)callbacks[i];
                pc.setPassword(password);
            } else {
                throw new UnsupportedCallbackException(callbacks[i],
                                                       "Unrecognized
Callback");
            }
        }
    }
}
```

Developers integrate with an authentication technology by creating an implementation of the **`LoginModule`** interface. This allows an administrator to plug different authentication technologies into an application. You can chain together multiple **`LoginModule`**s to allow for more than one authentication technology to participate in the authentication process. For example, one **`LoginModule`** may perform user name/password-based authentication, while another may interface to hardware devices such as smart card readers or biometric authenticators.

The life cycle of a **`LoginModule`** is driven by the **`LoginContext`** object against which the client creates and issues the login method. The process consists of two phases. The steps of the process are as follows:

- The **`LoginContext`** creates each configured **`LoginModule`** using its public no-arg constructor.
- Each **`LoginModule`** is initialized with a call to its initialize method. The **`Subject`** argument is guaranteed to be non-null. The signature of the initialize method is: **`public void initialize(Subject subject, CallbackHandler callbackHandler, Map sharedState, Map options)`**
- The **`login`** method is called to start the authentication process. For example, a method implementation might prompt the user for a user name and password and then verify the information against data stored in a naming service such as NIS or LDAP. Alternative implementations might interface to smart cards and biometric devices, or simply extract user information from the underlying operating system. The validation of user identity by each **`LoginModule`** is considered phase 1 of JAAS authentication. The signature of the **`login`** method is **`boolean login() throws LoginException`** . A **`LoginException`** indicates failure. A return value of true indicates that the method succeeded, whereas a return value of false indicates that the login module should be ignored.
- If the **`LoginContext`**'s overall authentication succeeds, **`commit`** is invoked on each **`LoginModule`**. If phase 1 succeeds for a **`LoginModule`**, then the commit method continues with phase 2 and associates the relevant principals, public credentials, and/or private credentials with the subject. If phase 1 fails for a **`LoginModule`**, then **`commit`** removes any previously stored authentication state, such as user names or passwords. The signature of the **`commit`** method is: **`boolean commit() throws LoginException`** . Failure to complete the commit phase is indicated by throwing a **`LoginException`**. A return of true indicates that the method succeeded, whereas a return of false indicates that the login module should be ignored.

- If the **LoginContext**'s overall authentication fails, then the **abort** method is invoked on each **LoginModule**. The **abort** method removes or destroys any authentication state created by the login or initialize methods. The signature of the **abort** method is **boolean abort() throws LoginException** . Failure to complete the **abort** phase is indicated by throwing a **LoginException**. A return of true indicates that the method succeeded, whereas a return of false indicates that the login module should be ignored.
- To remove the authentication state after a successful login, the application invokes **logout** on the **LoginContext**. This in turn results in a **logout** method invocation on each **LoginModule**. The **logout** method removes the principals and credentials originally associated with the subject during the **commit** operation. Credentials should be destroyed upon removal. The signature of the **logout** method is: **boolean logout() throws LoginException** . Failure to complete the logout process is indicated by throwing a **LoginException**. A return of true indicates that the method succeeded, whereas a return of false indicates that the login module should be ignored.

When a **LoginModule** must communicate with the user to obtain authentication information, it uses a **CallbackHandler** object. Applications implement the CallbackHandler interface and pass it to the **LoginContext**, which send the authentication information directly to the underlying login modules.

Login modules use the **CallbackHandler** both to gather input from users, such as a password or smart card PIN, and to supply information to users, such as status information. By allowing the application to specify the **CallbackHandler**, underlying **LoginModule**s remain independent from the different ways applications interact with users. For example, a **CallbackHandler**'s implementation for a GUI application might display a window to solicit user input. On the other hand, a **CallbackHandler** implementation for a non-GUI environment, such as an application server, might simply obtain credential information by using an application server API. The CallbackHandler interface has one method to implement:

```
void handle(Callback[] callbacks)
    throws java.io.IOException,
           UnsupportedCallbackException;
```

The **Callback** interface is the last authentication class we will look at. This is a tagging interface for which several default implementations are provided, including the **NameCallback** and **PasswordCallback** used in an earlier example. A **LoginModule** uses a **Callback** to request information required by the authentication mechanism. **LoginModule**s pass an array of **Callback**s directly to the **CallbackHandler.handle** method during the authentication's login phase. If a **callbackhandler** does not understand how to use a **Callback** object passed into the handle method, it throws an **UnsupportedCallbackException** to abort the login call.

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8.6.4. Authorization Using a SecurityManager

In Red Hat JBoss Data Grid's Remote Client-Server mode, authorization is able to work without a SecurityManager for basic cache operations. In Library mode, a SecurityManager may also be used to perform some of the more complex tasks, such as distexec, map/reduce, and query.

In order to enforce access restrictions, enable the SecurityManager in your JVM using one of the following methods:

Command Line

```
java -Djava.security.manager ...
```

Programmaticaly

```
System.setSecurityManager(new SecurityManager());
```

Using the JDK's default implementation is not required, however an appropriate policy file must be supplied. The JBoss Data Grid distribution includes an example policy file, which demonstrates the permissions required by some of JBoss Data Grid's JAR files. These permissions must be integrated with those required by your application.

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8.6.5. Security Manager in Java

8.6.5.1. About the Java Security Manager

Java Security Manager

> The Java Security Manager is a class that manages the external boundary of the Java Virtual Machine (JVM) sandbox, controlling how code executing within the JVM can interact with resources outside the JVM. When the Java Security Manager is activated, the Java API checks with the security manager for approval before executing a wide range of potentially unsafe operations.

The Java Security Manager uses a security policy to determine whether a given action will be permitted or denied.

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8.6.5.2. About Java Security Manager Policies

Security Policy

> A set of defined permissions for different classes of code. The Java Security Manager compares actions requested by applications against the security policy. If an action is allowed by the policy, the Security Manager will permit that action to take place. If the action is not allowed by the policy, the Security Manager will deny that action. The security policy can define permissions based on the location of code, on the code's signature, or based on the subject's principals.

The Java Security Manager and the security policy used are configured using the Java Virtual Machine options **`java.security.manager`** and **`java.security.policy`**.

Basic Information

A security policy's entry consists of the following configuration elements, which are connected to the **`policytool`**:

CodeBase

> The URL location (excluding the host and domain information) where the code originates from. This parameter is optional.

SignedBy

The alias used in the keystore to reference the signer whose private key was used to sign the code. This can be a single value or a comma-separated list of values. This parameter is optional. If omitted, presence or lack of a signature has no impact on the Java Security Manager.

Principals

A list of ***principal_type*/*principal_name*** pairs, which must be present within the executing thread's principal set. The Principals entry is optional. If it is omitted, it signifies that the principals of the executing thread will have no impact on the Java Security Manager.

Permissions

A permission is the access which is granted to the code. Many permissions are provided as part of the Java Enterprise Edition 6 (Java EE 6) specification. This document only covers additional permissions which are provided by JBoss EAP 6.

Important

Refer to your container documentation on how to configure the security policy, as it may differ depending on the implementation.

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8.6.5.3. Write a Java Security Manager Policy

Introduction

An application called **`policytool`** is included with most JDK and JRE distributions, for the purpose of creating and editing Java Security Manager security policies. Detailed information about **`policytool`** is linked from http://docs.oracle.com/javase/6/docs/technotes/tools/.

Procedure 8.1. Setup a new Java Security Manager Policy

1. **Start `policytool`.**

   Start the **`policytool`** tool in one of the following ways.

   A. **Red Hat Enterprise Linux**

   From your GUI or a command prompt, run **`/usr/bin/policytool`**.

   B. **Microsoft Windows Server**

   Run **`policytool.exe`** from your Start menu or from the **`bin\`** of your Java installation. The location can vary.

2. **Create a policy.**

   To create a policy, select **`Add Policy Entry`**. Add the parameters you need, then click **`Done`**.

3. **Edit an existing policy**

Select the policy from the list of existing policies, and select the **Edit Policy Entry** button. Edit the parameters as needed.

4. **Delete an existing policy.**

   Select the policy from the list of existing policies, and select the **Remove Policy Entry** button.

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8.6.5.4. Run Red Hat JBoss Data Grid Server Within the Java Security Manager

To specify a Java Security Manager policy, you need to edit the Java options passed to the domain or server instance during the bootstrap process. For this reason, you cannot pass the parameters as options to the **domain.sh** or **standalone.sh** scripts. The following procedure guides you through the steps of configuring your instance to run within a Java Security Manager policy.

Prerequisites

- Before you following this procedure, you need to write a security policy, using the **policytool** command which is included with your Java Development Kit (JDK). This procedure assumes that your policy is located at ***JDG_HOME*/bin/server.policy**. As an alternative, write the security policy using any text editor and manually save it as ***JDG_HOME*/bin/server.policy**
- The domain or standalone server must be completely stopped before you edit any configuration files.

Perform the following procedure for each physical host or instance in your domain, if you have domain members spread across multiple systems.

Procedure 8.2. Configure the Security Manager for JBoss Data Grid Server

1. **Open the configuration file.**

   Open the configuration file for editing. This file is located in one of two places, depending on whether you use a managed domain or standalone server. This is not the executable file used to start the server or domain.

   A. **Managed Domain**

   - For Linux: ***JDG_HOME*/bin/domain.conf**
   - For Windows: ***JDG_HOME*\bin\domain.conf.bat**

   B. **Standalone Server**

   - For Linux: ***JDG_HOME*/bin/standalone.conf**
   - For Windows: ***JDG_HOME*\bin\standalone.conf.bat**

2. **Add the Java options to the file.**

   To ensure the Java options are used, add them to the code block that begins with:

   ```
   if [ "x$JAVA_OPTS" = "x" ]; then
   ```

   You can modify the **-Djava.security.policy** value to specify the exact location of your

security policy. It should go onto one line only, with no line break. Using **==** when setting the **-Djava.security.policy** property specifies that the security manager will use *only* the specified policy file. Using **=** specifies that the security manager will use the specified policy *combined with* the policy set in the **policy.url** section of ***JAVA_HOME*/lib/security/java.security**.

Important

JBoss Enterprise Application Platform releases from 6.2.2 onwards require that the system property **jboss.modules.policy-permissions** is set to *true*.

Example 8.8. domain.conf

```
JAVA_OPTS="$JAVA_OPTS -Djava.security.manager -
Djava.security.policy==$PWD/server.policy -
Djboss.home.dir=/path/to/JDG_HOME -Djboss.modules.policy-
permissions=true"
```

Example 8.9. domain.conf.bat

```
set "JAVA_OPTS=%JAVA_OPTS% -Djava.security.manager -
Djava.security.policy==\path\to\server.policy -
Djboss.home.dir=\path\to\JDG_HOME -Djboss.modules.policy-
permissions=true"
```

Example 8.10. standalone.conf

```
JAVA_OPTS="$JAVA_OPTS -Djava.security.manager -
Djava.security.policy==$PWD/server.policy -
Djboss.home.dir=$JBOSS_HOME -Djboss.modules.policy-
permissions=true"
```

Example 8.11. standalone.conf.bat

```
set "JAVA_OPTS=%JAVA_OPTS% -Djava.security.manager -
Djava.security.policy==\path\to\server.policy -
Djboss.home.dir=%JBOSS_HOME% -Djboss.modules.policy-
permissions=true"
```

3. **Start the domain or server.**

   Start the domain or server as normal.

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8.7. Data Security for Remote Client Server Mode

8.7.1. About Security Realms

A *security realm* is a series of mappings between users and passwords, and users and roles. Security realms are a mechanism for adding authentication and authorization to your EJB and Web applications. Red Hat JBoss Data Grid Server provides two security realms by default:

- **`ManagementRealm`** stores authentication information for the Management API, which provides the functionality for the Management CLI and web-based Management Console. It provides an authentication system for managing JBoss Data Grid Server itself. You could also use the **`ManagementRealm`** if your application needed to authenticate with the same business rules you use for the Management API.
- **`ApplicationRealm`** stores user, password, and role information for Web Applications and EJBs.

Each realm is stored in two files on the filesystem:

- ***`REALM`*`-users.properties`** stores usernames and hashed passwords.
- ***`REALM`*`-roles.properties`** stores user-to-role mappings.
- **`mgmt-groups.properties`** stores user-to-role mapping file for **`ManagementRealm`**.

The properties files are stored in the **`domain/configuration/`** and **`standalone/configuration/`** directories. The files are written simultaneously by the **`add-user.sh`** or **`add-user.bat`** command. When you run the command, the first decision you make is which realm to add your new user to.

Report a bug

8.7.2. Add a New Security Realm

1. **Run the Management CLI.**

   Start the **`cli.sh`** or **`cli.bat`** command and connect to the server.

2. **Create the new security realm itself.**

   Run the following command to create a new security realm named **`MyDomainRealm`** on a domain controller or a standalone server.

   ```
   /host=master/core-service=management/security-
   realm=MyDomainRealm:add()
   ```

3. **Create the references to the properties file which will store information about the new role.**

   Run the following command to create a pointer a file named **`myfile.properties`**, which will contain the properties pertaining to the new role.

Note

The newly-created properties file is not managed by the included **`add-user.sh`** and **`add-user.bat`** scripts. It must be managed externally.

```
/host=master/core-service=management/security-
realm=MyDomainRealm/authentication=properties:add(path=myfile.prope
rties)
```

Result

Your new security realm is created. When you add users and roles to this new realm, the information will be stored in a separate file from the default security realms. You can manage this new file using your own applications or procedures.

Report a bug

8.7.3. Add a User to a Security Realm

1. **Run the `add-user.sh` or `add-user.bat` command.**

   Open a terminal and change directories to the ***`JDG_HOME`*`/bin/`** directory. If you run Red Hat Enterprise Linux or another UNIX-like operating system, run **`add-user.sh`**. If you run Microsoft Windows Server, run **`add-user.bat`**.

2. **Choose whether to add a Management User or Application User.**

   For this procedure, type **b** to add an Application User.

3. **Choose the realm the user will be added to.**

   By default, the only available realm is **`ApplicationRealm`**. If you have added a custom realm, you can type its name instead.

4. **Type the username, password, and roles, when prompted.**

   Type the desired username, password, and optional roles when prompted. Verify your choice by typing **yes**, or type **no** to cancel the changes. The changes are written to each of the properties files for the security realm.

Report a bug

8.7.4. Configuring Security Realms Declaratively

In Remote Client-Server mode, a Hot Rod endpoint must specify a security realm.

The security realm declares an ***`authentication`*** and an ***`authorization`*** section.

Example 8.12. Configuring Security Realms Declaratively

```
<security-realms>
            <security-realm name="ManagementRealm">
                <authentication>
                    <local default-user="$local" skip-group-
loading="true"/>
                    <properties path="mgmt-users.properties" relative-
to="jboss.server.config.dir"/>
                </authentication>
                <authorization map-groups-to-roles="false">
                    <properties path="mgmt-groups.properties"
```

```
relative-to="jboss.server.config.dir"/>
                </authorization>
            </security-realm>
            <security-realm name="ApplicationRealm">
                <authentication>
                    <local default-user="$local" allowed-users="*"
skip-group-loading="true"/>
                    <properties path="application-users.properties"
relative-to="jboss.server.config.dir"/>
                </authentication>
                <authorization>
                    <properties path="application-roles.properties"
relative-to="jboss.server.config.dir"/>
                </authorization>
            </security-realm>
        </security-realms>
```

The ***server-identities*** parameter can also be used to specify certificates.

Report a bug

8.7.5. Loading Roles from LDAP for Authorization (Remote Client-Server Mode)

An LDAP directory contains entries for user accounts and groups, cross referenced by attributes. Depending on the LDAP server configuration, a user entity may map the groups the user belongs to through **memberOf** attributes; a group entity may map which users belong to it through **uniqueMember** attributes; or both mappings may be maintained by the LDAP server.

Users generally authenticate against the server using a simple user name. When searching for group membership information, depending on the directory server in use, searches could be performed using this simple name or using the distinguished name of the user's entry in the directory.

The authentication step of a user connecting to the server always happens first. Once the user is successfully authenticated the server loads the user's groups. The authentication step and the authorization step each require a connection to the LDAP server. The realm optimizes this process by reusing the authentication connection for the group loading step. As will be shown within the configuration steps below it is possible to define rules within the authorization section to convert a user's simple user name to their distinguished name. The result of a "user name to distinguished name mapping" search during authentication is cached and reused during the authorization query when the **force** attribute is set to "false". When **force** is true, the search is performed again during authorization (while loading groups). This is typically done when different servers perform authentication and authorization.

```
<authorization>
    <ldap connection="...">
     <!-- OPTIONAL -->
       <username-to-dn force="true">
           <!-- Only one of the following. -->
           <username-is-dn />
           <username-filter base-dn="..." recursive="..." user-dn-
attribute="..." attribute="..." />
           <advanced-filter base-dn="..." recursive="..." user-dn-
attribute="..." filter="..." />
        </username-to-dn>
```

```
       <group-search group-name="..." iterative="..." group-dn-
attribute="..." group-name-attribute="..." >
           <!-- One of the following -->
           <group-to-principal base-dn="..." recursive="..." search-
by="...">
               <membership-filter principal-attribute="..." />
           </group-to-principal>
           <principal-to-group group-attribute="..." />
       </group-search>
    </ldap>
</authorization>
```

Important

These examples specify some attributes with their default values. This is done for demonstration. Attributes that specify their default values are removed from the configuration when it is persisted by the server. The exception is the **`force`** attribute. It is required, even when set to the default value of **`false`**.

username-to-dn

The **`username-to-dn`** element specifies how to map the user name to the distinguished name of their entry in the LDAP directory. This element is only required when *both* of the following are true:

- The authentication and authorization steps are against different LDAP servers.
- The group search uses the distinguished name.

1:1 username-to-dn

This specifies that the user name entered by the remote user is the user's distinguished name.

```
<username-to-dn force="false">
   <username-is-dn />
</username-to-dn>
```

This defines a 1:1 mapping and there is no additional configuration.

username-filter

The next option is very similar to the simple option described above for the authentication step. A specified attribute is searched for a match against the supplied user name.

```
<username-to-dn force="true">
    <username-filter base-
dn="dc=people,dc=harold,dc=example,dc=com" recursive="false"
attribute="sn" user-dn-attribute="dn" />
</username-to-dn>
```

The attributes that can be set here are:

- **`base-dn`**: The distinguished name of the context to begin the search.

- **recursive**: Whether the search will extend to sub contexts. Defaults to **false**.
- **attribute**: The attribute of the users entry to try and match against the supplied user name. Defaults to **uid**.
- **user-dn-attribute**: The attribute to read to obtain the users distinguished name. Defaults to **dn**.

advanced-filter

The final option is to specify an advanced filter, as in the authentication section this is an opportunity to use a custom filter to locate the users distinguished name.

```
<username-to-dn force="true">
    <advanced-filter base-
dn="dc=people,dc=harold,dc=example,dc=com" recursive="false"
filter="sAMAccountName={0}" user-dn-attribute="dn" />
</username-to-dn>
```

For the attributes that match those in the *username-filter* example, the meaning and default values are the same. There is one new attribute:

- **filter**: Custom filter used to search for a user's entry where the user name will be substituted in the **{0}** place holder.

Important

The XML must remain valid after the filter is defined so if any special characters are used such as **&** ensure the proper form is used. For example **&** for the **&** character.

The Group Search

There are two different styles that can be used when searching for group membership information. The first style is where the user's entry contains an attribute that references the groups the user is a member of. The second style is where the group contains an attribute referencing the users entry.

When there is a choice of which style to use Red Hat recommends that the configuration for a user's entry referencing the group is used. This is because with this method group information can be loaded by reading attributes of known distinguished names without having to perform any searches. The other approach requires extensive searches to identify the groups that reference the user.

Before describing the configuration here are some LDIF examples to illustrate this.

Example 8.13. Principal to Group - LDIF example.

This example illustrates where we have a user **TestUserOne** who is a member of **GroupOne**, **GroupOne** is in turn a member of **GroupFive**. The group membership is shown by the use of a **memberOf** attribute which is set to the distinguished name of the group of which the user (or group) is a member.

It is not shown here but a user could potentially have multiple **memberOf** attributes set, one for each group of which the user is directly a member.

```
dn: uid=TestUserOne,ou=users,dc=principal-to-group,dc=example,dc=org
objectClass: extensibleObject
objectClass: top
objectClass: groupMember
objectClass: inetOrgPerson
objectClass: uidObject
objectClass: person
objectClass: organizationalPerson
cn: Test User One
sn: Test User One
uid: TestUserOne
distinguishedName: uid=TestUserOne,ou=users,dc=principal-to-
group,dc=example,dc=org
memberOf: uid=GroupOne,ou=groups,dc=principal-to-
group,dc=example,dc=org
memberOf: uid=Slashy/Group,ou=groups,dc=principal-to-
group,dc=example,dc=org
userPassword::
e1NTSEF9WFpURzhLVjc4WVZBQUJNbEI3Ym96UVAva0RTNlFNWUpLOTdTMUE9PQ==

dn: uid=GroupOne,ou=groups,dc=principal-to-group,dc=example,dc=org
objectClass: extensibleObject
objectClass: top
objectClass: groupMember
objectClass: group
objectClass: uidObject
uid: GroupOne
distinguishedName: uid=GroupOne,ou=groups,dc=principal-to-
group,dc=example,dc=org
memberOf: uid=GroupFive,ou=subgroups,ou=groups,dc=principal-to-
group,dc=example,dc=org

dn: uid=GroupFive,ou=subgroups,ou=groups,dc=principal-to-
group,dc=example,dc=org
objectClass: extensibleObject
objectClass: top
objectClass: groupMember
objectClass: group
objectClass: uidObject
uid: GroupFive
distinguishedName: uid=GroupFive,ou=subgroups,ou=groups,dc=principal-
to-group,dc=example,dc=org
```

Example 8.14. Group to Principal - LDIF Example

This example shows the same user **`TestUserOne`** who is a member of **`GroupOne`** which is in turn a member of **`GroupFive`** - however in this case it is an attribute **`uniqueMember`** from the group to the user being used for the cross reference.

Again the attribute used for the group membership cross reference can be repeated, if you look at *GroupFive* there is also a reference to another user *TestUserFive* which is not shown here.

```
dn: uid=TestUserOne,ou=users,dc=group-to-principal,dc=example,dc=org
objectClass: top
objectClass: inetOrgPerson
```

```
objectClass: uidObject
objectClass: person
objectClass: organizationalPerson
cn: Test User One
sn: Test User One
uid: TestUserOne
userPassword::
e1NTSEF9SjR0OTRDR1ltaHc1VVZQOEJvbXhUYjl1dkFVd1lQTmRLSEdzaWc9PQ==

dn: uid=GroupOne,ou=groups,dc=group-to-principal,dc=example,dc=org
objectClass: top
objectClass: groupOfUniqueNames
objectClass: uidObject
cn: Group One
uid: GroupOne
uniqueMember: uid=TestUserOne,ou=users,dc=group-to-
principal,dc=example,dc=org

dn: uid=GroupFive,ou=subgroups,ou=groups,dc=group-to-
principal,dc=example,dc=org
objectClass: top
objectClass: groupOfUniqueNames
objectClass: uidObject
cn: Group Five
uid: GroupFive
uniqueMember: uid=TestUserFive,ou=users,dc=group-to-
principal,dc=example,dc=org
uniqueMember: uid=GroupOne,ou=groups,dc=group-to-
principal,dc=example,dc=org
```

General Group Searching

Before looking at the examples for the two approaches shown above we first need to define the attributes common to both of these.

```
<group-search group-name="..." iterative="..." group-dn-attribute="..."
group-name-attribute="..." >
    ...
</group-search>
```

- **`group-name`**: This attribute is used to specify the form that should be used for the group name returned as the list of groups of which the user is a member. This can either be the simple form of the group name or the group's distinguished name. If the distinguished name is required this attribute can be set to **`DISTINGUISHED_NAME`**. Defaults to **`SIMPLE`**.
- **`iterative`**: This attribute is used to indicate if, after identifying the groups a user is a member of, we should also iteratively search based on the groups to identify which groups the groups are a member of. If iterative searching is enabled we keep going until either we reach a group that is not a member if any other groups or a cycle is detected. Defaults to **`false`**.

Cyclic group membership is not a problem. A record of each search is kept to prevent groups that have already been searched from being searched again.

Important

For iterative searching to work the group entries need to look the same as user entries. The same approach used to identify the groups a user is a member of is then used to identify the groups of which the group is a member. This would not be possible if for group to group membership the name of the attribute used for the cross reference changes or if the direction of the reference changes.

- **`group-dn-attribute`**: On an entry for a group which attribute is its distinguished name. Defaults to **`dn`**.
- **`group-name-attribute`**: On an entry for a group which attribute is its simple name. Defaults to **`uid`**.

Example 8.15. Principal to Group Example Configuration

Based on the example LDIF from above here is an example configuration iteratively loading a user's groups where the attribute used to cross reference is the **`memberOf`** attribute on the user.

```
<authorization>
    <ldap connection="LocalLdap">
        <username-to-dn>
            <username-filter base-dn="ou=users,dc=principal-to-
group,dc=example,dc=org" recursive="false" attribute="uid" user-dn-
attribute="dn" />
        </username-to-dn>
        <group-search group-name="SIMPLE" iterative="true" group-dn-
attribute="dn" group-name-attribute="uid">
            <principal-to-group group-attribute="memberOf" />
        </group-search>
    </ldap>
</authorization>
```

The most important aspect of this configuration is that the **`principal-to-group`** element has been added with a single attribute.

- **`group-attribute`**: The name of the attribute on the user entry that matches the distinguished name of the group the user is a member of. Defaults to **`memberOf`**.

Example 8.16. Group to Principal Example Configuration

This example shows an iterative search for the group to principal LDIF example shown above.

```
<authorization>
      <ldap connection="LocalLdap">
          <username-to-dn>
              <username-filter base-dn="ou=users,dc=group-to-
principal,dc=example,dc=org" recursive="false" attribute="uid" user-dn-
attribute="dn" />
          </username-to-dn>
          <group-search group-name="SIMPLE" iterative="true" group-dn-
attribute="dn" group-name-attribute="uid">
```

```
            <group-to-principal base-dn="ou=groups,dc=group-to-
principal,dc=example,dc=org" recursive="true" search-
by="DISTINGUISHED_NAME">
                <membership-filter principal-
attribute="uniqueMember" />
            </group-to-principal>
          </group-search>
      </ldap>
  </authorization>
```

Here an element **`group-to-principal`** is added. This element is used to define how searches for groups that reference the user entry will be performed. The following attributes are set:

- **`base-dn`**: The distinguished name of the context to use to begin the search.
- **`recursive`**: Whether sub-contexts also be searched. Defaults to **`false`**.
- **`search-by`**: The form of the role name used in searches. Valid values are **`SIMPLE`** and **`DISTINGUISHED_NAME`**. Defaults to **`DISTINGUISHED_NAME`**.

Within the *group-to-principal* element there is a *membership-filter* element to define the cross reference.

- **`principal-attribute`**: The name of the attribute on the group entry that references the user entry. Defaults to **`member`**.

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8.7.6. Hot Rod Interface Security

8.7.6.1. Publish Hot Rod Endpoints as a Public Interface

Red Hat JBoss Data Grid's Hot Rod server operates as a management interface as a default. To extend its operations to a public interface, alter the value of the ***`interface`*** parameter in the **`socket-binding`** element from **`management`** to **`public`** as follows:

```
<socket-binding name="hotrod" interface="public" port="11222" />
```

Report a bug

8.7.6.2. Encryption of communication between Hot Rod Server and Hot Rod client

Hot Rod can be encrypted using TLS/SSL, and has the option to require certificate-based client authentication.

Use the following procedure to secure the Hot Rod connector using SSL.

Procedure 8.3. Secure Hot Rod Using SSL/TLS

1. **Generate a Keystore**

   Create a Java Keystore using the keytool application distributed with the JDK and add your certificate to it. The certificate can be either self signed, or obtained from a trusted CA depending on your security policy.

2. **Place the Keystore in the Configuration Directory**

Put the keystore in the **~/JDG_HOME/standalone/configuration** directory with the **standalone-hotrod-ssl.xml** file from the **~/JDG_HOME/docs/examples/configs** directory.

3. **Declare an SSL Server Identity**

   Declare an SSL server identity within a security realm in the management section of the configuration file. The SSL server identity must specify the path to a keystore and its secret key.

```
<server-identities>
  <ssl protocol="...">
    <keystore path="..." relative-to="..." keystore-
password="${VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::ENCRYPTED_VALUE}"
/>
  </ssl>
  <secret value="..." />
</server-identities>
```

   See Section 8.7.7.4, “Configure Hot Rod Authentication (X.509)” for details about these parameters.

4. **Add the Security Element**

   Add the security element to the Hot Rod connector as follows:

```
<hotrod-connector socket-binding="hotrod" cache-container="local">
    <encryption ssl="true" security-realm="ApplicationRealm"
require-ssl-client-auth="false" />
</hotrod-connector>
```

   a. **Server Authentication of Certificate**

      If you require the server to perform authentication of the client certificate, create a truststore that contains the valid client certificates and set the ***require-ssl-client-auth*** attribute to **true**.

5. **Start the Server**

   Start the server using the following:

```
bin/standalone.sh -c standalone-hotrod-ssl.xml
```

   This will start a server with a Hot Rod endpoint on port 11222. This endpoint will only accept SSL connections.

Securing Hot Rod using SSL can also be configured programmatically.

Example 8.17. Secure Hot Rod Using SSL/TLS

```
package org.infinispan.client.hotrod.configuration;

import java.util.Arrays;
```

```
import javax.net.ssl.KeyManager;
import javax.net.ssl.SSLContext;
import javax.net.ssl.TrustManager;

public class SslConfiguration {
 private final boolean enabled;
 private final String keyStoreFileName;
 private final char[]
VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::keyStorePassword;
 private final SSLContext sslContext;
 private final String trustStoreFileName;
 private final char[]
VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::trustStorePassword;

 SslConfiguration(boolean enabled, String keyStoreFileName, char[]
keyStorePassword, SSLContext sslContext, String trustStoreFileName,
char[] trustStorePassword) {
  this.enabled = enabled;
  this.keyStoreFileName = keyStoreFileName;
  this.keyStorePassword =
VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::keyStorePassword;
  this.sslContext = sslContext;
  this.trustStoreFileName = trustStoreFileName;
  this.trustStorePassword =
VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::trustStorePassword;
 }

 public boolean enabled() {
  return enabled;
 }

 public String keyStoreFileName() {
  return keyStoreFileName;
 }

 public char[] keyStorePassword() {
  return keyStorePassword;
 }

 public SSLContext sslContext() {
  return sslContext;
 }

 public String trustStoreFileName() {
  return trustStoreFileName;
 }

 public char[] trustStorePassword() {
  return trustStorePassword;
 }

 @Override
 public String toString() {
  return "SslConfiguration [enabled=" + enabled + ", keyStoreFileName="
   + keyStoreFileName + ", sslContext=" + sslContext + ",
```

```
trustStoreFileName=" + trustStoreFileName + "]";
 }
}
```

Important

To prevent plain text passwords from appearing in configurations or source codes, plain text passwords should be changed to Vault passwords. For more information about how to set up Vault passwords, see the *Red Hat Enterprise Application Platform Security Guide*.

Report a bug

8.7.6.3. Securing Hot Rod to LDAP Server using SSL

When connecting to an LDAP server with SSL enabled it may be necessary to specify a trust store or key store containing the appropriate certificates.

Section 8.7.6.2, “Encryption of communication between Hot Rod Server and Hot Rod client” describes how to set up SSL for Hot Rod client-server communication. This can be used, for example, for secure Hot Rod client authentication with **PLAIN** username/password. When the username/password is checked against credentials in LDAP, a secure connection from the Hot Rod server to the LDAP server is also required. To enable connection from the Hot Rod server to LDAP via SSL, a security realm must be defined as follows:

Example 8.18. Hot Rod Client Authentication to LDAP Server

```
<management>
        <security-realms>
            <security-realm name="LdapSSLRealm">
                <authentication>
                    <truststore  path="ldap.truststore" relative-
to="jboss.server.config.dir" keystore-
password=${VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::ENCRYPTED_VALUE} />
                </authentication>
            </security-realm>
        </security-realms>
        <outbound-connections>
            <ldap name="LocalLdap" url="ldaps://localhost:10389"
search-dn="uid=wildfly,dc=simple,dc=wildfly,dc=org" search-
credential="secret" security-realm="LdapSSLRealm" />
        </outbound-connections>
    </management>
```

Example 8.19. Hot Rod Client Authentication to LDAP Server

```
public class HotRodPlainAuthLdapOverSslIT extends
HotRodSaslAuthTestBase {
 private static final String KEYSTORE_NAME = "keystore_client.jks";
```

```
 private static final String KEYSTORE_PASSWORD =
"VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::ENCRYPTED_VALUE";

 private static ApacheDsLdap ldap;

 @InfinispanResource("hotrodAuthLdapOverSsl")
 private RemoteInfinispanServer server;

 @BeforeClass
 public static void kerberosSetup() throws Exception {
  ldap = new ApacheDSLdapSSL("localhost", ITestUtils.SERVER_CONFIG_DIR
+ File.separator + KEYSTORE_NAME, KEYSTORE_PASSWORD);
  ldap.start();
 }

 @AfterClass
 public static void ldapTearDown() throws Exception {
  ldap.stop();
 }

 @Override
 public String getTestedMech() {
  return "PLAIN";
 }

 @Override
 public RemoteInfinispanServer getRemoteServer() {
  return server;
 }

 @Override
 public void initAsAdmin() {
  initializeOverSsl(ADMIN_LOGIN, ADMIN_PASSWD);
 }

 @Override
 public void initAsReader() {
  initializeOverSsl(READER_LOGIN, READER_PASSWD);
 }

 @Override
 public void initAsWriter() {
  initializeOverSsl(WRITER_LOGIN, WRITER_PASSWD);
 }

 @Override
 public void initAsSupervisor() {
  initializeOverSsl(SUPERVISOR_LOGIN, SUPERVISOR_PASSWD);
 }
}
```

Important

To prevent plain text passwords from appearing in configurations or source codes, plain text passwords should be changed to Vault passwords. For more information about how to set up Vault passwords, see the *Red Hat Enterprise Application Platform Security Guide*.

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8.7.7. User Authentication over Hot Rod Using SASL

User authentication over Hot Rod can be implemented using the following Simple Authentication and Security Layer (SASL) mechanisms:

- **PLAIN** is the least secure mechanism because credentials are transported in plain text format. However, it is also the simplest mechanism to implement. This mechanism can be used in conjunction with encryption (SSL) for additional security.
- **DIGEST-MD5** is a mechanism than hashes the credentials before transporting them. As a result, it is more secure than the **PLAIN** mechanism.
- **GSSAPI** is a mechanism that uses Kerberos tickets. As a result, it requires a correctly configured Kerberos Domain Controller (for example, Microsoft Active Directory).
- **EXTERNAL** is a mechanism that obtains the required credentials from the underlying transport (for example, from a **X.509** client certificate) and therefore requires client certificate encryption to work correctly.

Report a bug

8.7.7.1. Configure Hot Rod Authentication (GSSAPI/Kerberos)

Use the following steps to set up Hot Rod Authentication using the SASL GSSAPI/Kerberos mechanism:

Procedure 8.4. Configure SASL GSSAPI/Kerberos Authentication

1. **Server-side Configuration**

   The following steps must be configured on the server-side:

   a. Define a Kerberos security login module using the security domain subsystem:

```
<system-properties>
    <property name="java.security.krb5.conf"
value="/tmp/infinispan/krb5.conf"/>
    <property name="java.security.krb5.debug" value="true"/>
    <property name="jboss.security.disable.secdomain.option"
value="true"/>
</system-properties>

<security-domain name="infinispan-server" cache-
type="default">
    <authentication>
        <login-module code="Kerberos" flag="required">
            <module-option name="debug" value="true"/>
```

```
            <module-option name="storeKey" value="true"/>
            <module-option name="refreshKrb5Config"
value="true"/>
            <module-option name="useKeyTab" value="true"/>
            <module-option name="doNotPrompt" value="true"/>
            <module-option name="keyTab"
value="/tmp/infinispan/infinispan.keytab"/>
            <module-option name="principal"
value="HOTROD/localhost@INFINISPAN.ORG"/>
        </login-module>
    </authentication>
</security-domain>
```

b. Configure a Hot Rod connector as follows:

```
<hotrod-connector socket-binding="hotrod"
    cache-container="default">
 <authentication security-realm="ApplicationRealm">
  <sasl server-name="node0"
        mechanisms="{mechanism_name}"
        qop="{qop_name}"
        strength="{value}">
   <policy>
    <no-anonymous value="true" />
   </policy>
   <property
name="com.sun.security.sasl.digest.utf8">true</property>
  </sasl>
  </authentication>
</hotrod-connector>
```

- The ***server-name*** attribute specifies the name that the server declares to incoming clients. The client configuration must also contain the same server name value.
- The ***server-context-name*** attribute specifies the name of the login context used to retrieve a server subject for certain SASL mechanisms (for example, GSSAPI).
- The ***mechanisms*** attribute specifies the authentication mechanism in use. See Section 8.7.7, “User Authentication over Hot Rod Using SASL” for a list of supported mechanisms.
- The ***qop*** attribute specifies the SASL quality of protection value for the configuration. Supported values for this attribute are **auth** (authentication), **auth-int** (authentication and integrity, meaning that messages are verified against checksums to detect tampering), and **auth-conf** (authentication, integrity, and confidentiality, meaning that messages are also encrypted). Multiple values can be specified, for example, **auth-int auth-conf**. The ordering implies preference, so the first value which matches both the client and server's preference is chosen.
- The ***strength*** attribute specifies the SASL cipher strength. Valid values are **low**, **medium**, and **high**.
- The **no-anonymous** element within the **policy** element specifies whether mechanisms that accept anonymous login are permitted. Set this value to **false** to permit and **true** to deny.

2. **Client-side Configuration**

The following steps must be configured on the client-side:

a. Define a login module in a login configuration file (**gss.conf**) on the client side:

```
GssExample {
    com.sun.security.auth.module.Krb5LoginModule required
client=TRUE;
};
```

b. Set up the following system properties:

```
java.security.auth.login.config=gss.conf
java.security.krb5.conf=/etc/krb5.conf
```

Note

The **krb5.conf** file is dependent on the environment and must point to the Kerberos Key Distribution Center.

c. Configure the Hot Rod Client:

```
public class MyCallbackHandler implements CallbackHandler {
   final private String username;
   final private char[] password;
   final private String realm;

   public MyCallbackHandler() { }

   public MyCallbackHandler (String username, String realm,
char[] password) {
      this.username = username;
      this.password = password;
      this.realm = realm;
   }

   @Override
   public void handle(Callback[] callbacks) throws
IOException, UnsupportedCallbackException {
      for (Callback callback : callbacks) {
         if (callback instanceof NameCallback) {
            NameCallback nameCallback = (NameCallback)
callback;
            nameCallback.setName(username);
         } else if (callback instanceof PasswordCallback) {
            PasswordCallback passwordCallback =
(PasswordCallback) callback;
            passwordCallback.setPassword(password);
         } else if (callback instanceof AuthorizeCallback) {
            AuthorizeCallback authorizeCallback =
(AuthorizeCallback) callback;
```

```
authorizeCallback.setAuthorized(authorizeCallback.getAuthenti
cationID().equals(
                  authorizeCallback.getAuthorizationID()));
         } else if (callback instanceof RealmCallback) {
            RealmCallback realmCallback = (RealmCallback)
callback;
            realmCallback.setText(realm);
         } else {
            throw new UnsupportedCallbackException(callback);
         }
      }
   }}
LoginContext lc = new LoginContext("GssExample", new
MyCallbackHandler("krb_user",
"krb_password".toCharArra()));lc.login();Subject
clientSubject = lc.getSubject();

ConfigurationBuilder clientBuilder = new
ConfigurationBuilder();clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .socketTimeout(1200000)
    .security()
        .authentication()
            .enable()
            .serverName("infinispan-server")
            .saslMechanism("GSSAPI")
            .clientSubject(clientSubject)
            .callbackHandler(new
MyCallbackHandler());remoteCacheManager = new
RemoteCacheManager(clientBuilder.build());RemoteCache<String,
String> cache = remoteCacheManager.getCache("secured");
```

Report a bug

8.7.7.2. Configure Hot Rod Authentication (MD5)

Use the following steps to set up Hot Rod Authentication using the SASL using the MD5 mechanism:

Procedure 8.5. Configure Hot Rod Authentication (MD5)

1. Set up the Hot Rod Connector configuration by adding the **`sasl`** element to the **`authentication`** element (for details on the **`authentication`** element, see Section 8.7.4, "Configuring Security Realms Declaratively") as follows:

```
<hotrod-connector socket-binding="hotrod"
                          cache-container="default">
    <authentication security-realm="ApplicationRealm">
        <sasl server-name="myhotrodserver"
              mechanisms="DIGEST-MD5"
              qop="auth" />
    </authentication>
</hotrod-connector>
```

- The ***server-name*** attribute specifies the name that the server declares to incoming clients. The client configuration must also contain the same server name value.
- The ***mechanisms*** attribute specifies the authentication mechanism in use. See Section 8.7.7, "User Authentication over Hot Rod Using SASL" for a list of supported mechanisms.
- The ***qop*** attribute specifies the SASL quality of production value for the configuration. Supported values for this attribute are **auth**, **auth-int**, and **auth-conf**.

2. Connect the client to the configured Hot Rod connector as follows:

```
public class MyCallbackHandler implements CallbackHandler {
   final private String username;
   final private char[] password;
   final private String realm;

   public MyCallbackHandler (String username, String realm, char[]
password) {
      this.username = username;
      this.password = password;
      this.realm = realm;
   }

   @Override
   public void handle(Callback[] callbacks) throws IOException,
UnsupportedCallbackException {
      for (Callback callback : callbacks) {
         if (callback instanceof NameCallback) {
            NameCallback nameCallback = (NameCallback) callback;
            nameCallback.setName(username);
         } else if (callback instanceof PasswordCallback) {
            PasswordCallback passwordCallback = (PasswordCallback)
callback;
            passwordCallback.setPassword(password);
         } else if (callback instanceof AuthorizeCallback) {
            AuthorizeCallback authorizeCallback =
(AuthorizeCallback) callback;

authorizeCallback.setAuthorized(authorizeCallback.getAuthentication
ID().equals(
                  authorizeCallback.getAuthorizationID()));
         } else if (callback instanceof RealmCallback) {
            RealmCallback realmCallback = (RealmCallback) callback;
            realmCallback.setText(realm);
         } else {
            throw new UnsupportedCallbackException(callback);
         }
      }
   }}
ConfigurationBuilder clientBuilder = new
ConfigurationBuilder();clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .socketTimeout(1200000)
    .security()
```

```
        .authentication()
            .enable()
            .serverName("myhotrodserver")
            .saslMechanism("DIGEST-MD5")
            .callbackHandler(new MyCallbackHandler("myuser",
"ApplicationRealm", "qwer1234!".toCharArray()));remoteCacheManager
= new
RemoteCacheManager(clientBuilder.build());RemoteCache<String,
String> cache = remoteCacheManager.getCache("secured");
```

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8.7.7.3. Configure Hot Rod Using LDAP/Active Directory

Use the following to configure authentication over Hot Rod using LDAP or Microsoft Active Directory:

```
<security-realms>
 <security-realm name="ApplicationRealm">
  <authentication>
   <ldap connection="ldap_connection"
         recursive="true"
         base-dn="cn=users,dc=infinispan,dc=org">
    <username-filter attribute="cn" />
   </ldap>
  </authentication>
 </security-realm>
</security-realms>
<outbound-connections>
 <ldap name="ldap_connection"
       url="ldap://my_ldap_server"
       search-dn="CN=test,CN=Users,DC=infinispan,DC=org"
       search-credential="Test_password"/>
</outbound-connections>
```

The following are some details about the elements and parameters used in this configuration:

- The **`security-realm`** element's ***`name`*** parameter specifies the security realm to reference to use when establishing the connection.
- The **`authentication`** element contains the authentication details.
- The **`ldap`** element specifies how LDAP searches are used to authenticate a user. First, a connection to LDAP is established and a search is conducted using the supplied user name to identify the distinguished name of the user. A subsequent connection to the server is established using the password supplied by the user. If the second connection succeeds, the authentication is a success.
  - The ***`connection`*** parameter specifies the name of the connection to use to connect to LDAP.
  - The (optional) ***`recursive`*** parameter specifies whether the filter is executed recursively. The default value for this parameter is **`false`**.
  - The ***`base-dn`*** parameter specifies the distinguished name of the context to use to begin the search from.
  - The (optional) ***`user-dn`*** parameter specifies which attribute to read for the user's distinguished name after the user is located. The default value for this parameter is **`dn`**.

- The **outbound-connections** element specifies the name of the connection used to connect to the LDAP. directory.
- The **ldap** element specifies the properties of the outgoing LDAP connection.
  - The ***name*** parameter specifies the unique name used to reference this connection.
  - The ***url*** parameter specifies the URL used to establish the LDAP connection.
  - The ***search-dn*** parameter specifies the distinguished name of the user to authenticate and to perform the searches.
  - The ***search-credential*** parameter specifies the password required to connect to LDAP as the ***search-dn***.
  - The (optional) ***initial-context-factory*** parameter allows the overriding of the initial context factory. the default value of this parameter is **com.sun.jndi.ldap.LdapCtxFactory**.

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8.7.7.4. Configure Hot Rod Authentication (X.509)

The **X.509** certificate can be installed at the node, and be made available to other nodes for authentication purposes for inbound and outbound SSL connections. This is enabled using the ***<server-identities/>*** element of a security realm definition, which defines how a server appears to external applications. This element can be used to configure a password to be used when establishing a remote connection, as well as the loading of an **X.509** key.

The following example shows how to install an **X.509** certificate on the node.

```
<security-realm name="ApplicationRealm">
  <server-identities>
    <ssl protocol="...">
      <keystore path="..." relative-to="..." keystore-password="..."
alias="..." key-password="..." />
    </ssl>
  </server-identities>

  [... authentication/authorization ...]

 </security-realms>
```

In the provided example, the SSL element contains the <keystore/> element, which is used to define how to load the key from the file-based keystore. The following parameters ave available for this element.

Table 8.4. <server-identities/> Options

Parameter	Mandatory/Optional	Description
path	Mandatory	This is the path to the keystore, this can be an absolute path or relative to the next attribute.
relative-to	Optional	The name of a service representing a path the keystore is relative to.

Parameter	Mandatory/Optional	Description
keystore-password	Mandatory	The password required to open the keystore.
alias	Optional	The alias of the entry to use from the keystore - for a keystore with multiple entries in practice the first usable entry is used but this should not be relied on and the alias should be set to guarantee which entry is used.
key-password	Optional	The password to load the key entry, if omitted the keystore-password will be used instead.

Note

If the following error occurs, specify a ***key-password*** as well as an ***alias*** to ensure only one key is loaded.

```
UnrecoverableKeyException: Cannot recover key
```

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8.8. Active Directory Authentication (Non-Kerberos)

See Example 8.2, “Example of JBoss EAP LDAP login module configuration” for a non-Kerberos Active Directory Authentication configuration example.

Report a bug

8.9. Active Directory Authentication Using Kerberos (GSSAPI)

When using Red Hat JBoss Data Grid with Microsoft Active Directory, data security can be enabled via Kerberos authentication. To configure Kerberos authentication for Microsoft Active Directory, use the following procedure.

Procedure 8.6. Configure Kerberos Authentication for Active Directory (Library Mode)

1. Configure JBoss EAP server to authenticate itself to Kerberos. This can be done by configuring a dedicated security domain, for example:

```
<security-domain name="ldap-service" cache-type="default">
    <authentication>
        <login-module code="Kerberos" flag="required">
            <module-option name="storeKey" value="true"/>
            <module-option name="useKeyTab" value="true"/>
            <module-option name="refreshKrb5Config" value="true"/>
            <module-option name="principal"
value="ldap/localhost@INFINISPAN.ORG"/>
```

```
            <module-option name="keyTab"
value="${basedir}/keytab/ldap.keytab"/>
            <module-option name="doNotPrompt" value="true"/>
        </login-module>
    </authentication>
</security-domain>
```

2. The security domain for authentication must be configured correctly for JBoss EAP, an application must have a valid Kerberos ticket. To initiate the Kerberos ticket, you must reference another security domain using

```
<module-option name="usernamePasswordDomain" value="krb-admin"/>
```

. This points to the standard Kerberos login module described in Step 3.

```
<security-domain name="ispn-admin" cache-type="default">
    <authentication>
        <login-module code="SPNEGO" flag="requisite">
            <module-option name="password-stacking"
value="useFirstPass"/>
            <module-option name="serverSecurityDomain"
value="ldap-service"/>
            <module-option name="usernamePasswordDomain"
value="krb-admin"/>
        </login-module>
        <login-module code="AdvancedAdLdap" flag="required">
            <module-option name="password-stacking"
value="useFirstPass"/>
            <module-option name="bindAuthentication"
value="GSSAPI"/>
            <module-option name="jaasSecurityDomain" value="ldap-
service"/>
            <module-option name="java.naming.provider.url"
value="ldap://localhost:389"/>
            <module-option name="baseCtxDN"
value="ou=People,dc=infinispan,dc=org"/>
            <module-option name="baseFilter" value="
(krb5PrincipalName={0})"/>
            <module-option name="rolesCtxDN"
value="ou=Roles,dc=infinispan,dc=org"/>
            <module-option name="roleFilter" value="(member=
{1})"/>
            <module-option name="roleAttributeID" value="cn"/>
        </login-module>
    </authentication>
</security-domain>
```

3. The security domain authentication configuration described in the previous step points to the following standard Kerberos login module:

```
<security-domain name="krb-admin" cache-type="default">
    <authentication>
        <login-module code="Kerberos" flag="required">
            <module-option name="useKeyTab" value="true"/>
            <module-option name="principal"
```

```
value="admin@INFINISPAN.ORG"/>
            <module-option name="keyTab"
value="${basedir}/keytab/admin.keytab"/>
        </login-module>
    </authentication>
</security-domain>
```

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8.10. The Security Audit Logger

Red Hat JBoss Data Grid includes a logger to audit security logs for the cache, specifically whether a cache or a cache manager operation was allowed or denied for various operations.

The default audit logger is **`org.infinispan.security.impl.DefaultAuditLogger`**. This logger outputs audit logs using the available logging framework (for example, JBoss Logging) and provides results at the **`TRACE`** level and the **`AUDIT`** category.

To send the **`AUDIT`** category to either a log file, a JMS queue, or a database, use the appropriate log appender.

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8.10.1. Configure the Security Audit Logger (Library Mode)

Use the following to declaratively configure the audit logger in Red Hat JBoss Data Grid:

```
<infinispan>
  ...
 <global-security>
  <authorization audit-logger =
"org.infinispan.security.impl.DefaultAuditLogger">
     ...
  </authorization>
 </global-security>
 ...
</infinispan>
```

Use the following to programatically configure the audit logger in JBoss Data Grid:

```
GlobalConfigurationBuilder global = new GlobalConfigurationBuilder();
   global.security()
      .authorization()
         .auditLogger(new DefaultAuditLogger());
```

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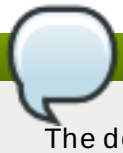
8.10.2. Configure the Security Audit Logger (Remote Client-Server Mode)

Use the following code to configure the audit logger in Red Hat JBoss Data Grid Remote Client-Server Mode.

To use a different audit logger, specify it in the **<authorization>** element. The **<authorization>** element must be within the **<cache-container>** element in the Infinispan subsystem (in the **standalone.xml** configuration file).

```
<cache-container name="local" default-cache="default">
 <security>
 <authorization audit-
logger="org.infinispan.security.impl.DefaultAuditLogger">
 <identity-role-mapper/>
 <role name="admin" permissions="ALL"/>
 <role name="reader" permissions="READ"/>
 <role name="writer" permissions="WRITE"/>
 <role name="supervisor" permissions="ALL_READ ALL_WRITE"/>
 </authorization>
 </security>
 <local-cache name="default" start="EAGER">
 <locking isolation="NONE" acquire-timeout="30000" concurrency-
level="1000" striping="false"/>
 <transaction mode="NONE"/>
 <security>
 <authorization roles="admin reader writer supervisor"/>
 </security>
 </local-cache>
```



Note

The default audit logger for server mode is **org.jboss.as.clustering.infinispan.subsystem.ServerAuditLogger** which sends the log messages to the server audit log. See the *Management Interface Audit Logging* chapter in the JBoss Enterprise Application Platform *Administration and Configuration Guide* for more information.

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8.10.3. Custom Audit Loggers

Users can implement custom audit loggers in Red Hat JBoss Data Grid Library and Remote Client-Server Mode. The custom logger must implement the **org.infinispan.security.AuditLogger** interface. If no custom logger is provided, the default logger (**DefaultAuditLogger**) is used.

Report a bug

Chapter 9. Security for Cluster Traffic

9.1. Node Authentication and Authorization (Remote Client-Server Mode)

Security can be enabled at node level via SASL protocol, which enables node authentication against a security realm. This requires nodes to authenticate each other when joining or merging with a cluster. For detailed information about security realms, see Section 8.7.1, “About Security Realms”.

The following example depicts the <sasl /> element, which leverages the SASL protocol. Both **DIGEST-MD5** or **GSSAPI** mechanisms are currently supported.

Example 9.1. Configure SASL Authentication

```
<management>
    <security-realms>
        <!-- Additional configuration information here -->
        <security-realm name="ClusterRealm">
            <authentication>
                <properties path="cluster-users.properties" relative-
to="jboss.server.config.dir"/>
                </authentication>
                <authorization>
                    <properties path="cluster-roles.properties"
relative-to="jboss.server.config.dir"/>
                </authorization>
            </security-realm>
        </security-realms>
        <!-- Additional configuration information here -->
    </security-realms>
</management>

<stack name="udp">
    <!-- Additional configuration information here -->
    <sasl mech="DIGEST-MD5" security-realm="ClusterRealm" cluster-
role="cluster">
        <property name="client_name">node1</property>
        <property name="client_password">password</property>
    </sasl>
    <!-- Additional configuration information here -->
</stack>
```

In the provided example, the nodes use the **DIGEST-MD5** mechanism to authenticate against the **ClusterRealm**. In order to join, nodes must have the ***cluster*** role.

The ***cluster-role*** attribute determines the role all nodes must belong to in the security realm in order to **JOIN** or **MERGE** with the cluster. Unless it has been specified, the ***cluster-role*** attribute is the name of the clustered ***<cache-container>*** by default. Each node identifies itself using the ***client-name*** property. If none is specified, the hostname on which the server is running will be used.

This name can also be overridden by specifying the **jboss.node.name** system property that can be overridden on the command line. For example:

```
$ clustered.sh -Djboss.node.name=node001
```

Note

JGroups AUTH protocol is not integrated with security realms, and its use is not advocated for Red Hat JBoss Data Grid.

Report a bug

9.1.1. Configure Node Authentication for Cluster Security (DIGEST-MD5)

The following example demonstrates how to use **`DIGEST-MD5`** with a properties-based security realm, with a dedicated realm for cluster node.

Example 9.2. Using the DIGEST-MD5 Mechanism

```
<management>
         <security-realms>
             <security-realm name="ClusterRealm">
                 <authentication>
                     <properties path="cluster-users.properties"
relative-to="jboss.server.config.dir"/>
                 </authentication>
                 <authorization>
                     <properties path="cluster-roles.properties"
relative-to="jboss.server.config.dir"/>
                 </authorization>
             </security-realm>
         </security-realms>
</management>
<subsystem xmlns="urn:infinispa:server:jgroups:6.1" default-
stack="${jboss.default.jgroups.stack:udp}">
     <stack name="udp">
         <transport type="UDP" socket-binding="jgroups-udp"/>
         <protocol type="PING"/>
         <protocol type="MERGE2"/>
         <protocol type="FD_SOCK" socket-binding="jgroups-udp-fd"/>
         <protocol type="FD_ALL"/>
         <protocol type="pbcast.NAKACK"/>
         <protocol type="UNICAST2"/>
         <protocol type="pbcast.STABLE"/>
         <protocol type="pbcast.GMS"/>
         <protocol type="UFC"/>
         <protocol type="MFC"/>
         <protocol type="FRAG2"/>
         <protocol type="RSVP"/>
         <sasl security-realm="ClusterRealm" mech="DIGEST-MD5">
             <property name="client_password>...</property>
         </sasl>
     </stack>
</subsystem>
<subsystem xmlns="urn:infinispan:server:core:6.1" default-cache-
```

```
container="clustered">
     <cache-container name="clustered" default-cache="default">
         <transport executor="infinispan-transport" lock-
timeout="60000" stack="udp"/>
         <!-- various clustered cache definitions here -->
     </cache-container>
</subsystem>
```

In the provided example, supposing the hostnames of the various nodes are **node001**, **node002**, **node003**, the ***cluster-users.properties*** will contain:

- **node001=/<node001passwordhash>/**
- **node002=/<node002passwordhash>/**
- **node003=/<node003passwordhash>/**

The ***cluster-roles.properties*** will contain:

- node001=clustered
- node002=clustered
- node003=clustered

To generate these values, the following **add-users.sh** script can be used:

```
$ add-user.sh -up cluster-users.properties -gp cluster-roles.properties -
r ClusterRealm -u node001 -g clustered -p <password>
```

The **MD5** password hash of the node must also be placed in the "***client_password***" property of the <sasl/> element.

```
<property name="client_password>...</property>
```

Note

To increase security, it is recommended that this password be stored using a Vault. For more information about vault expressions, see the *Red Hat Enterprise Application Platform Security Guide*

Once node security has been set up as discussed here, the cluster coordinator will validate each **JOIN**ing and **MERGE**ing node's credentials against the realm before letting the node become part of the cluster view.

Report a bug

9.1.2. Configure Node Authentication for Cluster Security (GSSAPI/Kerberos)

When using the **GSSAPI** mechanism, the ***client_name*** is used as the name of a Kerberos-enabled login module defined within the security domain subsystem. For a full procedure on how to do this, see Section 8.7.7.1, “Configure Hot Rod Authentication (GSSAPI/Kerberos)”.

Example 9.3. Using the Kerberos Login Module

```
<security-domain name="krb-node0" cache-type="default">
    <authentication>
        <login-module code="Kerberos" flag="required">
            <module-option name="storeKey" value="true"/>
            <module-option name="useKeyTab" value="true"/>
            <module-option name="refreshKrb5Config" value="true"/>
            <module-option name="principal"
value="jgroups/node0/clustered@INFINISPAN.ORG"/>
            <module-option name="keyTab"
value="${jboss.server.config.dir}/keytabs/jgroups_node0_clustered.keyta
b"/>
            <module-option name="doNotPrompt" value="true"/>
        </login-module>
    </authentication>
</security-domain>
```

The following property must be set in the <sasl/> element to reference it:

```
<sasl <!-- Additional configuration information here --> >
     <property name="login_module_name">
       <!-- Additional configuration information here -->
     </property>
</sasl>
```

As a result, the **`authentication`** section of the security realm is ignored, as the nodes will be validated against the Kerberos Domain Controller. The **`authorization`** configuration is still required, as the node principal must belong to the required cluster-role.

In all cases, it is recommended that a shared authorization database, such as LDAP, be used to validate node membership in order to simplify administration.

By default, the principal of the joining node must be in the following format:

```
jgroups/$NODE_NAME/$CACHE_CONTAINER_NAME@REALM
```

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9.2. Configure Node Security in Library Mode

In Library mode, node authentication is configured directly in the JGroups configuration. JGroups can be configured so that nodes must authenticate each other when joining or merging with a cluster. The authentication uses SASL and is enabled by adding the **SASL** protocol to your JGroups XML configuration.

SASL relies on JAAS notions, such as **`CallbackHandlers`**, to obtain certain information necessary for the authentication handshake. Users must supply their own **`CallbackHandlers`** on both client and server sides.

Important

The **JAAS** API is only available when configuring user authentication and authorization, and is not available for node security.

Note

In the provided example, **CallbackHandler** classes are examples only, and not contained in the Red Hat JBoss Data Grid release. Users must provide the appropriate **CallbackHandler** classes for their specific LDAP implementation.

Example 9.4. Setting Up SASL Authentication in JGroups

```
<SASL mech="DIGEST-MD5"
    client_name="node_user"
    client_password="node_password"

server_callback_handler_class="org.example.infinispan.security.JGroupsS
aslServerCallbackHandler"

client_callback_handler_class="org.example.infinispan.security.JGroupsS
aslClientCallbackHandler"
    sasl_props="com.sun.security.sasl.digest.realm=test_realm" />
```

The above example uses the **DIGEST-MD5** mechanism. Each node must declare the user and password it will use when joining the cluster.

Important

The SASL protocol must be placed before the GMS protocol in order for authentication to take effect.

The following example demonstrates how to implement a **CallbackHandler** class. In this example, login and password are checked against values provided via Java properties when JBoss Data Grid is started, and authorization is checked against ***role*** which is defined in the class (**"test_user"**).

Example 9.5. Callback Handler Class

```
public class SaslPropAuthUserCallbackHandler implements CallbackHandler
{

   private static final String APPROVED_USER = "test_user";

   private final String name;
   private final char[] password;
   private final String realm;
```

```
   public SaslPropAuthUserCallbackHandler() {
      this.name = System.getProperty("sasl.username");
      this.password =
System.getProperty("sasl.password").toCharArray();
      this.realm = System.getProperty("sasl.realm");
   }

   @Override
   public void handle(Callback[] callbacks) throws IOException,
UnsupportedCallbackException {
      for (Callback callback : callbacks) {
         if (callback instanceof PasswordCallback) {
            ((PasswordCallback) callback).setPassword(password);
         } else if (callback instanceof NameCallback) {
            ((NameCallback) callback).setName(name);
         } else if (callback instanceof AuthorizeCallback) {
            AuthorizeCallback authorizeCallback = (AuthorizeCallback)
callback;
            if
(APPROVED_USER.equals(authorizeCallback.getAuthorizationID())) {
               authorizeCallback.setAuthorized(true);
            } else {
               authorizeCallback.setAuthorized(false);
            }
         } else if (callback instanceof RealmCallback) {
            RealmCallback realmCallback = (RealmCallback) callback;
            realmCallback.setText(realm);
         } else {
            throw new UnsupportedCallbackException(callback);
         }
      }
   }

}
```

For authentication, specify the **`javax.security.auth.callback.NameCallback`** and **`javax.security.auth.callback.PasswordCallback`** callbacks

For authorization, specify the callbacks required for authentication, as well as specifying the **`javax.security.sasl.AuthorizeCallback`** callback.

Report a bug

9.2.1. Configure Node Authentication for Library Mode (DIGEST-MD5)

The behavior of a node differs depending on whether it is the coordinator node or any other node. The coordinator acts as the SASL server, with the joining or merging nodes behaving as SASL clients. When using the DIGEST-MD5 mechanism in Library mode, the server and client callback must be specified so that the server and client are aware of how to obtain the credentials. Therefore, two **`CallbackHandlers`** are required:

- The **`server_callback_handler_class`** is used by the coordinator.
- The **`client_callback_handler_class`** is used by other nodes.

The following example demonstrates these **CallbackHandlers**.

Example 9.6. Callback Handlers

```
<SASL mech="DIGEST-MD5"
      client_name="node_name"
      client_password="node_password"

client_callback_handler_class="${CLIENT_CALLBACK_HANDLER_IN_CLASSPATH}"

server_callback_handler_class="${SERVER_CALLBACK_HANDLER_IN_CLASSPATH}"
      sasl_props="com.sun.security.sasl.digest.realm=test_realm"
/>
```

JGroups is designed so that all nodes are able to act as coordinator or client depending on cluster behavior, so if the current coordinator node goes down, the next node in the succession chain will become the coordinator. Given this behavior, both server and client callback handlers must be identified within SASL for Red Hat JBoss Data Grid implementations.

Report a bug

9.2.2. Configure Node Authentication for Library Mode (GSSAPI)

When performing node authentication in Library mode using the GSSAPI mechanism, the ***login_module_name*** parameter must be specified instead of ***callback***.

This login module is used to obtain a valid Kerberos ticket, which is used to authenticate a client to the server. The ***server_name*** must also be specified, as the client principal is constructed as **jgroups/$server_name@REALM**.

Example 9.7. Specifying the login module and server on the coordinator node

```
<SASL mech="GSSAPI"
         server_name="node0/clustered"
         login_module_name="krb-node0"

server_callback_handler_class="org.infinispan.test.integration.security
.utils.SaslPropCallbackHandler" />
```

On the coordinator node, the ***server_callback_handler_class*** must be specified for node authorization. This will determine if the authenticated joining node has permission to join the cluster.

Note

The server principal is always constructed as **jgroups/server_name**, therefore the server principal in Kerberos must also be **jgroups/server_name**. For example, if the server name in Kerberos is **jgroups/node1/mycache**, then the server name must be **node1/mycache**.

Report a bug

9.2.3. Node Authorization in Library Mode

The **SASL** protocol in JGroups is concerned only with the authentication process. To implement node authorization, you can do so within the server callback handler by throwing an Exception.

The following example demonstrates this.

Example 9.8. Implementing Node Authorization

```
public class AuthorizingServerCallbackHandler implements
CallbackHandler {

@Override
public void handle(Callback[] callbacks) throws IOException,
UnsupportedCallbackException {
        for (Callback callback : callbacks) {
            <!-- Additional configuration information here -->
            if (callback instanceof AuthorizeCallback) {
                AuthorizeCallback acb = (AuthorizeCallback) callback;
                if
(!"myclusterrole".equals(acb.getAuthenticationID()))) {
                    throw new SecurityException("Unauthorized node "
+user);
            }
            <!-- Additional configuration information here -->
        }
    }
}
```

Report a bug

9.3. JGroups ENCRYPT

JGroups includes the **ENCRYPT** protocol to provide encryption for cluster traffic.

By default, encryption only encrypts the message body; it does not encrypt message headers. To encrypt the entire message, including all headers, as well as destination and source addresses, the property ***encrypt_entire_message*** must be **true**. **ENCRYPT** must also be below any protocols with headers that must be encrypted.

The **ENCRYPT** layer is used to encrypt and decrypt communication in JGroups. The JGroups **ENCRYPT** protocol can be used in two ways:

- Configured with a secretKey in a keystore.
- Configured with algorithms and key sizes.

Each message is identified as encrypted with a specific encryption header identifying the encrypt header and an MD5 digest identifying the version of the key being used to encrypt and decrypt messages.

Report a bug

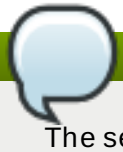
9.3.1. ENCRYPT Configured with a secretKey in a Key Store

The **ENCRYPT** class can be configured with a secretKey in a keystore so it is usable at any layer in JGroups without requiring a coordinator. This also provides protection against passive monitoring without the complexity of key exchange.

This method can be used by inserting the encryption layer at any point in the JGroups stack, which will encrypt all events of a type MSG that have a non-nill message buffer. The following is an example of the entry in this form:

```
<ENCRYPT key_store_name="defaultStore.keystore"
store_password="${VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::ENCRYPTED_VALUE}"
alias="myKey"/>
```

The secretKey must be already generated in a keystore file in order to use the **ENCRYPT** layer in this manner. The directory containing the keystore file must be on the application classpath.



Note

The secretKey keystore file cannot be created using the keytool application shipped with JDK. The **KeyStoreGenerator** java file is included in the demo package that can be used to generate a suitable keystore.

Report a bug

9.3.2. ENCRYPT Using a Key Store

ENCRYPT uses store type JCEKS. To generate a keystore compatible with JCEKS, use the following command line options:

```
$ keytool -genseckey -alias myKey -keypass changeit -storepass changeit -
keyalg Blowfish -keysize 56 -keystore defaultStore.keystore -storetype
JCEKS
```

ENCRYPT can then be configured by adding the following information to the JGroups file used by the application.

```
<ENCRYPT key_store_name="defaultStore.keystore"

store_password="${VAULT::VAULT_BLOCK::ATTRIBUTE_NAME::ENCRYPTED_VALUE}"
         alias="myKey"/>
```

Standard Java properties can also be used in the configuration, and it is possible to pass the path to JGroups configuration via the **-D** option during start up.

The default, pre-configured JGroups files are packaged in **infinispan-embedded.jar**, alternatively, you can create your own configuration file. See the *Configure JGroups (Library Mode)* section in the *Red Hat JBoss Data Grid Administration and Configuration Guide* for instructions on how to set up JBoss Data Grid to use custom JGroups configurations in library mode.

In Remote Client-Server mode, the JGroups configuration is part of the main server configuration file.

Note

The ***defaultStore.keystore*** must be found in the classpath.

Report a bug

9.3.3. ENCRYPT Configured with Algorithms and Key Sizes

In this encryption mode, the coordinator selects the secretKey and distributes it to all peers. There is no keystore, and keys are distributed using a public/private key exchange. Instead, encryption occurs as follows:

1. The secret key is generated and distributed by the controller.
2. When a view change occurs, a peer requests the secret key by sending a key request with its own public key.
3. The controller encrypts the secret key with the public key, and sends it back to the peer.
4. The peer then decrypts and installs the key as its own secret key.

In this mode, the **ENCRYPT** layer must be placed above the GMS protocol in the configuration.

Example 9.9. ENCRYPT Layer

```
<config <!-- Additional configuration information here --> >
    <UDP />
    <PING />
    <MERGE2 />
    <FD />
    <VERIFY_SUSPECT />
    <ENCRYPT encrypt_entire_message="false"
             sym_init="128" sym_algorithm="AES/ECB/PKCS5Padding"
             asym_init="512" asym_algorithm="RSA"/>
    <pbcast.NAKACK />
    <UNICAST />
    <pbcast.STABLE />
    <FRAG2 />
    <pbcast.GMS />
</config>
```

In the provided example, the sequence numbers for the **NAKACK** and **UNICAST** protocols will be encrypted.

View changes that identify a new controller result in a new session key being generated and distributed to all peers. This is a substantial overhead in an application with high peer churn.

When encrypting an entire message, the message must be marshalled into a byte buffer before being encrypted, resulting in decreased performance.

Report a bug

9.3.4. ENCRYPT Configuration Parameters

The following table provides configuration parameters for the **ENCRYPT** JGroups protocol:

Table 9.1. Configuration Parameters

Name	Description
alias	Alias used for recovering the key. Change the default.
asymAlgorithm	Cipher engine transformation for asymmetric algorithm. Default is RSA.
asymInit	Initial public/private key length. Default is 512.
asymProvider	Cryptographic Service Provider. Default is Bouncy Castle Provider.
encrypt_entire_message	
id	Give the protocol a different ID if needed so we can have multiple instances of it in the same stack.
keyPassword	Password for recovering the key. Change the default.
keyStoreName	File on classpath that contains keystore repository.
level	Sets the logger level (see javadocs).
name	Give the protocol a different name if needed so we can have multiple instances of it in the same stack.
stats	Determines whether to collect statistics (and expose them via JMX). Default is true.
storePassword	Password used to check the integrity/unlock the keystore. Change the default. It is recommended that passwords are stored using Vault.
symAlgorithm	Cipher engine transformation for symmetric algorithm. Default is AES.
symInit	Initial key length for matching symmetric algorithm. Default is 128.

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Part III. Advanced Features in Red Hat JBoss Data Grid

Red Hat JBoss Data Grid includes some advanced features. Some of these features are listed in the *JBoss Data Grid Administration and Configuration Guide* with instructions for a basic configuration. The *JBoss Data Grid Developer Guide* explores these features and others in more detail and with instructions for more advanced usage.

The advanced features explored in this guide are as follows:

- Transactions
- Marshalling
- Listeners and Notifications
- The Infinispan CDI Module
- MapReduce
- Distributed Execution
- Interoperability and Compatibility Mode

Report a bug

Chapter 10. Transactions

10.1. About Java Transaction API

Red Hat JBoss Data Grid supports configuring, use of, and participation in Java Transaction API (JTA) compliant transactions.

JBoss Data Grid does the following for each cache operation:

1. First, it retrieves the transactions currently associated with the thread.
2. If not already done, it registers an **`XAResource`** with the transaction manager to receive notifications when a transaction is committed or rolled back.

Report a bug

10.2. Transactions Spanning Multiple Cache Instances

Each cache operates as a separate, standalone Java Transaction API (JTA) resource. However, components can be internally shared by Red Hat JBoss Data Grid for optimization, but this sharing does not affect how caches interact with a Java Transaction API (JTA) Manager.

Report a bug

10.3. The Transaction Manager

Use the following to obtain the TransactionManager from the cache:

```
TransactionManager tm =
cache.getAdvancedCache().getTransactionManager();
```

To execute a sequence of operations within transaction, wrap these with calls to methods begin() and commit() or rollback() on the TransactionManager:

Example 10.1. Performing Operations

```
tm.begin();
Object value = cache.get("A");
cache.remove("A");
Object prev = cache.put("B", value);
if (prev == null)
    tm.commit();
else
    tm.rollback();
```

Note

If a cache method returns a CacheException (or a subclass of the CacheException) within the scope of a JTA transaction, the transaction is automatically marked to be rolled back.

To obtain a reference to a Red Hat JBoss Data Grid XAResource, use the following API:

```
XAResource xar = cache.getAdvancedCache().getXAResource();
```

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10.4. About JTA Transaction Manager Lookup Classes

In order to execute a cache operation, the cache requires a reference to the environment's Transaction Manager. Configure the cache with the class name that belongs to an implementation of the **`TransactionManagerLookup`** interface. When initialized, the cache creates an instance of the specified class and invokes its **`getTransactionManager()`** method to locate and return a reference to the Transaction Manager.

Table 10.1. Transaction Manager Lookup Classes

Class Name	Details
org.infinispan.transaction.lookup.DummyTransactionManagerLookup	Used primarily for testing environments. This testing transaction manager is not for use in a production environment and is severely limited in terms of functionality, specifically for concurrent transactions and recovery.
org.infinispan.transaction.lookup.JBossStandaloneJTAManagerLookup	It is a fully functional JBoss Transactions based transaction manager that overcomes the functionality limits of the **`DummyTransactionManager`**.
org.infinispan.transaction.lookup.GenericTransactionManagerLookup	GenericTransactionManagerLookup is used by default when no transaction lookup class is specified. This lookup class is recommended when using JBoss Data Grid with Java EE-compatible environment that provides a TransactionManager interface, and is capable of locating the Transaction Manager in most Java EE application servers. If no transaction manager is located, it defaults to **`DummyTransactionManager`**.

It is important to note that when using Red Hat JBoss Data Grid with Tomcat or an ordinary Java Virtual Machine (JVM), the recommended Transaction Manager Lookup class is **`JBossStandaloneJTAManagerLookup`**, which uses JBoss Transactions.

Report a bug

Chapter 11. Marshalling

Marshalling is the process of converting Java objects into a format that is transferable over the wire. Unmarshalling is the reversal of this process where data read from a wire format is converted into Java objects.

Red Hat JBoss Data Grid uses marshalling and unmarshalling to:

- transform data for relay to other JBoss Data Grid nodes within the cluster.
- transform data to be stored in underlying cache stores.

Report a bug

11.1. About Marshalling Framework

Red Hat JBoss Data Grid uses the JBoss Marshalling Framework to marshall and unmarshall Java POJOs. Using the JBoss Marshalling Framework offers a significant performance benefit, and is therefore used instead of Java Serialization. Additionally, the JBoss Marshalling Framework can efficiently marshall Java POJOs, including Java classes.

The Java Marshalling Framework uses high performance **`java.io.ObjectOutput`** and **`java.io.ObjectInput`** implementations compared to the standard **`java.io.ObjectOutputStream`** and **`java.io.ObjectInputStream`**.

Report a bug

11.2. Support for Non-Serializable Objects

A common user concern is whether Red Hat JBoss Data Grid supports the storage of non-serializable objects. In JBoss Data Grid, marshalling is supported for non-serializable key-value objects; users can provide externalizer implementations for non-serializable objects.

If you are unable to retrofit **`Serializable`** or **`Externalizable`** support into your classes, you could (as an example) use XStream to convert the non-serializable objects into a String that can be stored in JBoss Data Grid.

Note

XStream slows down the process of storing key-value objects due to the required XML transformations.

Report a bug

11.3. Hot Rod and Marshalling

In Remote Client-Server mode, marshalling occurs both on the Red Hat JBoss Data Grid server and the client levels, but to varying degrees.

- All data stored by clients on the JBoss Data Grid server are provided either as a byte array, or in a primitive format that is marshalling compatible for JBoss Data Grid.

On the server side of JBoss Data Grid, marshalling occurs where the data stored in primitive format are converted into byte array and replicated around the cluster or stored to a cache store. No marshalling configuration is required on the server side of JBoss Data Grid.

- At the client level, marshalling must have a ***`Marshaller`*** configuration element specified in the RemoteCacheManager configuration in order to serialize and deserialize POJOs.

  Due to Hot Rod's binary nature, it relies on marshalling to transform POJOs, specifically keys or values, into byte array.

Report a bug

11.4. Configuring the Marshaller using the RemoteCacheManager

A Marshaller is specified using the ***`marshaller`*** configuration element in the RemoteCacheManager, the value of which must be the name of the class implementing the Marshaller interface. The default value for this property is ***`org.infinispan.commons.marshall.jboss.GenericJBossMarshaller`***.

The following procedure describes how to define a Marshaller to use with RemoteCacheManager.

Procedure 11.1. Define a Marshaller

1. **Create a ConfigurationBuilder**

   Create a ConfigurationBuilder and configure it with the required settings.

   ```
   ConfigurationBuilder builder = new ConfigurationBuilder();
   //... (other configuration)
   ```

2. **Add a Marshaller Class**

   Add a Marshaller class specification within the Marshaller method.

   ```
   builder.marshaller(GenericJBossMarshaller.class);
   ```

   A. Alternatively, specify a custom Marshaller instance.

   ```
   builder.marshaller(new GenericJBossMarshaller());
   ```

3. **Start the RemoteCacheManager**

   Build the configuration containing the Marshaller, and start a new RemoteCacheManager with it.

   ```
   Configuration configuration = builder.build();
   RemoteCacheManager manager = new
   RemoteCacheManager(configuration);
   ```

At the client level, POJOs need to be either Serializable, Externalizable, or primitive types.

Note

The Hot Rod Java client does not support providing Externalizer instances to serialize POJOs. This is only available for JBoss Data Grid Library mode.

Report a bug

11.5. Troubleshooting

11.5.1. Marshalling Troubleshooting

In Red Hat JBoss Data Grid, the marshalling layer and JBoss Marshalling in particular, can produce errors when marshalling or unmarshalling a user object. The exception stack trace contains further information to help you debug the problem.

Example 11.1. Exception Stack Trace

```
java.io.NotSerializableException: java.lang.Object
at
org.jboss.marshalling.river.RiverMarshaller.doWriteObject(RiverMarshall
er.java:857)
at
org.jboss.marshalling.AbstractMarshaller.writeObject(AbstractMarshaller
.java:407)
at
org.infinispan.marshall.exts.ReplicableCommandExternalizer.writeObject(
ReplicableCommandExternalizer.java:54)
at
org.infinispan.marshall.jboss.ConstantObjectTable$ExternalizerAdapter.w
riteObject(ConstantObjectTable.java:267)
at
org.jboss.marshalling.river.RiverMarshaller.doWriteObject(RiverMarshall
er.java:143)
at
org.jboss.marshalling.AbstractMarshaller.writeObject(AbstractMarshaller
.java:407)
at
org.infinispan.marshall.jboss.JBossMarshaller.objectToObjectStream(JBoss
Marshaller.java:167)
at
org.infinispan.marshall.VersionAwareMarshaller.objectToBuffer(VersionAw
areMarshaller.java:92)
at
org.infinispan.marshall.VersionAwareMarshaller.objectToByteBuffer(Versi
onAwareMarshaller.java:170)
at
org.infinispan.marshall.VersionAwareMarshallerTest.testNestedNonSeriali
zable(VersionAwareMarshallerTest.java:415)
Caused by: an exception which occurred:
in object java.lang.Object@b40ec4
in object org.infinispan.commands.write.PutKeyValueCommand@df661da7
... Removed 22 stack frames
```

Messages starting with **`in object`** and stack traces are read in the same way: the highest **`in object`** message is the innermost one and the outermost **`in object`** message is the lowest.

The provided example indicates that a **`java.lang.Object`** instance within an **`org.infinispan.commands.write.PutKeyValueCommand`** instance cannot be serialized because **`java.lang.Object@b40ec4`** is not serializable.

However, if the **`DEBUG`** or **`TRACE`** logging levels are enabled, marshalling exceptions will contain **`toString()`** representations of objects in the stack trace. The following is an example that depicts such a scenario:

Example 11.2. Exceptions with Logging Levels Enabled

```
java.io.NotSerializableException: java.lang.Object
...
Caused by: an exception which occurred:
in object java.lang.Object@b40ec4
-> toString = java.lang.Object@b40ec4
in object org.infinispan.commands.write.PutKeyValueCommand@df661da7
->  toString = PutKeyValueCommand{key=k,
value=java.lang.Object@b40ec4,  putIfAbsent=false, lifespanMillis=0,
maxIdleTimeMillis=0}
```

Displaying this level of information for unmarshalling exceptions is expensive in terms of resources. However, where possible, JBoss Data Grid displays class type information. The following example depicts such levels of information on display:

Example 11.3. Unmarshalling Exceptions

```
java.io.IOException: Injected failue!
at
org.infinispan.marshall.VersionAwareMarshallerTest$1.readExternal(Versi
onAwareMarshallerTest.java:426)
at
org.jboss.marshalling.river.RiverUnmarshaller.doReadNewObject(RiverUnma
rshaller.java:1172)
at
org.jboss.marshalling.river.RiverUnmarshaller.doReadObject(RiverUnmarsh
aller.java:273)
at
org.jboss.marshalling.river.RiverUnmarshaller.doReadObject(RiverUnmarsh
aller.java:210)
at
org.jboss.marshalling.AbstractUnmarshaller.readObject(AbstractUnmarshal
ler.java:85)
at
org.infinispan.marshall.jboss.JBossMarshaller.objectFromObjectStream(JB
ossMarshaller.java:210)
at
org.infinispan.marshall.VersionAwareMarshaller.objectFromByteBuffer(Ver
sionAwareMarshaller.java:104)
```

```
at
org.infinispan.marshall.VersionAwareMarshaller.objectFromByteBuffer(Ver
sionAwareMarshaller.java:177)
at
org.infinispan.marshall.VersionAwareMarshallerTest.testErrorUnmarshalli
ng(VersionAwareMarshallerTest.java:431)
Caused by: an exception which occurred:
in object of type org.infinispan.marshall.VersionAwareMarshallerTest$1
```

In the provided example, an **`IOException`** was thrown when an instance of the inner class **`org.infinispan.marshall.VersionAwareMarshallerTest$1`** is unmarshalled.

In a manner similar to marshalling exceptions, when **`DEBUG`** or **`TRACE`** logging levels are enabled, the class type's classloader information is provided. An example of this classloader information is as follows:

Example 11.4. Classloader Information

```
java.io.IOException: Injected failue!
...
Caused by: an exception which occurred:
in object of type org.infinispan.marshall.VersionAwareMarshallerTest$1
-> classloader hierarchy:
-> type classloader = sun.misc.Launcher$AppClassLoader@198dfaf
-
>...file:/opt/eclipse/configuration/org.eclipse.osgi/bundles/285/1/.cp/
eclipse-testng.jar
-
>...file:/opt/eclipse/configuration/org.eclipse.osgi/bundles/285/1/.cp/
lib/testng-jdk15.jar
->...file:/home/galder/jboss/infinispan/code/trunk/core/target/test-
classes/
->...file:/home/galder/jboss/infinispan/code/trunk/core/target/classes/
->...file:/home/galder/.m2/repository/org/testng/testng/5.9/testng-5.9-
jdk15.jar
->...file:/home/galder/.m2/repository/net/jcip/jcip-
annotations/1.0/jcip-annotations-1.0.jar
-
>...file:/home/galder/.m2/repository/org/easymock/easymockclassextensio
n/2.4/easymockclassextension-2.4.jar
-
>...file:/home/galder/.m2/repository/org/easymock/easymock/2.4/easymock
-2.4.jar
->...file:/home/galder/.m2/repository/cglib/cglib-nodep/2.1_3/cglib-
nodep-2.1_3.jar
->...file:/home/galder/.m2/repository/javax/xml/bind/jaxb-
api/2.1/jaxb-api-2.1.jar
->...file:/home/galder/.m2/repository/javax/xml/stream/stax-api/1.0-
2/stax-api-1.0-2.jar
-
>...file:/home/galder/.m2/repository/javax/activation/activation/1.1/ac
tivation-1.1.jar
-
>...file:/home/galder/.m2/repository/jgroups/jgroups/2.8.0.CR1/jgroups-
```

```
2.8.0.CR1.jar
->...file:/home/galder/.m2/repository/org/jboss/javaee/jboss-
transaction-api/1.0.1.GA/jboss-transaction-api-1.0.1.GA.jar
-
>...file:/home/galder/.m2/repository/org/jboss/marshalling/river/1.2.0.
CR4-SNAPSHOT/river-1.2.0.CR4-SNAPSHOT.jar
-
>...file:/home/galder/.m2/repository/org/jboss/marshalling/marshalling-
api/1.2.0.CR4-SNAPSHOT/marshalling-api-1.2.0.CR4-SNAPSHOT.jar
->...file:/home/galder/.m2/repository/org/jboss/jboss-common-
core/2.2.14.GA/jboss-common-core-2.2.14.GA.jar
->...file:/home/galder/.m2/repository/org/jboss/logging/jboss-logging-
spi/2.0.5.GA/jboss-logging-spi-2.0.5.GA.jar
->...file:/home/galder/.m2/repository/log4j/log4j/1.2.14/log4j-
1.2.14.jar
-
>...file:/home/galder/.m2/repository/com/thoughtworks/xstream/xstream/1
.2/xstream-1.2.jar
->...file:/home/galder/.m2/repository/xpp3/xpp3_min/1.1.3.4.O/xpp3_min-
1.1.3.4.O.jar
->...file:/home/galder/.m2/repository/com/sun/xml/bind/jaxb-
impl/2.1.3/jaxb-impl-2.1.3.jar
-> parent classloader = sun.misc.Launcher$ExtClassLoader@1858610
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/localedata.jar
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/sunpkcs11.jar
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/sunjce_provider.jar
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/dnsns.jar
... Removed 22 stack frames
```

Report a bug

11.5.2. Other Marshalling Related Issues

Issues and exceptions related to Marshalling can also appear in different contexts, for example during the State transfer with **`EOFException`**. During a state transfer, if an **`EOFException`** is logged that states that the state receiver has **`Read past end of file`**, this can be dealt with depending on whether the state provider encounters an error when generating the state. For example, if the state provider is currently providing a state to a node, when another node requests a state, the state generator log can contain:

Example 11.5. State Generator Log

```
2010-12-09 10:26:21,533 20267 ERROR
[org.infinispan.remoting.transport.jgroups.JGroupsTransport]
(STREAMING_STATE_TRANSFER-sender-1,Infinispan-Cluster,NodeJ-2368:)
Caught while responding to state transfer request
org.infinispan.statetransfer.StateTransferException:
java.util.concurrent.TimeoutException: Could not obtain exclusive
processing lock
     at
org.infinispan.statetransfer.StateTransferManagerImpl.generateState(Sta
teTransferManagerImpl.java:175)
     at
org.infinispan.remoting.InboundInvocationHandlerImpl.generateState(Inb
```

```
oundInvocationHandlerImpl.java:119)
     at
org.infinispan.remoting.transport.jgroups.JGroupsTransport.getState(JGr
oupsTransport.java:586)
     at
org.jgroups.blocks.MessageDispatcher$ProtocolAdapter.handleUpEvent(Mess
ageDispatcher.java:691)
     at
org.jgroups.blocks.MessageDispatcher$ProtocolAdapter.up(MessageDispatch
er.java:772)
     at org.jgroups.JChannel.up(JChannel.java:1465)
     at org.jgroups.stack.ProtocolStack.up(ProtocolStack.java:954)
     at org.jgroups.protocols.pbcast.FLUSH.up(FLUSH.java:478)
     at
org.jgroups.protocols.pbcast.STREAMING_STATE_TRANSFER$StateProviderHan
dler.process(STREAMING_STATE_TRANSFER.java:653)
     at
org.jgroups.protocols.pbcast.STREAMING_STATE_TRANSFER$StateProviderThr
eadSpawner$1.run(STREAMING_STATE_TRANSFER.java:582)
     at
java.util.concurrent.ThreadPoolExecutor$Worker.runTask(ThreadPoolExecu
tor.java:886)
     at
java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.
java:908)
     at java.lang.Thread.run(Thread.java:680)
Caused by: java.util.concurrent.TimeoutException: Could not obtain
exclusive processing lock
     at
org.infinispan.remoting.transport.jgroups.JGroupsDistSync.acquireProces
singLock(JGroupsDistSync.java:71)
     at
org.infinispan.statetransfer.StateTransferManagerImpl.generateTransacti
onLog(StateTransferManagerImpl.java:202)
     at
org.infinispan.statetransfer.StateTransferManagerImpl.generateState(Sta
teTransferManagerImpl.java:165)
     ... 12 more
```

In logs, you can also spot exceptions which seems to be related to marshaling. However, the root cause of the exception can be different. The implication of this exception is that the state generator was unable to generate the transaction log hence the output it was writing in now closed. In such a situation, the state receiver will often log an ***EOFException***, displayed as follows, when failing to read the transaction log that was not written by the sender:

Example 11.6. *EOFException*

```
2010-12-09 10:26:21,535 20269 TRACE
[org.infinispan.marshall.VersionAwareMarshaller] (Incoming-
2,Infinispan-Cluster,NodeI-38030:) Log exception reported
java.io.EOFException: Read past end of file
     at
org.jboss.marshalling.AbstractUnmarshaller.eofOnRead(AbstractUnmarshall
er.java:184)
```

```
     at
org.jboss.marshalling.AbstractUnmarshaller.readUnsignedByteDirect(Abstr
actUnmarshaller.java:319)
     at
org.jboss.marshalling.AbstractUnmarshaller.readUnsignedByte(AbstractUnm
arshaller.java:280)
     at
org.jboss.marshalling.river.RiverUnmarshaller.doReadObject(RiverUnmarsh
aller.java:207)
     at
org.jboss.marshalling.AbstractUnmarshaller.readObject(AbstractUnmarshal
ler.java:85)
     at
org.infinispan.marshall.jboss.GenericJBossMarshaller.objectFromObjectSt
ream(GenericJBossMarshaller.java:175)
     at
org.infinispan.marshall.VersionAwareMarshaller.objectFromObjectStream(V
ersionAwareMarshaller.java:184)
     at
org.infinispan.statetransfer.StateTransferManagerImpl.processCommitLog(
StateTransferManagerImpl.java:228)
     at
org.infinispan.statetransfer.StateTransferManagerImpl.applyTransactionL
og(StateTransferManagerImpl.java:250)
     at
org.infinispan.statetransfer.StateTransferManagerImpl.applyState(StateT
ransferManagerImpl.java:320)
     at
org.infinispan.remoting.InboundInvocationHandlerImpl.applyState(Inboun
dInvocationHandlerImpl.java:102)
     at
org.infinispan.remoting.transport.jgroups.JGroupsTransport.setState(JGr
oupsTransport.java:603)
        ...
```

When this error occurs, the state receiver attempts the operation every few seconds until it is successful. In most cases, after the first attempt, the state generator has already finished processing the second node and is fully receptive to the state, as expected.

Report a bug

Chapter 12. The Infinispan CDI Module

Infinispan includes Context and Dependency Injection (CDI) in the **`infinispan-cdi`** module. The **`infinispan-cdi`** module offers:

- Configuration and injection using the Cache API.
- A bridge between the cache listeners and the CDI event system.
- Partial support for the JCACHE caching annotations.

Report a bug

12.1. Using Infinispan CDI

12.1.1. Infinispan CDI Prerequisites

The following is a list of prerequisites to use the Infinispan CDI module with Red Hat JBoss Data Grid:

- Ensure that the most recent version of the infinispan-cdi module is used.
- Ensure that the correct dependency information is set.

Report a bug

12.1.2. Set the CDI Maven Dependency

Add the following dependency information to the **`pom.xml`** file in your maven project:

```
<dependencies>
<!-- Additional configuration information here -->
 <dependency>
     <groupId>org.infinispan</groupId>
     <artifactId>infinispan-cdi</artifactId>
     <version>${infinispan.version}</version>
 </dependency>
<!-- Additional configuration information here -->
</dependencies>
```

Report a bug

12.2. Using the Infinispan CDI Module

The Infinispan CDI module can be used for the following purposes:

- To configure and inject Infinispan caches into CDI Beans and Java EE components.
- To configure cache managers.
- To control storage and retrieval using CDI annotations.

Report a bug

12.2.1. Configure and Inject Infinispan Caches

12.2.1.1. Inject an Infinispan Cache

An Infinispan cache is one of the multiple components that can be injected into the project's CDI beans.

The following code snippet illustrates how to inject a cache instance into the CDI bean:

```
public class MyCDIBean {
    @Inject
    Cache<String, String> cache;
}
```

Report a bug

12.2.1.2. Inject a Remote Infinispan Cache

The code snippet to inject a normal cache is slightly modified to inject a remote Infinispan cache, as follows:

```
public class MyCDIBean {
    @Inject
    RemoteCache<String, String> remoteCache;
}
```

Report a bug

12.2.1.3. Set the Injection's Target Cache

The following are the three steps to set an injection's target cache:

1. Create a qualifier annotation.
2. Add a producer class.
3. Inject the desired class.

Report a bug

12.2.1.3.1. Create a Qualifier Annotation

To use CDI to return a specific cache, create custom cache qualifier annotations as follows:

Example 12.1. Custom Cache Qualifier

```
@javax.inject.Qualifier
@Target({ElementType.FIELD, ElementType.PARAMETER,
ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
@Documented
public @interface SmallCache {}
```

Use the created **@SmallCache** qualifier to specify how to create specific caches.

Report a bug

12.2.1.3.2. Add a Producer Class

The following code snippet illustrates how the **@SmallCache** qualifier (created in the previous step) specifies a way to create a cache:

Example 12.2. Using the @SmallCache Qualifier

```
import org.infinispan.configuration.cache.Configuration;
import org.infinispan.configuration.cache.ConfigurationBuilder;
import org.infinispan.cdi.ConfigureCache;
import javax.enterprise.inject.Proces;

public class CacheCreator {
    @ConfigureCache("smallcache")
    @SmallCache
    @Produces
    public Configuration specialCacheCfg() {
        return new ConfigurationBuilder()
                    .eviction()
                        .strategy(EvictionStrategy.LRU)
                        .maxEntries(10)
                    .build();
    }
}
```

The elements in the code snippet are:

- **@ConfigureCache** specifies the name of the cache.
- **@SmallCache** is the cache qualifier.

Report a bug

12.2.1.3.3. Inject the Desired Class

Use the **@SmallCache** qualifier and the new producer class to inject a specific cache into the CDI bean as follows:

```
public class MyCDIBean {
    @Inject @SmallCache
    Cache<String, String> mySmallCache;
}
```

Report a bug

12.2.2. Configure Cache Managers with CDI

A Red Hat JBoss Data Grid Cache Manager (both embedded and remote) can be configured using CDI. Whether configuring an embedded or remote cache manager, the first step is to specify a default configuration that is annotated to act as a producer.

Report a bug

12.2.2.1. Specify the Default Configuration

Specify a method annotated as a producer for the Red Hat JBoss Data Grid configuration object to replace the default Infinispan Configuration. The following sample configuration illustrates this step:

Example 12.3. Specifying the Default Configuration

```
public class Config {
    @Produces
    public Configuration defaultEmbeddedConfiguration () {
        return new ConfigurationBuilder()
                        .eviction()
                                .strategy(EvictionStrategy.LRU)
                                .maxEntries(100)
                        .build();
    }
}
```

Note

CDI adds a **`@Default`** qualifier if no other qualifiers are provided.

If a **`@Produces`** annotation is placed in a method that returns a Configuration instance, the method is invoked when a Configuration object is required.

In the provided example configuration, the method creates a new Configuration object which is subsequently configured and returned.

Report a bug

12.2.2.2. Override the Creation of the Embedded Cache Manager

Prerequisites

Section 12.2.2.1, “Specify the Default Configuration”

Creating Non Clustered Caches

After a producer method is annotated, this method will be called when creating an **`EmbeddedCacheManager`**, as follows:

Example 12.4. Create a Non Clustered Cache

```
public class Config {

    @Produces
    @ApplicationScoped
    public EmbeddedCacheManager defaultEmbeddedCacheManager() {
```

```
        Configuration cfg = new ConfigurationBuilder()
                                        .eviction()

.strategy(EvictionStrategy.LRU)
                                                .maxEntries(150)
                                        .build();
        return new DefaultCacheManager(cfg);
    }
}
```

The **@ApplicationScoped** annotation specifies that the method is only called once.

Creating Clustered Caches

The following configuration can be used to create an **EmbeddedCacheManager** that can create clustered caches.

Example 12.5. Create Clustered Caches

```
public class Config {

 @Produces
 @ApplicationScoped
 public EmbeddedCacheManager defaultClusteredCacheManager() {
  GlobalConfiguration g = new GlobalConfigurationBuilder()
    .clusteredDefault()
    .transport()
    .clusterName("InfinispanCluster")
    .build();
  Configuration cfg = new ConfigurationBuilder()
    .eviction()
    .strategy(EvictionStrategy.LRU)
    .maxEntries(150)
    .build();
  return new DefaultCacheManager(g, cfg);
 }
}
```

Invoke the Method to Generate an EmbeddedCacheManager

The method annotated with **@Produces** in the non clustered method generates **Configuration** objects. The methods in the clustered cache example annonated with **@Produces** generate **EmbeddedCacheManager** objects.

Add an injection as follows in your CDI Bean to invoke the appropriate annotated method. This generates **EmbeddedCacheManager** and injects it into the code at runtime.

Example 12.6. Generate an EmbeddedCacheManager

```
...
@Inject
EmbeddedCacheManager cacheManager;
...
```

Report a bug

12.2.2.3. Configure a Remote Cache Manager

The **RemoteCacheManager** is configured in a manner similar to **EmbeddedCacheManagers**, as follows:

Example 12.7. Configuring the Remote Cache Manager

```
public class Config {
 @Produces
 @ApplicationScoped
 public RemoteCacheManager defaultRemoteCacheManager() {
           Configuration conf = new
ConfigurationBuilder().addServer().host(ADDRESS).port(PORT).build();
            return new RemoteCacheManager(conf);
 }
}}
```

Report a bug

12.2.2.4. Configure Multiple Cache Managers with a Single Class

A single class can be used to configure multiple cache managers and remote cache managers based on the created qualifiers. An example of this is as follows:

Example 12.8. Configure Multiple Cache Managers

```
public class Config {
    @Produces
    @ApplicationScoped
    public org.infinispan.manager.EmbeddedCacheManager
    defaultEmbeddedCacheManager() {
        Configuration cfg = new ConfigurationBuilder()
                .eviction()
                .strategy(EvictionStrategy.LRU)
                .maxEntries(150)
                .build();
        return new DefaultCacheManager(cfg);
    }

    @Produces
    @ApplicationScoped
    @DefaultClustered
    public org.infinispan.manager.EmbeddedCacheManager
    defaultClusteredCacheManager() {
```

```
        GlobalConfiguration g = new GlobalConfigurationBuilder()
                .clusteredDefault()
                .transport()
                .clusterName("InfinispanCluster")
                .build();
        Configuration cfg = new ConfigurationBuilder()
                .eviction()
                .strategy(EvictionStrategy.LRU)
                .maxEntries(150)
                .build();
        return new DefaultCacheManager(g, cfg);
    }

    @Produces
    @ApplicationScoped
    @DefaultRemote
    public RemoteCacheManager
    defaultRemoteCacheManager() {
        org.infinispan.client.hotrod.configuration.Configuration conf =
new
org.infinispan.client.hotrod.configuration.ConfigurationBuilder().addSe
rver().host(ADDRESS).port(PORT).build();
        return new RemoteCacheManager(conf);
    }

    @Produces
    @ApplicationScoped
    @RemoteCacheInDifferentDataCentre
    public RemoteCacheManager newRemoteCacheManager() {
        org.infinispan.client.hotrod.configuration.Configuration confid
= new
org.infinispan.client.hotrod.configuration.ConfigurationBuilder().addSe
rver().host(ADDRESS_FAR_AWAY).port(PORT).build();
        return new RemoteCacheManager(confid);
    }
}
```

Report a bug

12.2.3. Storage and Retrieval Using CDI Annotations

12.2.3.1. Configure Cache Annotations

Specific CDI annotations are accepted for the JCache (JSR-107) specification. All included annotations are located in the **`javax.cache`** package.

The annotations intercept method calls on CDI beans and perform storage and retrieval tasks as a result of these interceptions.

Report a bug

12.2.3.2. Enable Cache Annotations

Interceptors can be added to the CDI bean archive using the **beans.xml** file. Adding the following code adds interceptors such as the **CacheResultInterceptor**, **CachePutInterceptor**, **CacheRemoveEntryInterceptor** and the **CacheRemoveAllInterceptor**:

Example 12.9. Adding Interceptors

```
<beans xmlns="http://java.sun.som/xml/ns/javaee"
       xmlns:xsi="http://www/w3/org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://java.sun.com/xml/ns/javaee
http://java.sun.com/xml/ns/javaee/beans_1_0.xsd" >
 <interceptors>
  <class>
   org.infinispan.cdi.interceptor.CacheResultInterceptor
  </class>
  <class>
   org.infinispan.cdi.interceptor.CachePutInterceptor
  </class>
  <class>
   org.infinispan.cdi.interceptor.CacheRemoveEntryInterceptor
  </class>
  <class>
   org.infinispan.cdi.interceptor.CacheRemoveAllInterceptor
  </class>
 </interceptors>
</beans>
```

Note

The listed interceptors must appear in the **beans.xml** file for Red Hat JBoss Data Grid to use javax.cache annotations.

Report a bug

12.2.3.3. Caching the Result of a Method Invocation

A common practice for time or resource intensive operations is to save the results in a cache for future access. The following code is an example of such an operation:

```
public String toCelsiusFormatted(float fahrenheit) {
 return
  NumberFormat.getInstance()
  .format((fahrenheit * 5 / 9) - 32)
  + " degrees Celsius";
}
```

A common approach is to cache the results of this method call and to check the cache when the result is next required. The following is an example of a code snippet that looks up the result of such an operation in a cache. If the results are not found, the code snippet runs the **toCelsiusFormatted** method again and stores the result in the cache.

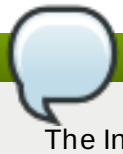
```
float f = getTemperatureInFahrenheit();
```

```
Cache<Float, String>
 fahrenheitToCelsiusCache = getCache();
String celsius =
 fahrenheitToCelsiusCache = get(f);
     if (celsius == null) {
      celsius = toCelsiusFormatted(f);
      fahrenheitToCelsiusCache.put(f, celsius);
     }
```

In such cases, the Infinispan CDI module can be used to eliminate all the extra code in the related examples. Annotate the method with the **`@CacheResult`** annotation instead, as follows:

```
@javax.cache.interceptor.CacheResult
public String toCelsiusFormatted(float fahrenheit) {
 return NumberFormat.getInstance()
 .format((fahrenheit * 5 / 9) - 32)
 + " degrees Celsius";
}
```

Due to the annotation, Infinispan checks the cache and if the results are not found, it invokes the **`toCelsiusFormatted()`** method call.



Note

The Infinispan CDI module allows checking the cache for saved results, but this approach should be carefully considered before application. If the results of the call should always be fresh data, or if the cache reading requires a remote network lookup or deserialization from a cache loader, checking the cache before call method invocation can be counter productive.

Report a bug

12.2.3.3.1. Specify the Cache Used

Add the following optional attribute (***`cacheName`***) to the **`@CacheResult`** annotation to specify the cache to check for results of the method call:

```
@CacheResult(cacheName = "mySpecialCache")
public String doSomething(String parameter) {
<!-- Additional configuration information here -->
}
```

Report a bug

12.2.3.3.2. Cache Keys for Cached Results

As a default, the **`@CacheResult`** annotation creates a key for the results fetched from a cache. The key consists of a combination of all parameters in the relevant method.

Create a custom key using the **`@CacheKey`** annotation as follows:

Example 12.10. Create a Custom Key

```
@CacheResult
public String doSomething
 (@CacheKey String p1,
 @CacheKey String p2,
 String dontCare) {
<!-- Additional configuration information here -->
}
```

In the specified example, only the values of **p1** and **p2** are used to create the cache key. The value of **dontCare** is not used when determining the cache key.

Report a bug

12.2.3.3.3. Generate a Custom Key

Generate a custom key as follows:

```
import javax.cache.annotation.CacheKey;
import javax.cache.annotation.CacheKeyGenerator;
import javax.cache.annotation.CacheKeyInvocationContext;
import java.lang.annotation.Annotation;

public class MyCacheKeyGenerator implements CacheKeyGenerator {

   @Override
   public CacheKey generateCacheKey(CacheKeyInvocationContext<? extends
Annotation> ctx) {

      return new MyCacheKey(
            ctx.getAllParameters()[0].getValue()
      );
   }
}
```

The listed method constructs a custom key. This key is passed as part of the value generated by the first parameter of the invocation context.

To specify the custom key generation scheme, add the optional parameter ***cacheKeyGenerator*** to the **@CacheResult** annotation as follows:

```
@CacheResult(cacheKeyGenerator = MyCacheKeyGenerator.class)
public void doSomething(String p1, String p2) {
<!-- Additional configuration information here -->
}
```

Using the provided method, **p1** contains the custom key.

Report a bug

12.2.4. Cache Operations

12.2.4.1. Update a Cache Entry

When the method that contains the **@CachePut** annotation is invoked, a parameter (normally passed to the method annotated with **@CacheValue**) is stored in the cache.

Example 12.11. Sample @CachePut Annotated Method

```
import javax.cache.annotation.CachePut
@CachePut (cacheName = "personCache")
public void updatePerson
 (@CacheKey long personId,
 @CacheValue Person newPerson) {
<!-- Additional configuration information here -->
 }
```

Further customization is possible using **cacheName** and **cacheKeyGenerator** in the **@CachePut** method. Additionally, some parameters in the invoked method may be annotated with **@CacheKey** to control key generation.

See Also:

- Section 12.2.3.3.2, “Cache Keys for Cached Results”

Report a bug

12.2.4.2. Remove an Entry from the Cache

The following is an example of a **@CacheRemoveEntry** annotated method that is used to remove an entry from the cache:

Example 12.12. Removing an Entry from the Cache

```
import javax.cache.annotation.CacheRemoveEntry
@CacheRemoveEntry (cacheName = "cacheOfPeople")
public void changePersonName
 (@CacheKey long personId,
 string newName {
<!-- Additional configuration information here -->
 }
```

The annotation accepts the optional **cacheName** and **cacheKeyGenerator** attributes.

Report a bug

12.2.4.3. Clear the Cache

Invoke the **@CacheRemoveAll** method to clear all entries from the cache.

Example 12.13. Clear All Entries from the Cache with @CacheRemoveAll

```
import javax.cache.annotation.CacheResult
@CacheRemoveAll (cacheName = "statisticsCache")
public void resetStatistics() {
```

```
<!-- Additional configuration information here -->
}
```

As displayed in the example, this annotation accepts an optional **`cacheName`** attribute.

Report a bug

Chapter 13. Rolling Upgrades

In Red Hat JBoss Data Grid, rolling upgrades permit a cluster to be upgraded from one version to a new version without experiencing any downtime. This allows nodes to be upgraded without the need to restart the application or risk losing data.

In JBoss Data Grid, rolling upgrades can only be performed in Remote Client-Server mode.

Report a bug

13.1. Rolling Upgrades Using Hot Rod

The following process is used to perform rolling upgrades on Red Hat JBoss Data Grid running in Remote Client-Server mode, using Hot Rod. This procedure is designed to upgrade the data grid itself, and does not upgrade the client application.

Important

Ensure that the correct version of the Hot Rod protocol is used with your JBoss Data Grid version:

- For JBoss Data Grid 6.1, use Hot Rod protocol version 1.2
- For JBoss Data Grid 6.2, use Hot Rod protocol version 1.3
- For JBoss Data Grid 6.3, use Hot Rod protocol version 2.0
- For JBoss Data Grid 6.4, use Hot Rod protocol version 2.0

Prerequisite

This procedure assumes that a cluster is already configured and running, and that it is using an older version of JBoss Data Grid. This cluster is referred to below as the Source Cluster and the Target Cluster refers to the new cluster to which data will be migrated.

1. **Configure the Target Cluster**

   Use either different network settings or a different JGroups cluster name to set the Target Cluster (consisting of nodes with new JBoss Data Grid) apart from the Source Cluster. For each cache, configure a **`RemoteCacheStore`** with the following settings:

   a. Ensure that ***`remote-server`*** points to the Source Cluster.

   b. Ensure that the cache name matches the name of the cache on the Source Cluster.

   c. Ensure that ***`hotrod-wrapping`*** is enabled (set to **`true`**).

   d. Ensure that ***`purge`*** is disabled (set to **`false`**).

   e. Ensure that ***`passivation`*** is disabled (set to **`false`**).

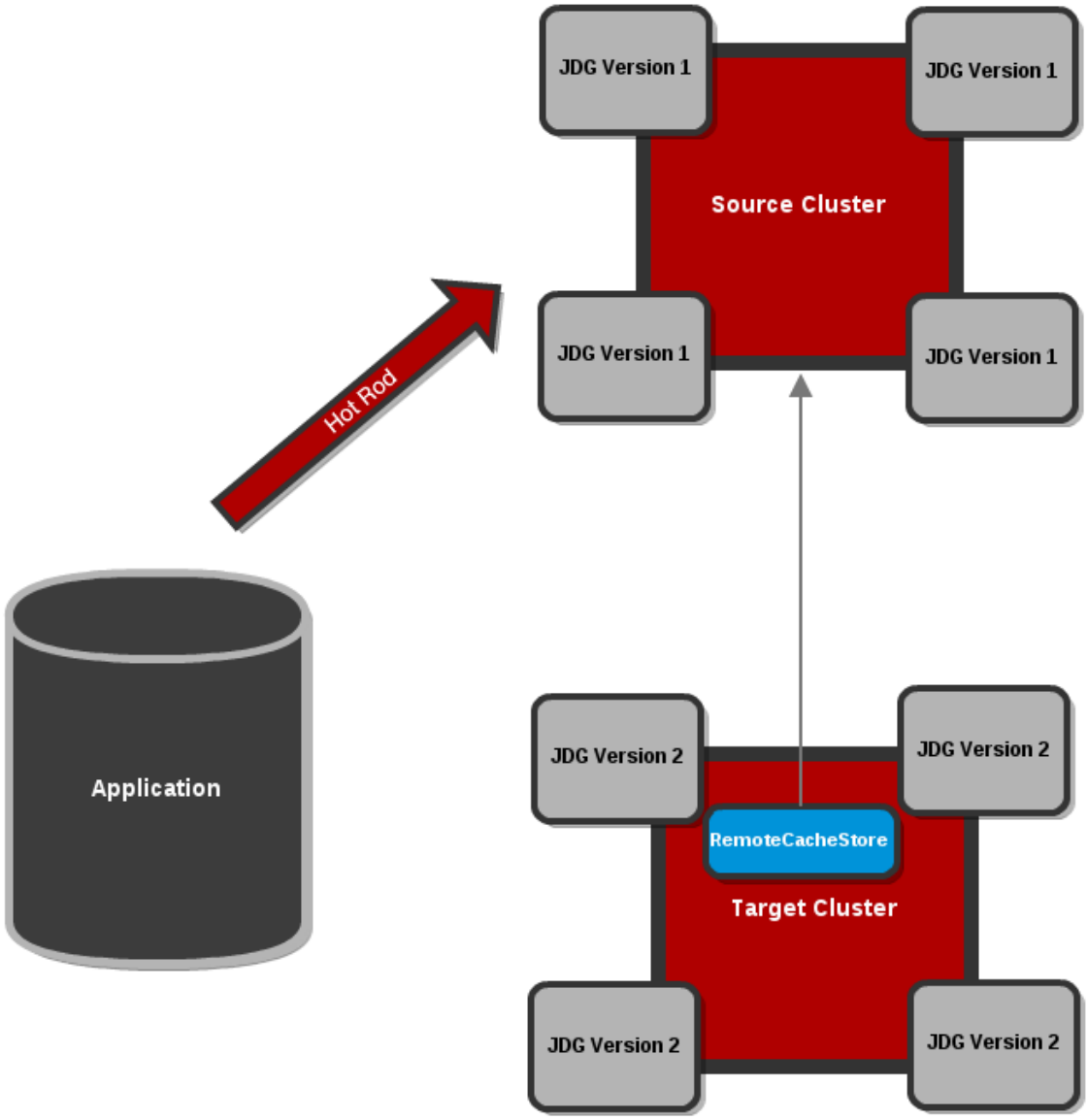


Figure 13.1. Configure the Target Cluster with a RemoteCacheStore

Note

See the **`$JDG_HOME/docs/examples/configs/standalone-hotrod-rolling-upgrade.xml`** file for a full example of the Target Cluster configuration for performing Rolling Upgrades.

2. **Start the Target Cluster**

   Start the Target Cluster's nodes. Configure each client to point to the Target Cluster instead of the Source Cluster. Eventually, the Target Cluster handles all requests instead of the Source Cluster. The Target Cluster then lazily loads data from the Source Cluster on demand using the **`RemoteCacheStore`**.

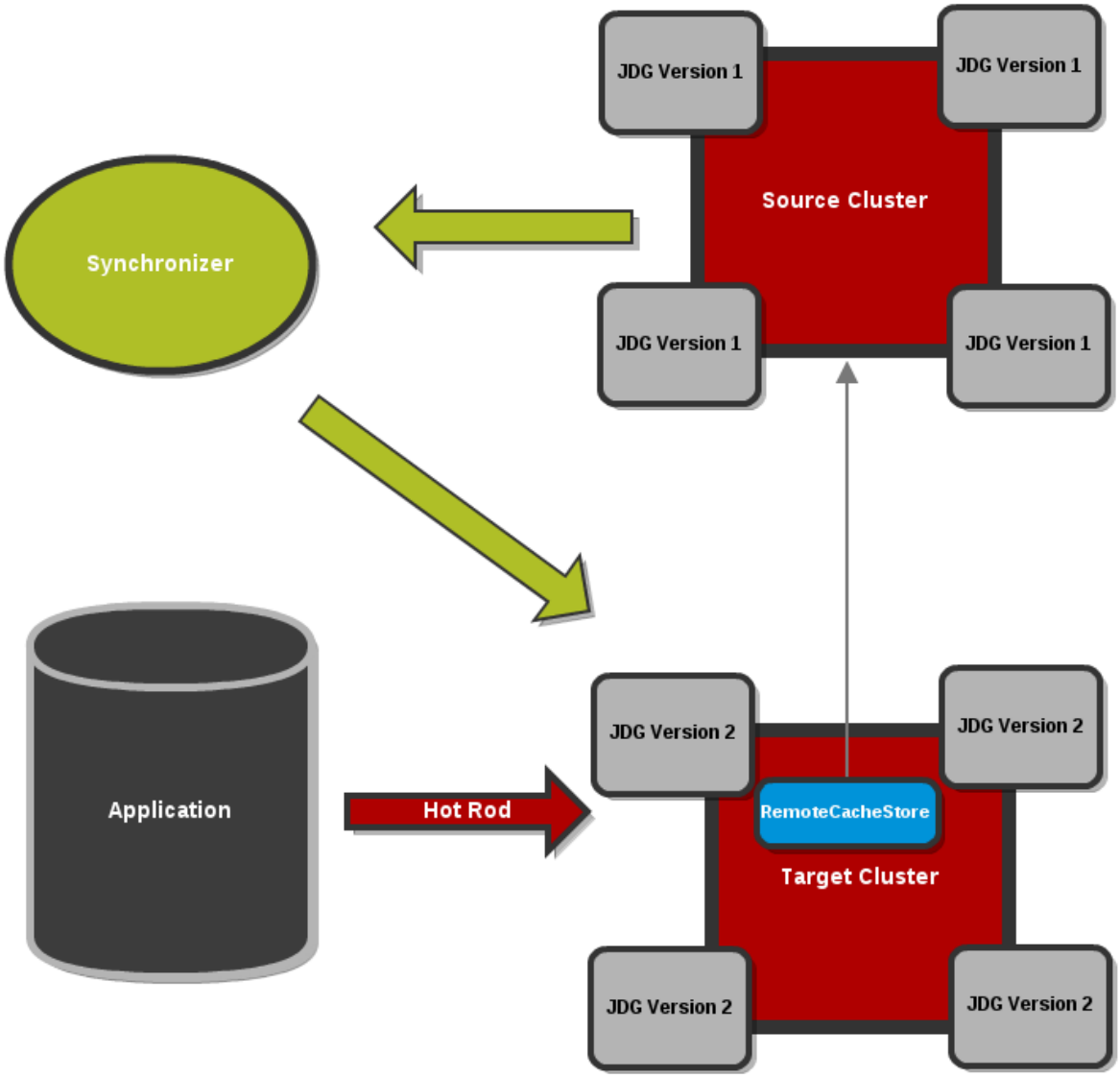


Figure 13.2. Clients point to the Target Cluster with the Source Cluster as `RemoteCacheStore` for the Target Cluster.

3. **Dump the Source Cluster keyset**

   When all connections are using the Target Cluster, the keyset on the Source Cluster must be dumped. This can be done using either JMX or the CLI:

   A. **JMX**

      Invoke the ***`recordKnownGlobalKeyset`*** operation on the **`RollingUpgradeManager`** MBean on the Source Cluster for every cache that must be migrated.

   B. **CLI**

      Invoke the **`upgrade --dumpkeys`** command on the Source Cluster for every cache that must be migrated, or use the **`--all`** switch to dump all caches in the cluster.

4. **Fetch remaining data from the Source Cluster**

   The Target Cluster fetches all remaining data from the Source Cluster. Again, this can be done using either JMX or CLI:

A. **JMX**

Invoke the ***synchronizeData*** operation and specify the ***hotrod*** parameter on the **RollingUpgradeManager** MBean on the Target Cluster for every cache that must be migrated.

B. **CLI**

Invoke the **upgrade --synchronize=hotrod** command on the Target Cluster for every cache that must be migrated, or use the **--all** switch to synchronize all caches in the cluster.

5. **Disabling the RemoteCacheStore**

Once the Target Cluster has obtained all data from the Source Cluster, the **RemoteCacheStore** on the Target Cluster must be disabled. This can be done as follows:

A. **JMX**

Invoke the **disconnectSource** operation specifying the ***hotrod*** parameter on the **RollingUpgradeManager** MBean on the Target Cluster.

B. **CLI**

Invoke the **upgrade --disconnectsource=hotrod** command on the Target Cluster.

6. **Decommission the Source Cluster**

As a final step, decommission the Source Cluster.

Report a bug

13.2. Rolling Upgrades Using REST

The following procedure outlines using Red Hat JBoss Data Grid installations as a remote grid using the REST protocol. This procedure applies to rolling upgrades for the grid, not the client application.

Procedure 13.1. Perform Rolling Upgrades Using REST

In the instructions, the Source Cluster refers to the old cluster that is currently in use and the Target Cluster refers to the destination cluster for our data.

1. **Configure the Target Cluster**

Use either different network settings or a different JGroups cluster name to set the Target Cluster (consisting of nodes with new JBoss Data Grid) apart from the Source Cluster. For each cache, configure a **RestCacheStore** with the following settings:

a. Ensure that the host and port values point to the Source Cluster.

b. Ensure that the path value points to the Source Cluster's REST endpoint.

2. **Start the Target Cluster**

Start the Target Cluster's nodes. Configure each client to point to the Target Cluster instead of the Source Cluster. Eventually, the Target Cluster handles all requests instead of the Source Cluster. The Target Cluster then lazily loads data from the Source Cluster on demand using the **`RestCacheStore`**.

3. **Do not dump the Key Set during REST Rolling Upgrades**

   The REST Rolling Upgrades use case is designed to fetch all the data from the Source Cluster without using the **`recordKnownGlobalKeyset`** operation.

   Warning

   Do not invoke the **`recordKnownGlobalKeyset`** operation for REST Rolling Upgrades. If you invoke this operation, it will cause data corruption and REST Rolling Upgrades will not complete successfully.

4. **Fetch the Remaining Data**

   The Target Cluster must fetch all the remaining data from the Source Cluster. This is done either using JMX or the CLI as follows:

   a. **Using JMX**

      Invoke the **`synchronizeData`** operation with the **`rest`** parameter specified on the **`RollingUpgradeManager`** MBean on the Target Cluster for all caches to be migrated.

   b. **Using the CLI**

      Run the **`upgrade --synchronize=rest`** on the Target Cluster for all caches to be migrated. Optionally, use the ***`--all`*** switch to synchronize all caches in the cluster.

5. **Disable the RestCacheStore**

   Disable the **`RestCacheStore`** on the Target Cluster using either JMX or the CLI as follows:

   a. **Using JMX**

      Invoke the **`disconnectSource`** operation with the **`rest`** parameter specified on the **`RollingUpgradeManager`** MBean on the Target Cluster.

   b. **Using the CLI**

      Run the **`upgrade --disconnectsource=rest`** command on the Target Cluster. Optionally, use the ***`--all`*** switch to disconnect all caches in the cluster.

Result

Migration to the Target Cluster is complete. The Source Cluster can now be decommissioned.

Report a bug

13.3. RollingUpgradeManager Operations

The **`RollingUpgradeManager`** Mbean handles the operations that allow data to be migrated from one version of Red Hat JBoss Data Grid to another when performing rolling upgrades. The **`RollingUpgradeManager`** operations are:

- ***`recordKnownGlobalKeyset`*** retrieves the entire keyset from the cluster running on the old version of JBoss Data Grid.
- ***`synchronizeData`*** performs the migration of data from the Source Cluster to the Target Cluster, which is running the new version of JBoss Data Grid.
- ***`disconnectSource`*** disables the Source Cluster, the older version of JBoss Data Grid, once data migration to the Target Cluster is complete.

Report a bug

13.4. RemoteCacheStore Parameters for Rolling Upgrades

13.4.1. rawValues and RemoteCacheStore

By default, the RemoteCacheStore store's values are wrapped in InternalCacheEntry. Enabling the ***`rawValues`*** parameter causes the raw values to be stored instead for interoperability with direct access by RemoteCacheManagers.

`rawValues` must be enabled in order to interact with a Hot Rod cache via both RemoteCacheStore and RemoteCacheManager.

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13.4.2. hotRodWrapping

The ***`hotRodWrapping`*** parameter is a shortcut that enables rawValues and sets an appropriate marshaller and entry wrapper for performing Rolling Upgrades.

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Chapter 14. MapReduce

The Red Hat JBoss Data Grid MapReduce model is an adaptation of Google's **MapReduce** model.

MapReduce is a programming model used to process and generate large data sets. It is typically used in distributed computing environments where nodes are clustered. In JBoss Data Grid, MapReduce allows transparent distributed processing of large amounts of data across the grid. It does this by performing computations locally where the data is stored whenever possible.

MapReduce uses the two distinct computational phases of map and reduce to process information requests through the data grid. The process occurs as follows:

1. The user initiates a task on a cache instance, which runs on a cluster node (the master node).
2. The master node receives the task input, divides the task, and sends tasks for map phase execution on the grid.
3. Each node executes a **Mapper** function on its input, and returns intermediate results back to the master node.
    A. If the ***useIntermediateSharedCache*** parameter is set to **"true"**, the map results are inserted in an intermediary cache, rather than being returned to the master node.
    B. If a **Combiner** has been specified with ***task.combinedWith(combiner)***, the **Combiner** is called on the **Mapper** results and the combiner's results are returned to the master node or inserted in the intermediary cache.

Note

Combiners are not required but can only be used when the function is both commutative (changing the order of the operands does not change the results) and associative (the order in which the operations are performed does not matter as long as the sequence of the operands is not changed). Combiners are advantageous to use because they can improve the speeds of MapReduceTask executions.

4. The master node collects all intermediate results from the map phase and merges all intermediate values associated with the same intermediate key.
    A. If the ***distributedReducePhase*** parameter is set to **true**, the merging of the intermediate values is done on each node, as the **Mapper** or **Combiner** results are inserted in the intermediary cache.The master node only receives the intermediate keys.
5. The master node sends intermediate key/value pairs for reduction on the grid.
    A. If the ***distributedReducePhase*** parameter is set to **"false"**, the reduction phase is executed only on the master node.
6. The final results of the reduction phase are returned. Optionally specify the target cache for the results using the instructions in Section 14.1.2, “Specify the Target Cache”.
    A. If the ***distributedReducePhase*** parameter is set to **"true"**, the master node running the task receives all results from the reduction phase and returns the final result to the MapReduce task initiator.

B. If no target cache is specified and no collator is specified (using ***task.execute(Collator)***), the result map is returned to the master node.

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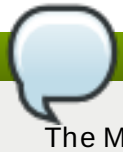
14.1. The MapReduce API

In Red Hat JBoss Data Grid, each MapReduce task has five main components:

- **Mapper**
- **Reducer**
- **Collator**
- **MapReduceTask**
- **Combiners**

The **Mapper** class implementation is a component of **MapReduceTask**, which is invoked once per input cache entry key/value pair. **Map** is a process of applying a given function to each element of a list, returning a list of results.

Each node in the JBoss Data Grid executes the **Mapper** on a given cache entry key/value input pair. It then transforms this cache entry key/value pair into an intermediate key/value pair, which is emitted into the provided **Collector** instance.



Note

The MapReduceTask requires a Mapper and a Reducer but using a Collator or Combiner is optional.

Example 14.1. Executing the Mapper

```
public interface Mapper<KIn, VIn, KOut, VOut> extends Serializable {

   /**
    * Invoked once for each input cache entry KIn,VOut pair.
    */
   void map(KIn key, VIn value, Collector<KOut, VOut> collector);
```

At this stage, for each output key there may be multiple output values. The multiple values must be reduced to a single value, and this is the task of the **Reducer**. JBoss Data Grid's distributed execution environment creates one instance of **Reducer** per execution node.

Example 14.2. Reducer

```
public interface Reducer<KOut, VOut> extends Serializable {

   /**
    * Combines/reduces all intermediate values for a particular
```

```
intermediate key to a single value.
     * <p>
     *
     */
    VOut reduce(KOut reducedKey, Iterator<VOut> iter);

}
```

The same **Reducer** interface is used for **Combiners**. A **Combiner** is similar to a **Reducer**, except that it must be able to work on partial results. The **Combiner** is executed on the results of the **Mapper**, on the same node, without considering the other nodes that might have generated values for the same intermediate key.

Note

Combiners are not required but can only be used when the function is both commutative (changing the order of the operands does not change the results) and associative (the order in which the operations are performed does not matter as long as the sequence of the operands is not changed). Combiners are advantageous to use because they can improve the speeds of MapReduceTask executions.

As **Combiners** only see a part of the intermediate values, they cannot be used in all scenarios, however when used they can reduce network traffic and memory consumption in the intermediate cache significantly.

The **Collator** coordinates results from **Reducers** that have been executed on JBoss Data Grid, and assembles a final result that is delivered to the initiator of the **MapReduceTask**. The **Collator** is applied to the final map key/value result of **MapReduceTask**.

Example 14.3. Assembling the Result

```
public interface Collator<KOut, VOut, R> {
    /**
     * Collates all reduced results and returns R to invoker of
distributed task.
     *
     * @return final result of distributed task computation
     */
    R collate(Map<KOut, VOut> reducedResults);
```

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14.1.1. MapReduceTask

In Red Hat JBoss Data Grid, **MapReduceTask** is a distributed task, which unifies the **Mapper**, **Combiner**, **Reducer**, and **Collator** components into a cohesive computation, which can be parallelized and executed across a large-scale cluster.

These components can be specified with a fluent API. However,as most of them are serialized and executed on other nodes, using inner classes is not recommended.

Example 14.4. Specifying MapReduceTask Components

```
new MapReduceTask(cache)
      .mappedWith(new MyMapper())
      .combinedWith(new MyCombiner())
      .reducedWith(new MyReducer())
      .execute(new MyCollator());
```

MapReduceTask requires a cache containing data that will be used as input for the task. The JBoss Data Grid execution environment will instantiate and migrate instances of provided **Mappers** and **Reducers** seamlessly across the nodes.

By default, all available key/value pairs of a specified cache will be used as input data for the task. This can be modified by using the ***onKeys*** method as an input key filter.

There are two **MapReduceTask** constructor parameters that determine how the intermediate values are processed:

- ***distributedReducePhase*** - When set to **false**, the default setting, the reducers are only executed on the master node. If set to **true**, the reducers are executed on every node in the cluster.
- ***useIntermediateSharedCache*** - Only important if ***distributedReducePhase*** is set to **true**. If **true**, which is the default setting, this task will share intermediate value cache with other executing MapReduceTasks on the grid. If set to **false**, this task will use its own dedicated cache for intermediate values.

Note

The default timeout for **MapReduceTask** is 0 (zero). That is, the task will wait indefinitely for its completion by default.

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14.1.2. Specify the Target Cache

Red Hat JBoss Data Grid's MapReduce implementation allows users to specify a target cache to store the results of an executed task. The results are available after the execute method (which is synchronous) is complete.

This variant of the execute method prevents the master JVM node from exceeding its allows maximum heap size. This is especially relevant if objects that are the results of the reduce phase have a large memory footprint or if multiple MapReduceTasks are concurrently executing on the master task node.

Use the following method of MapReduceTask to specify a Cache object to store the results:

```
public void execute(Cache<KOut, VOut> resultsCache) throws
CacheException
```

Use the following method of MapReduceTask to specify a name for the target cache:

```
public void execute(String resultsCache) throws CacheException
```

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14.1.3. Mapper and CDI

The **Mapper** is invoked with appropriate input key/value pairs on an executing node, however Red Hat JBoss Data Grid also provides a CDI injection for an input cache. The CDI injection can be used where additional data from the input cache is required in order to complete map transformation.

When the **Mapper** is executed on a JBoss Data Grid executing node, the JBoss Data Grid CDI module provides an appropriate cache reference, which is injected to the executing **Mapper**. To use the JBoss Data Grid CDI module with **Mapper**:

1. Declare a cache field in **Mapper**.
2. Annotate the cache field **Mapper** with **@org.infinispan.cdi.Input**.
3. Annotate with mandatory **@Inject annotation**.

Example 14.5. Using a CDI Injection

```
public class WordCountCacheInjecterMapper implements Mapper<String,
String, String, Integer> {

   @Inject
   @Input
   private Cache<String, String> cache;

   @Override
   public void map(String key, String value, Collector<String,
Integer> collector) {

      //use injected cache if needed
      StringTokenizer tokens = new StringTokenizer(value);
      while (tokens.hasMoreElements()) {
         for(String token : value.split("\\w")) {
            collector.emit(token, 1);
         }
      }
   }
}
```

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14.2. MapReduceTask Distributed Execution

MapReduceTask is a distributed task that allows a large-scale computation to be transparently parallelized across Red Hat JBoss Data Grid cluster nodes. MapReduceTask can be instantiated with a reference to a cache containing data that is used as input for this task. JBoss Data Grid's execution environment can migrate and execute instances of provided **Mapper** and **Reducer** seamlessly across JBoss Data Grid nodes.

MapReduceTask distributed execution distributes the reduce phase execution. Previously, the reduce phase was performed on a single master task node. This limitation has been removed, and the reduce phase execution can now be distributed across the cluster also. The distribution of reduce phase is achieved by relying on consistent hashing.

It is still possible to use MapReduceTask with the reduce phase performed on a single node, and this is recommended for smaller input tasks.

Distributed Execution of the MapReduceTask occurs in three phases:

- Mapping phase.
- Outgoing Key and Outgoing Value Migration.
- Reduce phase.

Map Phase

MapReduceTask hashes task input keys and groups them by the execution node that they are hashed to. After key node mapping, MapReduceTask sends a map function and inputs keys to each node. The map function is invoked using given keys and locally loaded corresponding values.

Results are collected with a Red Hat JBoss Data Grid supplied Collector, and the combine phase is initiated. A Combiner, if specified, takes KOut keys and immediately invokes the reduce phase on keys. The result of mapping phase executed on each node is KOut/VOut map. There is one resulting map per execution node per launched MapReduceTask.

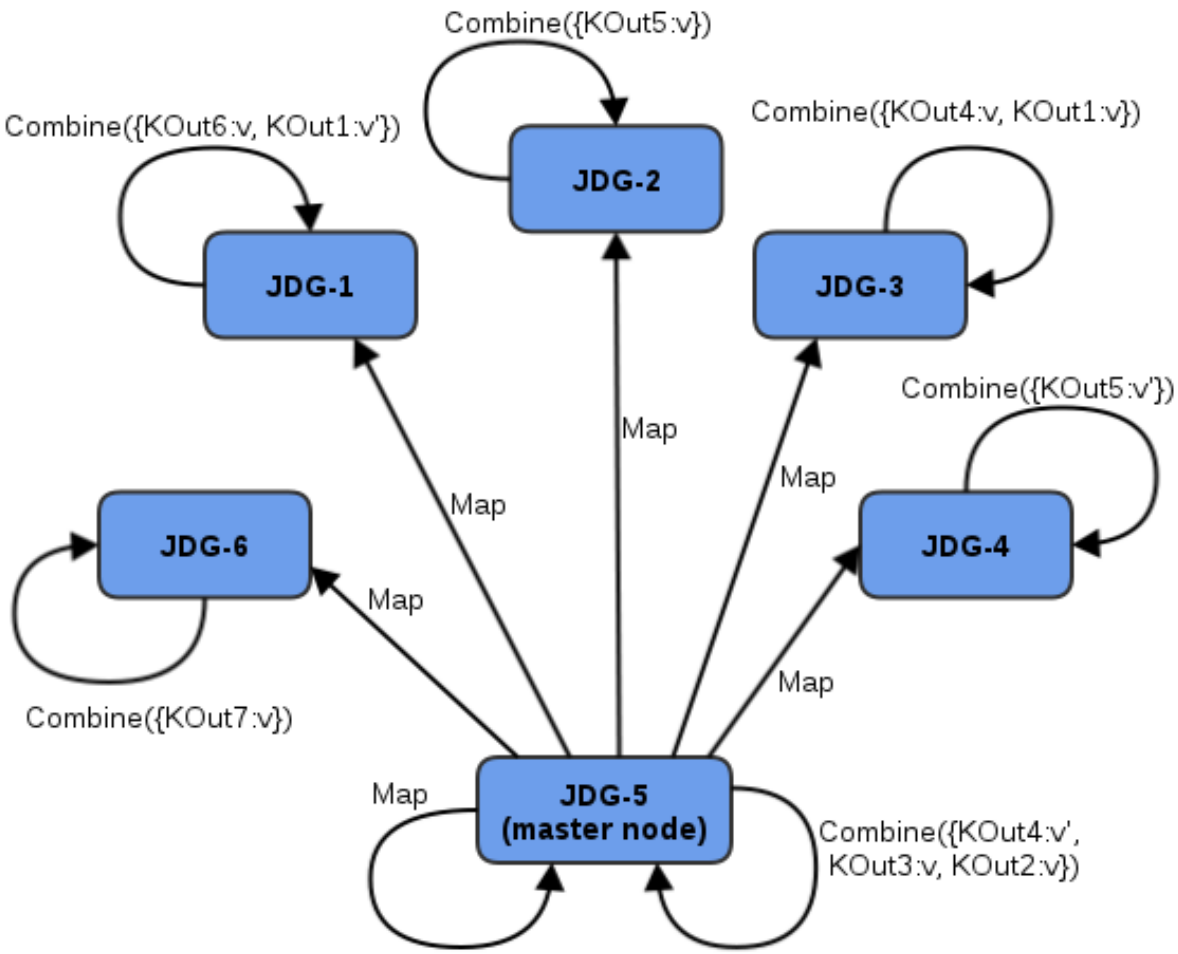

Figure 14.1. Map Phase

Intermediate KOut/VOut migration phase

In order to proceed with reduce phase, all intermediate keys and values must be grouped by intermediate KOut keys. As map phases around the cluster can produce identical intermediate keys, all identical intermediate keys and their values must be grouped before reduce is executed on any particular intermediate key.

At the end of the combine phase, each intermediate KOut key is hashed and migrated with its VOut values to the JBoss Data Grid node where keys KOut are hashed to. This is achieved using a temporary distributed cache and underlying consistent hashing mechanism.

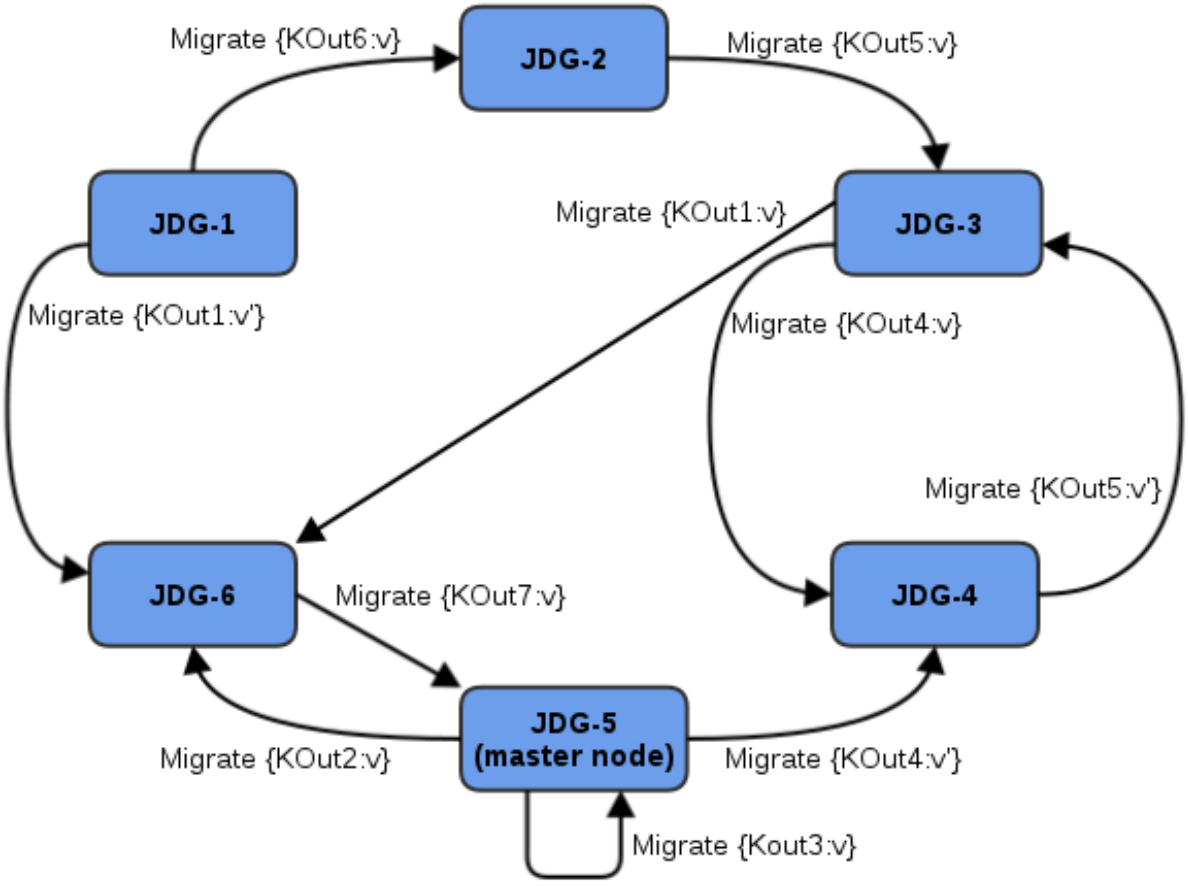

Figure 14.2. Kout/VOut Migration

Once Map and Combine phase have finished execution, a list of KOut keys is returned to a master node and it is initiating MapReduceTask. VOut values are not returned as they are not required at the master task node. MapReduceTask is ready to start with reduce phase.

Reduce Phase

To complete reduce phase, MapReduceTask groups KOut keys by execution node N they are hashed to. For each node and its grouped input KOut keys, MapReduceTask sends a reduce command to a node where KOut keys are hashed. Once the reduce command is executed on the target execution node, it locates the temporary cache belonging to MapReduce task. For each KOut key, the reduce command obtains a list of VOut values, wraps it with an Iterator, and invokes reduce on it.

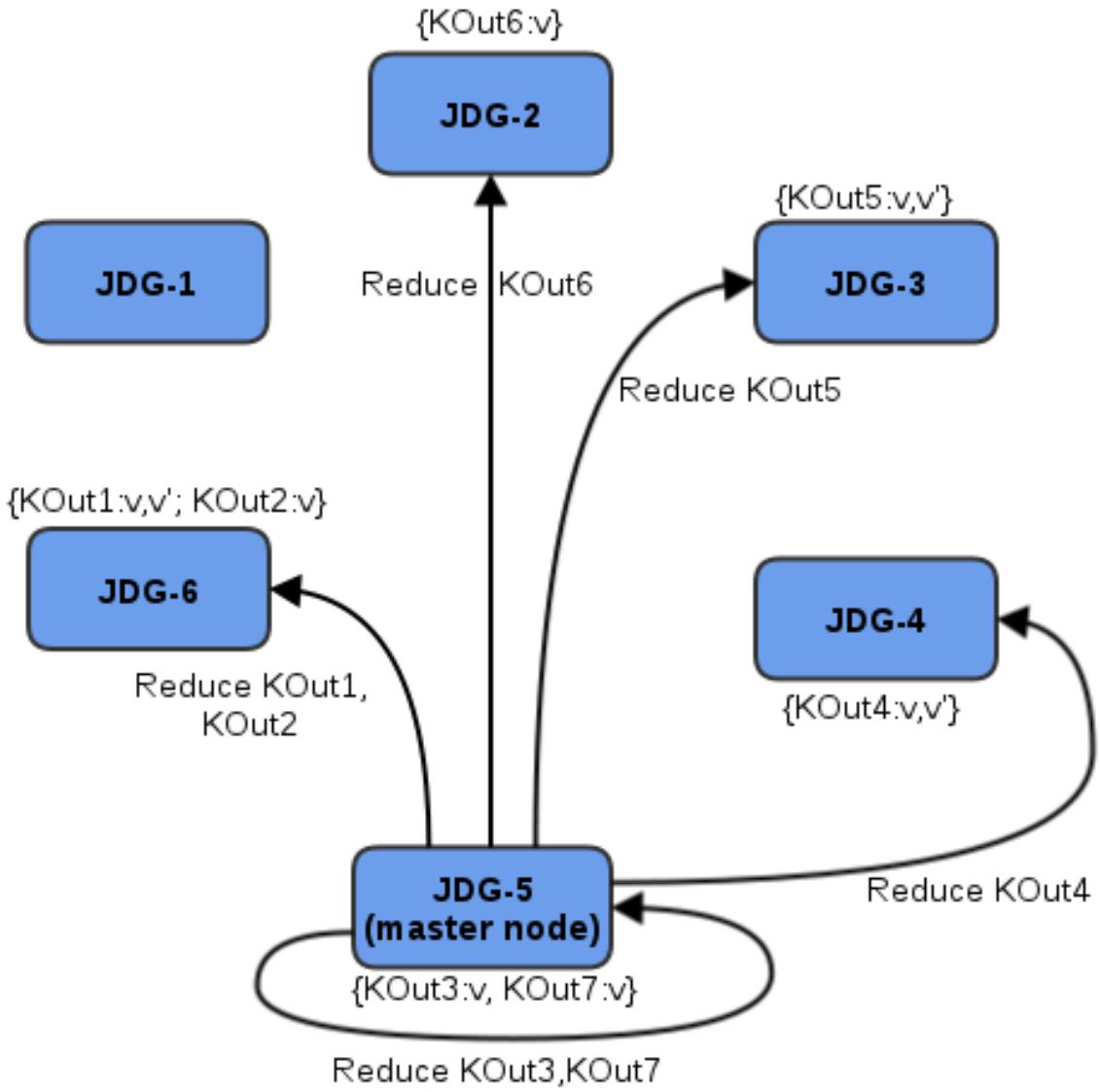

Figure 14.3. Reduce Phase

The result of each reduce is a map where each key is KOut and value is VOut. Each JBoss Data Grid execution node returns one map with KOut/VOut result values. As all initiated reduce commands return to a calling node, MapReduceTask combines all resulting maps into a map and returns the map as a result of MapReduceTask.

Distributed reduce phase is enabled by using a MapReduceTask constructor specifying the cache to use as input data for the task and boolean parameter ***`distributeReducePhase`*** set to **`true`**. For more information, see the Map/Reduce section of the *Red Hat JBoss Data Grid API Documentation*.

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14.3. Map Reduce Example

The following example uses a word count application to demonstrate MapReduce and its distributed task abilities.

This example assumes we have a mapping of the key sentence stored on JBoss Data Grid nodes.

- Key is a String.
- Each sentence is a String.

All words that appear in all sentences must be counted.

Example 14.6. Implementing the Distributed Task

```
public class WordCountExample {

   /**
    * In this example replace c1 and c2 with
    * real Cache references
    *
    * @param args
    */
   public static void main(String[] args) {
      Cache c1 = null;
      Cache c2 = null;

      c1.put("1", "Hello world here I am");
      c2.put("2", "Infinispan rules the world");
      c1.put("3", "JUDCon is in Boston");
      c2.put("4", "JBoss World is in Boston as well");
      c1.put("12","WildFly");
      c2.put("15", "Hello world");
      c1.put("14", "Infinispan community");
      c2.put("15", "Hello world");

      c1.put("111", "Infinispan open source");
      c2.put("112", "Boston is close to Toronto");
      c1.put("113", "Toronto is a capital of Ontario");
      c2.put("114", "JUDCon is cool");
      c1.put("211", "JBoss World is awesome");
      c2.put("212", "JBoss rules");
      c1.put("213", "JBoss division of RedHat ");
      c2.put("214", "RedHat community");

      MapReduceTask<String, String, String, Integer> t =
         new MapReduceTask<String, String, String, Integer>(c1);
      t.mappedWith(new WordCountMapper())
         .reducedWith(new WordCountReducer());
      Map<String, Integer> wordCountMap = t.execute();
   }

   static class WordCountMapper implements
Mapper<String,String,String,Integer> {
      /** The serialVersionUID */
      private static final long serialVersionUID = -
5943370243108735560L;

      @Override
      public void map(String key, String value, Collector<String,
Integer> collector) {
         StringTokenizer tokens = new StringTokenizer(value);
```

```
   for(String token : value.split("\\w")) {
            collector.emit(token, 1);
            }
      }
}

   static class WordCountReducer implements Reducer<String, Integer> {
      /** The serialVersionUID */
      private static final long serialVersionUID =
1901016598354633256L;

      @Override
      public Integer reduce(String key, Iterator<Integer> iter) {
         int sum = 0;
         while (iter.hasNext()) {
            Integer i = (Integer) iter.next();
            sum += i;
         }
         return sum;
      }
   }
}
```

In this second example, a ***Collator*** is defined, which will transform the result of MapReduceTask Map<KOut,VOut> into a String that is returned to a task invoker. The ***Collator*** is a transformation function applied to a final result of MapReduceTask.

Example 14.7. Defining the *Collator*

```
MapReduceTask<String, String, String, Integer> t = new
MapReduceTask<String, String, String, Integer>(cache);
t.mappedWith(new WordCountMapper()).reducedWith(new
WordCountReducer());
String mostFrequentWord = t.execute(
      new Collator<String,Integer,String>() {

         @Override
         public String collate(Map<String, Integer> reducedResults) {
            String mostFrequent = "";
            int maxCount = 0;
            for (Entry<String, Integer> e : reducedResults.entrySet())
{
               Integer count = e.getValue();
               if(count > maxCount) {
                  maxCount = count;
                  mostFrequent = e.getKey();
               }
            }
         return mostFrequent;
         }

      });
System.out.println("The most frequent word is " + mostFrequentWord);
```

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Chapter 15. Distributed Execution

Red Hat JBoss Data Grid provides distributed execution through a standard JDK **`ExecutorService`** interface. Tasks submitted for execution are executed on an entire cluster of JBoss Data Grid nodes, rather than being executed in a local JVM.

JBoss Data Grid's distributed task executors can use data from JBoss Data Grid cache nodes as input for execution tasks. As a result, there is no need to configure the cache store for intermediate or final results. As input data in JBoss Data Grid is already load balanced, tasks are also automatically balanced, therefore there is no need to explicitly assign tasks to specific nodes.

In JBoss Data Grid's distributed execution framework:

- Each **`DistributedExecutorService`** is bound to a single cache. Tasks submitted have access to key/value pairs from that particular cache if the task submitted is an instance of **`DistributedCallable`**.
- Every **`Callable`**, **`Runnable`**, and/or **`DistributedCallable`** submitted must be either **`Serializable`** or **`Externalizable`**, in order to prevent task migration to other nodes each time one of these tasks is performed. The value returned from a **`Callable`** must also be **`Serializable`** or **`Externalizable`**.

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15.1. DistributedCallable API

The **`DistributedCallable`** interface is a subtype of the existing **`Callable`** from *java.util.concurrent.package*, and can be executed in a remote JVM and receive input from Red Hat JBoss Data Grid. The **`DistributedCallable`** interface is used to facilitate tasks that require access to JBoss Data Grid cache data.

When using the **`DistributedCallable`** API to execute a task, the task's main algorithm remains unchanged, however the input source is changed.

Users who have already implemented **`Callable`** interface to describe task units must extend **`DistributedCallable`** and use keys from JBoss Data Grid execution environment as input for the task.

Example 15.1. Using the `DistributedCallable` API

```
public interface DistributedCallable<K, V, T> extends Callable<T> {

   /**
    * Invoked by execution environment after DistributedCallable
    * has been migrated for execution to a specific Infinispan node.
    *
    * @param cache
    *           cache whose keys are used as input data for this
    *           DistributedCallable task
    * @param inputKeys
    *           keys used as input for this DistributedCallable task
    */
   public void setEnvironment(Cache<K, V> cache, Set<K> inputKeys);

}
```

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15.2. Callable and CDI

Where **DistributedCallable** cannot be implemented or is not appropriate, and a reference to input cache used in **DistributedExecutorService** is still required, there is an option to inject the input cache by CDI mechanism.

When the **Callable** task arrives at a Red Hat JBoss Data Grid executing node, JBoss Data Grid's CDI mechanism provides an appropriate cache reference, and injects it to the executing **Callable**.

To use the JBoss Data Grid CDI with **Callable**:

1. Declare a ***Cache*** field in **Callable** and annotate it with ***org.infinispan.cdi.Input***
2. Include the mandatory ***@Inject*** annotation.

Example 15.2. Using Callable and the CDI

```
public class CallableWithInjectedCache implements Callable<Integer>,
Serializable {

      @Inject
      @Input
      private Cache<String, String> cache;


      @Override
      public Integer call() throws Exception {
        //use injected cache reference
        return 1;
      }
}
```

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15.3. Distributed Task Failover

Red Hat JBoss Data Grid's distributed execution framework supports task failover in the following cases:

- Failover due to a node failure where a task is executing.
- Failover due to a task failure; for example, if a **Callable** task throws an exception.

The failover policy is disabled by default, and **Runnable**, **Callable**, and **DistributedCallable** tasks fail without invoking any failover mechanism.

JBoss Data Grid provides a random node failover policy, which will attempt to execute a part of a **Distributed** task on another random node if one is available.

A random failover execution policy can be specified using the following as an example:

Example 15.3. Random Failover Execution Policy

```
DistributedExecutorService des = new DefaultExecutorService(cache);
DistributedTaskBuilder<Boolean> taskBuilder =
des.createDistributedTaskBuilder(new SomeCallable());
taskBuilder.failoverPolicy(DefaultExecutorService.RANDOM_NODE_FAILOVER)
;
DistributedTask<Boolean> distributedTask = taskBuilder.build();
Future<Boolean> future = des.submit(distributedTask);
Boolean r = future.get();
```

The **`DistributedTaskFailoverPolicy`** interface can also be implemented to provide failover management.

Example 15.4. Distributed Task Failover Policy Interface

```
/**
 * DistributedTaskFailoverPolicy allows pluggable fail over target
selection for a failed remotely
 * executed distributed task.
 *
 */
public interface DistributedTaskFailoverPolicy {

   /**
    * As parts of distributively executed task can fail due to the task
itself throwing an exception
    * or it can be an Infinispan system caused failure (e.g node failed
or left cluster during task
    * execution etc).
    *
    * @param failoverContext
    *           the FailoverContext of the failed execution
    * @return result the Address of the Infinispan node selected for
fail over execution
    */
   Address failover(FailoverContext context);

   /**
    * Maximum number of fail over attempts permitted by this
DistributedTaskFailoverPolicy
    *
    * @return max number of fail over attempts
    */
   int maxFailoverAttempts();
}
```

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15.4. Distributed Task Execution Policy

The **`DistributedTaskExecutionPolicy`** allows tasks to specify a custom execution policy across the Red Hat JBoss Data Grid cluster, by scoping execution of tasks to a subset of nodes.

For example, **`DistributedTaskExecutionPolicy`** can be used to manage task execution in the following cases:

- where a task is to be exclusively executed on a local network site instead of a backup remote network center.
- where only a dedicated subset of a certain JBoss Data Grid rack nodes are required for specific task execution.

Example 15.5. Using Rack Nodes to Execute a Specific Task

```
DistributedExecutorService des = new DefaultExecutorService(cache);
DistributedTaskBuilder<Boolean> taskBuilder =
des.createDistributedTaskBuilder(new SomeCallable());
taskBuilder.executionPolicy(DistributedTaskExecutionPolicy.SAME_RACK);
DistributedTask<Boolean> distributedTask = taskBuilder.build();
Future<Boolean> future = des.submit(distributedTask);
Boolean r = future.get();
```

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15.5. Distributed Execution Example

In this example, parallel distributed execution is used to approximate the value of Pi (π)

1. As shown below, the area of a square is:
   Area of a Square (S) = $4r^2$
2. The following is an equation for the area of a circle:
   Area of a Circle (C) = $\pi \times r^2$
3. Isolate r^2 from the first equation:
   $r^2 = S/4$
4. Inject this value of r^2 into the second equation to find a value for Pi:
   $C = S\pi/4$
5. Isolating π in the equation results in:
   $C = S\pi/4$
   $4C = S\pi$
   $4C/S = \pi$

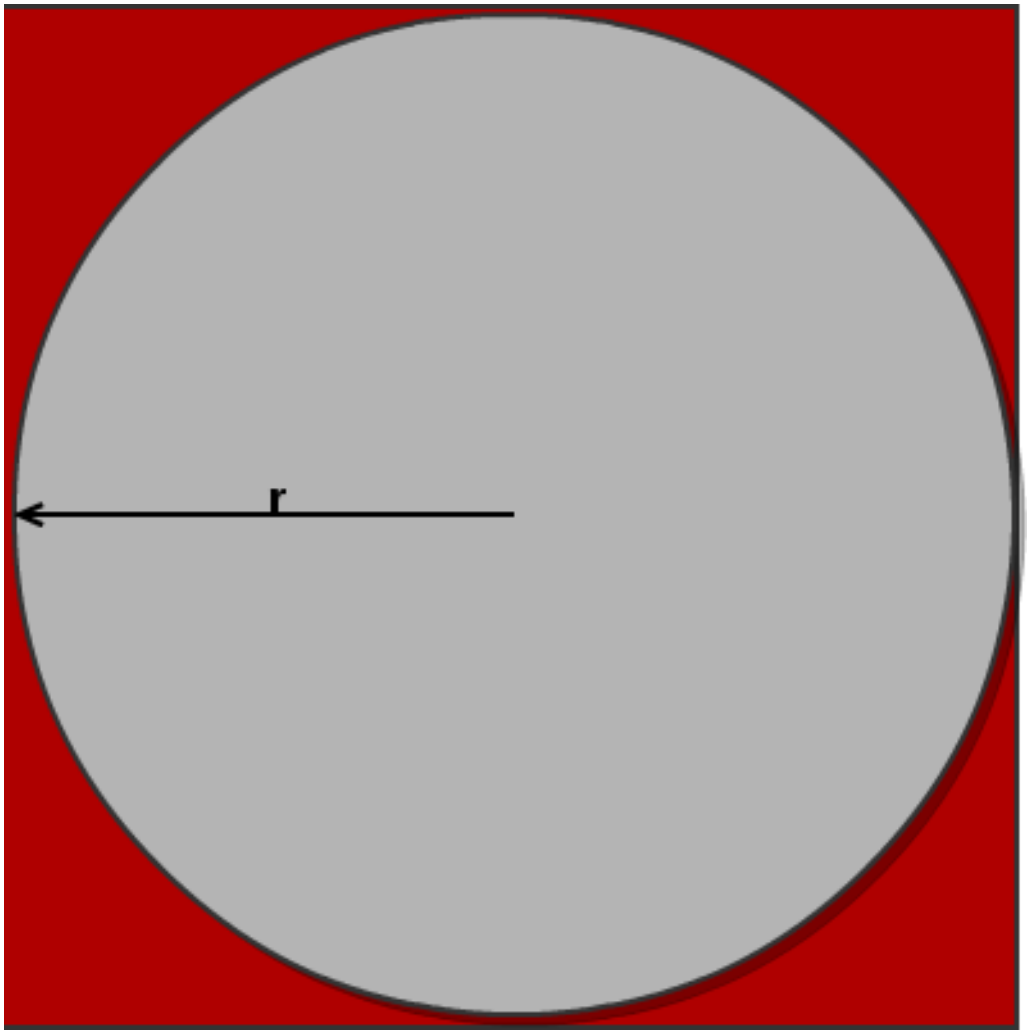

Figure 15.1. Distributed Execution Example

If we now throw a large number of darts into the square, then draw a circle inside the square, and discard all dart throws that landed outside the circle, we can approximate the C/S value.

The value of π is previously worked out to 4C/S. We can use this to derive the approximate value of π. By maximizing the amount of darts thrown, we can derive an improved approximation of π.

In the following example, we throw 10 million darts by parallelizing the dart tossing across the cluster:

Example 15.6. Distributed Execution Example

```
public class PiAppx {

   public static void main (String [] arg){
      List<Cache> caches = ...;
      Cache cache = ...;

      int numPoints = 10000000;
      int numServers = caches.size();
      int numberPerWorker = numPoints / numServers;

      DistributedExecutorService des = new
DefaultExecutorService(cache);
```

```
      long start = System.currentTimeMillis();
      CircleTest ct = new CircleTest(numberPerWorker);
      List<Future<Integer>> results = des.submitEverywhere(ct);
      int countCircle = 0;
      for (Future<Integer> f : results) {
         countCircle += f.get();
      }
      double appxPi = 4.0 * countCircle / numPoints;

      System.out.println("Distributed PI appx is " + appxPi +
      " completed in " + (System.currentTimeMillis() - start) + " ms");
   }

   private static class CircleTest implements Callable<Integer>,
Serializable {

      /** The serialVersionUID */
      private static final long serialVersionUID =
3496135215525904755L;

      private final int loopCount;

      public CircleTest(int loopCount) {
         this.loopCount = loopCount;
      }

      @Override
      public Integer call() throws Exception {
         int insideCircleCount = 0;
         for (int i = 0; i < loopCount; i++) {
            double x = Math.random();
            double y = Math.random();
            if (insideCircle(x, y))
               insideCircleCount++;
         }
         return insideCircleCount;
      }

      private boolean insideCircle(double x, double y) {
         return (Math.pow(x - 0.5, 2) + Math.pow(y - 0.5, 2))
         <= Math.pow(0.5, 2);
      }
   }
}
```

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Chapter 16. Data Interoperability

16.1. Interoperability Between Library and Remote Client-Server Endpoints

Red Hat JBoss Data Grid offers multiple ways to interact with data, for example:

- store and retrieve data in a local (embedded) way
- store and retrieve data remotely using various endpoints

In previous versions of JBoss Data Grid, selecting one of these methods ensured that if one method was used to store data, the same method was required to retrieve it. For example, storing data in embedded mode required retrieval via embedded mode instead of a different method, for example using a REST endpoint.

JBoss Data Grid now offers a compatibility mode to allow users to access data with any interface regardless of the method used to store the data. In compatibility mode, the data format is automatically converted for each endpoint, which allows information to be stored and retrieved using different interfaces.

JBoss Data Grid's compatibility mode makes the following assumption about data: the most common use for compatibility mode is to store Java objects. As a result, when enabled, compatibility mode unmarshalls or deserializes data when storing it. This results in increased efficiency when using Java objects with an embedded cache.

Compatibility mode comes at a higher performance cost than non-compatibility mode. As a result, this feature is disabled by default in JBoss Data Grid.

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16.2. Using Compatibility Mode

Red Hat JBoss Data Grid's compatibility mode requires the following to work as expected:

- all endpoints configurations specify the same cache manager
- all endpoints can interact with the same target cache

Using JBoss Data Grid's Remote Client-Server distribution ensures that these requirements are configured by default.

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16.3. Protocol Interoperability

Red Hat JBoss Data Grid protocol interoperability allows data in the form of raw bytes to be read/write accessed by different protocols, such as REST, Memcached, library, and Hot Rod, that are written in various programming languages, such as C++ or Java.

By default, each protocol stores data in the most efficient format for that protocol, ensuring transformations are not required when retrieving entries. When this data is required to be accessed from multiple protocols, compatibility mode must be enabled on caches that are being shared.

Enable Compatibility Mode declaratively in Client-Server mode

The **compatibility** element's ***enabled*** parameter is set to **true** or **false** to determine whether compatibility mode is in use.

Example 16.1. Compatibility Mode Enabled

```
<cache-container name="local" default-cache="default"
statistics="true">
    <local-cache name="default" start="EAGER" statistics="true">
        <compatibility enabled="true"/>
    </local-cache>
</cache-container>
```

Enable Compatibility Mode programmatically in Library mode

Use a configurationBuilder with the compatibility mode enabled as follows:

```
ConfigurationBuilder builder = ...
builder.compatibility().enable();
```

Enable Compatibility Mode declaratively in Library mode

The **compatibility** element's ***enabled*** parameter is set to **true** or **false** to determine whether compatibility mode is in use.

```
<namedCache name="compatcache">
 <compatibility enabled="true"/>
</namedCache>
```

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16.3.1. Use Cases and Requirements

The following table outlines typical use cases for data interoperability in Red Hat JBoss Data Grid.

Table 16.1. Compatibility Mode Use Cases

Use Case	Client A (Reader or Writer)	Client B (Write/Read Counterpart of Client A)
1	Memcached	Hot Rod Java
2	REST	Hot Rod Java
3	Memcached	REST
4	Hot Rod Java	Hot Rod C++
5	Embedded	Hot Rod Java
6	REST	Hot Rod C++
7	Memcached	Hot Rod C++

In the provided use cases, marshalling is entirely up to the user. JBoss Data Grid stores a byte[], while the user marshalls or unmarshalls this into meaningful data.

For example, in Use Case 1, interoperability is between a Memcached client (A), and a Hot Rod Java client (B). If Client A wishes to serialize an application-specific Object, such as a **Person** instance, it would use a String as a key.

The following steps apply to all use cases:

Client A Side

1. A uses a third-party marshaller, such as Protobuf or Avro, to serialize the **Person** value into a byte[]. A UTF-8 encoded string must be used as the key (according to Memcached protocol requirements).
2. A writes a key-value pair to the server (key as UTF-8 string, the value as byte arrays).

Client B Side

1. B must read a **Person** for a specific key (String).
2. B serializes the same UTF-8 key into the corresponding byte[].
3. B invokes **get(byte[])**
4. B obtains a byte[] representing the serialized object.
5. B uses the same marshaller as A to unmarshall the byte[] into the corresponding **Person** object.

Note

- In Use Case 4, the Protostream Marshaller, which is included with the Hot Rod Java client, is recommended. For the Hot Rod C++ client, the Protobuf Marshaller from Google (https://developers.google.com/protocol-buffers/docs/overview) is recommended.
- In Use Case 5, the default Hot Rod marshaller can be used.

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16.3.2. Protocol Interoperability Over REST

When data is stored via the REST interface the values are interpreted by embedded, Hot Rod or Memcached clients as a sequence of bytes. Meaning is given to this byte-sequence using the MIME type specified via the "Content-Type" HTTP header, but the content type information is only available to REST clients. No specific interoperability configuration is required for this to occur.

When retrieving data via REST, primitive types stored are read in their primitive format. If a UTF-8 String has been stored via Hot Rod, Embedded, or Memcached, it will be retrieved as String from REST. If custom objects have been serialized and stored via the embedded or remote cache, these can be retrieved as **application/x-java-serialized-object**, **application/xml**, or **application/json**. Any other byte arrays are treated as **application/octet-stream**.

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Revision History

Revision 6.4.0-6	**Tue Jan 27 2015**	**Misha Husnain Ali**

Updated for release.

Revision 6.4.0-5	**Fri Jan 23 2015**	**Gemma Sheldon**

BZ-1182594: Various corrections and changes to Part 1.

Revision 6.4.0-4	**Mon Jan 12 2015**	**Gemma Sheldon**

BZ-1157392: Filtering and converting can be performed in one step (Clustered Listeners).
BZ-1108483: Added section about Remote Event Listeners (Hot Rod).
BZ-1181082: Added warning admonition to REST Rolling Upgrades.

Revision 6.4.0-3	**Tue Nov 18 2014**	**Misha Husnain Ali**

Final version for Beta.

Revision 6.4.0-2	**Thu Nov 13 2014**	**Gemma Sheldon**

BZ-1108482: Added clustered listeners content.

Revision 6.4.0-0	**Wed Sep 24 2014**	**Misha Husnain Ali**

First draft for new release.