Infinispan Guide to Cross-Site Replication

Table of Contents

1. Infinispan Cross-Site Replication . . . 2
   1.1. Cross-Site Replication . . . 2
      1.1.1. Site Masters . . . 2
   1.2. Adding Backups to Caches . . . 3
   1.3. Backup Strategies . . . 3
      1.3.1. Synchronous Backups . . . 3
      1.3.2. Asynchronous Backups . . . 4
      1.3.3. Synchronous vs Asynchronous Backups . . . 4
   1.4. Automatically Taking Backups Offline . . . 4
   1.5. State Transfer . . . 5
   1.6. Client Connections Across Sites . . . 6
      1.6.1. Concurrent Writes and Conflicting Entries . . . 7
   1.7. Expiration and Cross-Site Replication . . . 9
2. Configuring Infinispan for Cross-Site Replication . . . 10
   2.1. Configuring Cluster Transport for Cross-Site Replication . . . 10
      2.1.1. JGroups RELAY2 Stacks . . . 10
      2.1.2. Custom JGroups RELAY2 Stacks . . . 11
   2.2. Adding Backup Locations to Caches . . . 12
   2.3. Backing Up to Caches with Different Names . . . 13
   2.4. Configuring Cross-Site Conflict Resolution . . . 13
   2.5. Verifying Cross-Site Views . . . 14
   2.6. Configuring Hot Rod Clients for Cross-Site Replication . . . 14
3. Performing Cross-Site Replication Operations . . . 16
   3.1. Performing Cross-Site Operations with the CLI . . . 16
      3.1.1. Bringing Backup Locations Offline and Online . . . 16
      3.1.2. Pushing State to Backup Locations . . . 16
   3.2. Performing Cross-Site Operations with the REST API . . . 17
      3.2.1. Getting Status of All Backup Locations . . . 17
      3.2.2. Getting Status of Specific Backup Locations . . . 18
      3.2.3. Taking Backup Locations Offline . . . 18
      3.2.4. Bringing Backup Locations Online . . . 18
      3.2.5. Pushing State to Backup Locations . . . 18
      3.2.6. Canceling State Transfer . . . 19
      3.2.7. Getting State Transfer Status . . . 19
      3.2.8. Clearing State Transfer Status . . . 19
      3.2.9. Modifying Take Offline Conditions . . . 19
      3.2.10. Canceling State Transfer from Receiving Sites . . . 20
      3.2.11. Getting Status of Backup Locations . . . 20

3.2.12. Taking Backup Locations Offline . . . 21
3.2.13. Bringing Backup Locations Online . . . 21
3.2.14. Starting State Transfer . . . 21
3.2.15. Canceling State Transfer . . . 22
3.3. Performing Cross-Site Operations with JMX . . . 22
3.3.1. Configuring Infinispan to Register JMX MBeans . . . 22
3.3.2. Performing Cross-Site Operations . . . 22
4. Monitoring and Troubleshooting Global Infinispan Clusters . . . 24
4.1. Enabling Infinispan Statistics . . . 24
4.2. Enabling Infinispan Metrics . . . 25
4.2.1. Collecting Infinispan Metrics . . . 25
4.3. Configuring Infinispan to Register JMX MBeans . . . 26
4.3.1. JMX MBeans for Cross-Site Replication . . . 26
4.4. Collecting Logs and Troubleshooting Cross-Site Replication . . . 27
4.4.1. Cross-Site Log Messages . . . 28

Find out how Infinispan performs cross-site replication so you can get optimal performance and avoid issues. Learn how to configure Infinispan to back up data to remote clusters. Follow procedures to transfer state from one cluster to another, take sites offline, and so on.

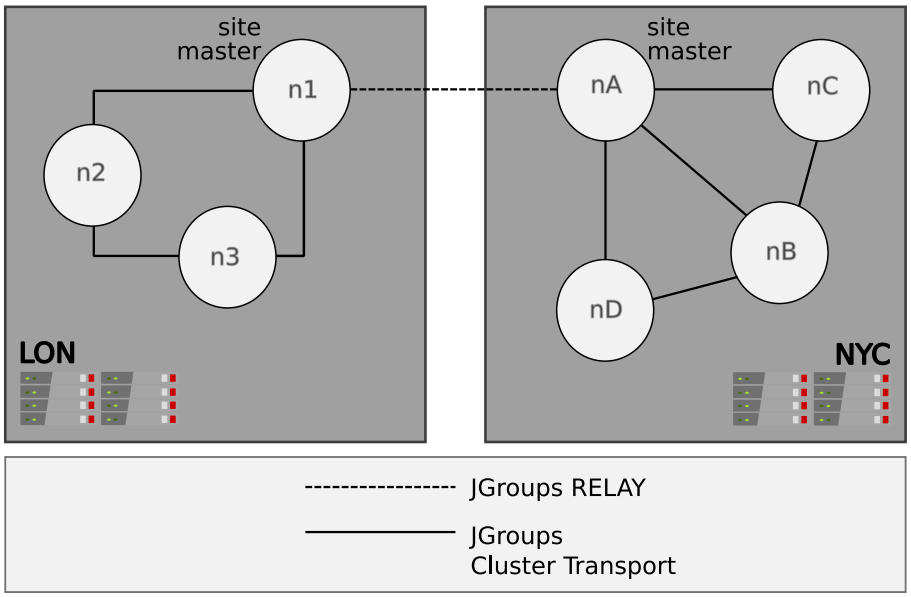
Chapter 1. Infinispan Cross-Site Replication

Cross-site replication allows you to back up data from one Infinispan cluster to another. Learn the concepts to understand how Infinispan cross-site replication works before you configure your clusters.

1.1. Cross-Site Replication

Infinispan clusters running in different locations can discover and communicate with each other.

Sites are typically data centers in various geographic locations. Cross-site replication bridges Infinispan clusters in sites to form global clusters, as in the following diagram:



LON is a datacenter in London, England.
NYC is a datacenter in New York City, USA.

Infinispan can form global clusters across two or more sites.

For example, configure a third Infinispan cluster running in San Francisco, **SFO**, as backup location for **LON** and **NYC**.

1.1.1. Site Masters

Site masters are the nodes in Infinispan clusters that are responsible for sending and receiving requests from backup locations.

If a node is not a site master, it must forward backup requests to a local site master. Only site masters can send requests to backup locations.

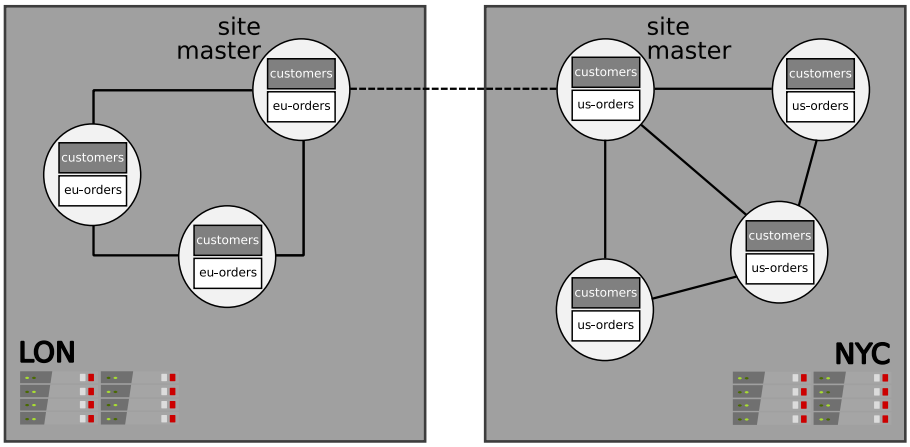
For optimal performance, you should configure all nodes as site masters. This increases the speed of backup requests because each node in the cluster can backup to remote sites directly without having to forward backup requests to site masters.

Diagrams in this document illustrate Infinispan clusters with one site master because this is the default for the JGroups RELAY2 protocol. Likewise, a single site master is easier to illustrate because each site master in a cluster communicates with each site master in the remote cluster.

1.2. Adding Backups to Caches

Name remote sites as backup locations in your cache definitions.

For example, the following diagram shows three caches, "customers", "eu-orders", and "us-orders":



- In **LON**, "customers" names **NYC** as a backup location.
- In **NYC**, "customers" names **LON** as a backup location.
- "eu-orders" and "us-orders" do not have backups and are local to the respective cluster.

1.3. Backup Strategies

Infinispan clusters can use different strategies for backing up data to remote sites.

Infinispan replicates across sites at the same time that writes to local caches occur. For example, if a client writes "k1" to **LON**, Infinispan backs up "k1" to **NYC** at the same time.

1.3.1. Synchronous Backups

When Infinispan replicates data to backup locations, it waits until the operation completes before writing to the local cache.

You can control how Infinispan handles writes to the local cache if backup operations fail. For example, you can configure Infinispan to attempt to abort local writes and throw exceptions if backups to remote sites fail.

Synchronous backups also support two-phase commits with caches that participate in optimistic transactions. The first phase of the backup acquires a lock. The second phase commits the modification.

Two-phase commit with cross-site replication has a significant performance impact because it requires two round-trips across the network.

1.3.2. Asynchronous Backups

When Infinispan replicates data to backup locations, it does not wait until the operation completes before writing to the local cache.

Asynchronous backup operations and writes to the local cache are independent of each other. If backup operations fail, write operations to the local cache continue and no exceptions occur.

1.3.3. Synchronous vs Asynchronous Backups

Synchronous backups offer the strongest guarantee of data consistency across sites. If `strategy=sync`, when `cache.put()` calls return you know the value is up to date in the local cache and in the backup locations.

The trade-off for this consistency is performance. Synchronous backups have much greater latency in comparison to asynchronous backups.

Asynchronous backups, on the other hand, do not add latency to client requests so they have no performance impact. However, if `strategy=async`, when `cache.put()` calls return you cannot be sure of the value in the backup locations is the same as in the local cache.

1.4. Automatically Taking Backups Offline

You can configure backup locations to go offline automatically when the remote sites become unavailable. This prevents Infinispan nodes from continuously attempting to replicate data to offline backup locations, which results in error messages and consumes resources.

Timeout for backup operations

Backup configurations include timeout values for operations to replicate data. If operations do not complete before the timeout occurs, Infinispan records them as failures.

```
<backup site="NYC" strategy="ASYNC" timeout="10000"> ①
    ...
</backup>
```

① Operations to replicate data to **NYC** are recorded as failures if they do not complete after 10 seconds.

Number of failures

You can specify the number of **consecutive** failures that can occur before backup locations go offline.

For example, the following configuration for **NYC** sets five as the number of failed operations before it goes offline:

```
<backup site="NYC" strategy="ASYNC" timeout="10000">
    <take-offline after-failures="5"/> ①
</backup>
```

① If a cluster attempts to replicate data to **NYC** and five consecutive operations fail, Infinispan automatically takes the backup offline.

Time to wait

You can also specify how long to wait before taking sites offline when backup operations fail. If a backup request succeeds before the wait time runs out, Infinispan does not take the site offline.

```
<backup site="NYC" strategy="ASYNC" timeout="10000">
    <take-offline after-failures="5"
                  min-wait="15000"/> ①
</backup>
```

① If a cluster attempts to replicate data to **NYC** and there are five consecutive failures and 15 seconds elapse after the first failed operation, Infinispan automatically takes the backup offline.

Set a negative or zero value for the `after-failures` attribute if you want to use only a minimum time to wait to take sites offline.

```
<take-offline after-failures="-1" min-wait="10000"/>
```

1.5. State Transfer

State transfer is an administrative operation that synchronizes data between sites.

For example, **LON** goes offline and **NYC** starts handling client requests. When you bring **LON** back online, the Infinispan cluster in **LON** does not have the same data as the cluster in **NYC**.

To ensure the data is consistent between **LON** and **NYC**, you can push state from **NYC** to **LON**.

- State transfer is bidirectional. For example, you can push state from **NYC** to **LON** or from **LON** to **NYC**.
- Pushing state to offline sites brings them back online.
- State transfer overwrites only data that exists on both sites, the originating site and the receiving site. Infinispan does not delete data.

  For example, "k2" exists on **LON** and **NYC**. "k2" is removed from **NYC** while **LON** is offline. When you bring **LON** back online, "k2" still exists at that location. If you push state from **NYC** to **LON**, the transfer does not affect "k2" on **LON**.

To ensure contents of the cache are identical after state transfer, remove all data from the cache on the receiving site before pushing state. Use the `clear()` method.

- State transfer does not overwrite updates to data that occur after you initiate the push.

  For example, "k1,v1" exists on **LON** and **NYC**. **LON** goes offline so you push state transfer to **LON** from **NYC**, which brings **LON** back online. Before state transfer completes, a client puts "k1,v2" on **LON**.

  In this case the state transfer from **NYC** does not overwrite "k1,v2" because that modification happened after you initiated the push.

Reference

- org.infinispan.Cache.clear()
- Clearing Caches with the CLI

Run `help clearcache` from the CLI for command details and examples.

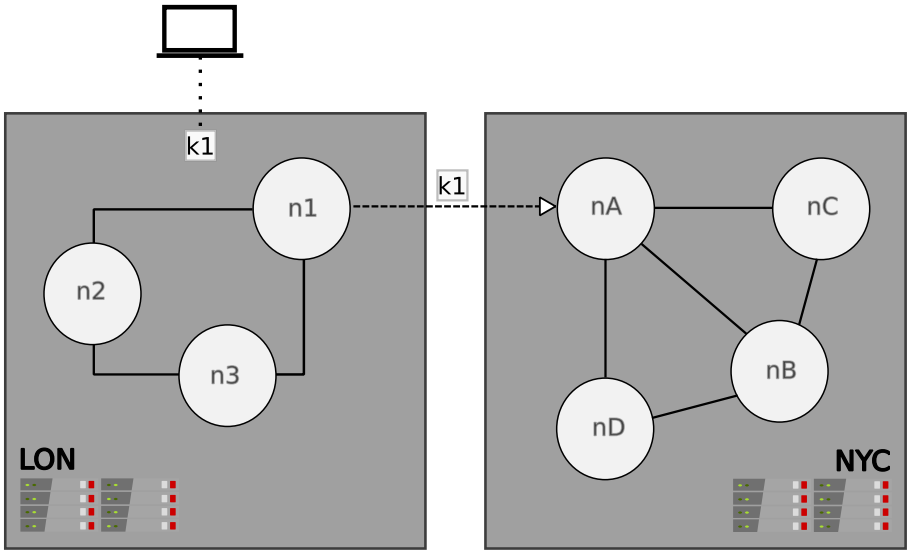
- Clearing Caches with the REST API

1.6. Client Connections Across Sites

Clients can write to Infinispan clusters in either an Active/Passive or Active/Active configuration.

Active/Passive

The following diagram illustrates Active/Passive where Infinispan handles client requests from one site only:



In the preceding image:

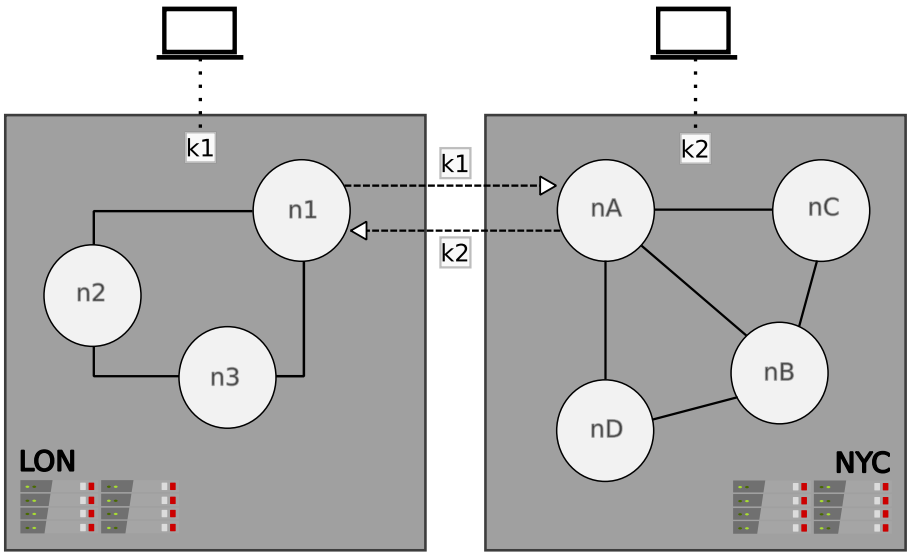
1. Client connects to the Infinispan cluster at **LON**.

2. Client writes "k1" to the cache.
3. The site master at **LON**, "n1", sends the request to replicate "k1" to the site master at **NYC**, "nA".

With Active/Passive, **NYC** provides data redundancy. If the Infinispan cluster at **LON** goes offline for any reason, clients can start sending requests to **NYC**. When you bring **LON** back online you can synchronize data with **NYC** and then switch clients back to **LON**.

Active/Active

The following diagram illustrates Active/Active where Infinispan handles client requests at two sites:



In the preceding image:

1. Client A connects to the Infinispan cluster at **LON**.
2. Client A writes "k1" to the cache.
3. Client B connects to the Infinispan cluster at **NYC**.
4. Client B writes "k2" to the cache.
5. Site masters at **LON** and **NYC** send requests so that "k1" is replicated to **NYC** and "k2" is replicated to **LON**.

With Active/Active both **NYC** and **LON** replicate data to remote caches while handling client requests. If either **NYC** or **LON** go offline, clients can start sending requests to the online site. You can then bring offline sites back online, push state to synchronize data, and switch clients as required.

1.6.1. Concurrent Writes and Conflicting Entries

Conflicting entries can occur with Active/Active site configurations if clients write to the same entries at the same time but at different sites.

For example, client A writes to "k1" in **LON** at the same time that client B writes to "k1" in **NYC**. In this case, "k1" has a different value in **LON** than in **NYC**. After replication occurs, there is no

guarantee which value for "k1" exists at which site.

To ensure data consistency, Infinispan uses a vector clock algorithm to detect conflicting entries during backup operations, as in the following illustration:

```
            LON       NYC

k1=(n/a)    0,0       0,0

k1=2        1,0  -->  1,0   k1=2

k1=3        1,1  <--  1,1   k1=3

k1=5        2,1       1,2   k1=8

                 -->  2,1 (conflict)
(conflict)  1,2  <--
```

Vector clocks are timestamp metadata that increment with each write to an entry. In the preceding example, `0,0` represents the initial value for the vector clock on "k1".

A client puts "k1=2" in **LON** and the vector clock is `1,0`, which Infinispan replicates to **NYC**. A client then puts "k1=3" in **NYC** and the vector clock updates to `1,1`, which Infinispan replicates to **LON**.

However if a client puts "k1=5" in **LON** at the same time that a client puts "k1=8" in **NYC**, Infinispan detects a conflicting entry because the vector value for "k1" is not strictly greater or less between **LON** and **NYC**.

When it finds conflicting entries, Infinispan uses the Java `compareTo(String anotherString)` method to compare site names. To determine which key takes priority, Infinispan selects the site name that is lexicographically less than the other. Keys from a site named **AAA** take priority over keys from a site named **AAB** and so on.

Following the same example, to resolve the conflict for "k1", Infinispan uses the value for "k1" that originates from **LON**. This results in "k1=5" in both **LON** and **NYC** after Infinispan resolves the conflict and replicates the value.

Prepend site names with numbers as a simple way to represent the order of priority for resolving conflicting entries; for example, **1LON** and **2NYC**.

Custom Conflict Resolution

Infinispan provides other algorithms for conflict resolution. They can found in XSiteMergePolicy enum.

- `DEFAULT`: Uses the algorithm described above.
- `PREFER_NON_NULL`: If there is a write/remove conflict it keeps the write operation and discards the remove operation. For all other combinations, it uses the `DEFAULT`.

- `PREFER_NULL`: Similar to `PREFER_NON_NULL` but, instead, it discards the write operation.
- `ALWAYS_REMOVE`: In case of any conflict, it removes the `key` from both sites.

In addition, XSiteEntryMergePolicy interface can be implemented to add your own conflict resolution algorithm:

XSiteEntryMergePolicy class

```
public interface XSiteEntryMergePolicy<K, V> {
   CompletionStage<SiteEntry<V>> mrege(K key, SiteEntry<V> localEntry, SiteEntry<V>
remoteEntry);
}
```

The SiteEntry contains the `value` and `Metadata` associates with a specific site.

Reference

- java.lang.String#compareTo()
- XSiteEntryMergePolicy
- XSiteMergePolicy
- SiteEntry
- Configure Cross-Site Conflict Resolution

1.7. Expiration and Cross-Site Replication

Infinispan expiration controls how long entries remain in the cache.

- `lifespan` expiration is suitable for cross-site replication. When entries reach the maximum lifespan, Infinispan expires them independently of the remote sites.
- `max-idle` expiration does not work with cross-site replication. Infinispan cannot determine when cache entries reach the idle timeout in remote sites.

Chapter 2. Configuring Infinispan for Cross-Site Replication

Configuring Infinispan to replicate data across sites, you first set up cluster transport so Infinispan clusters can discover each other and site masters can communicate. You then add backup locations to cache definitions in your Infinispan configuration.

2.1. Configuring Cluster Transport for Cross-Site Replication

Add JGroups RELAY2 to your transport layer so that Infinispan clusters can communicate with backup locations.

Procedure

1. Open `infinispan.xml` for editing.
2. Add the RELAY2 protocol to a JGroups stack, for example:

```
<jgroups>
   <stack name="xsite" extends="udp">
      <relay.RELAY2 site="LON" xmlns="urn:org:jgroups" max_site_masters="1000"/>
      <remote-sites default-stack="tcp">
         <remote-site name="LON"/>
         <remote-site name="NYC"/>
      </remote-sites>
   </stack>
</jgroups>
```

3. Configure Infinispan cluster transport to use the stack, as in the following example:

```
<cache-container name="default" statistics="true">
  <transport cluster="${cluster.name}" stack="xsite"/>
</cache-container>
```

4. Save and close `infinispan.xml`.

Reference

- JGroups RELAY2 Stacks
- Infinispan Configuration Schema

2.1.1. JGroups RELAY2 Stacks

Infinispan clusters use JGroups RELAY2 for inter-cluster discovery and communication.

```
<jgroups>
   <stack name="xsite" ①
          extends="udp"> ②
      <relay.RELAY2 xmlns="urn:org:jgroups" ③
                    site="LON" ④
                    max_site_masters="1000"/> ⑤
      <remote-sites default-stack="tcp"> ⑥
         <remote-site name="LON"/> ⑦
         <remote-site name="NYC"/>
      </remote-sites>
   </stack>
</jgroups>
```

① Defines a stack named "xsite" that declares which protocols to use for your Infinispan cluster transport.

② Uses the default JGroups UDP stack for intra-cluster traffic.

③ Adds `RELAY2` to the stack for inter-cluster transport.

④ Names the local site. Infinispan replicates data in caches from this site to backup locations.

⑤ Configures a maximum of 1000 site masters for the local cluster. You should set `max_site_masters` >= the number of nodes in the Infinispan cluster for optimal performance with backup requests.

⑥ Specifies all site names and uses the default JGroups TCP stack for inter-cluster transport.

⑦ Names each remote site as a backup location.

2.1.2. Custom JGroups RELAY2 Stacks

```
<jgroups>
   <stack name="relay-global" extends="tcp"> ①
         <MPING stack.combine="REMOVE"/>
         <TCPPING initial_hosts="192.0.2.0[7800]" stack.combine="INSERT_AFTER"
stack.position="TCP"/>
    </stack>
   <stack name="xsite" extends="udp">
      <relay.RELAY2 site="LON" xmlns="urn:org:jgroups"
                    max_site_masters="10" ②
                    can_become_site_master="true"/>
      <remote-sites default-stack="relay-global">
         <remote-site name="LON"/>
         <remote-site name="NYC"/>
      </remote-sites>
   </stack>
</jgroups>
```

① Adds a custom RELAY2 stack that extends the TCP stack and uses TCPPING instead of MPING for discovery.

② Sets the maximum number of site masters and optionally specifies additional RELAY2

properties. See JGroups RELAY2 documentation.

You can also reference externally defined JGroups stack files as follows:

```
<stack-file name="relay-global" path="jgroups-relay.xml"/>
```

In the preceding configuration `jgroups-relay.xml` provides a JGroups stack such as this:

```
<config xmlns="urn:org:jgroups"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="urn:org:jgroups http://www.jgroups.org/schema/jgroups-
4.1.xsd">

    <!-- Use TCP for inter-cluster transport. -->
    <TCP bind_addr="127.0.0.1"
         bind_port="7200"
         port_range="30"

         thread_pool.min_threads="0"
         thread_pool.max_threads="8"
         thread_pool.keep_alive_time="5000"
    />

    <!-- Use TCPPING for inter-cluster discovery. -->
    <TCPPING timeout="3000"
             initial_hosts="127.0.0.1[7200]"
             port_range="3"
             ergonomics="false"/>

    <!-- Provide other JGroups stack configuration as required. -->
</config>
```

Reference

- Cluster Transport Configuration
- JGroups RELAY2
- Relaying between multiple sites (RELAY2)

2.2. Adding Backup Locations to Caches

Specify the names of remote sites so Infinispan can back up data to those locations.

Procedure

1. Add the `backups` element to your cache definition.
2. Specify the name of each remote site with the `backup` element.

   As an example, in the **LON** configuration, specify **NYC** as the remote site.

3. Repeat the preceding steps so that each site is a backup for all other sites. For example, you cannot add **LON** as a backup for **NYC** without adding **NYC** as a backup for **LON**.

Cache configurations can be different across sites and use different backup strategies. Infinispan replicates data based on cache names.

Example "customers" configuration in **LON**

```
<replicated-cache name="customers">
  <backups>
    <backup site="NYC" strategy="ASYNC" />
  </backups>
</replicated-cache>
```

Example "customers" configuration in **NYC**

```
<distributed-cache name="customers">
  <backups>
    <backup site="LON" strategy="SYNC" />
  </backups>
</distributed-cache>
```

Reference

- Infinispan Configuration Schema

2.3. Backing Up to Caches with Different Names

By default, Infinispan replicates data between caches that have the same name.

Procedure

- Use `backup-for` to replicate data from a remote site into a cache with a different name on the local site.

For example, the following configuration backs up the "customers" cache on **LON** to the "eu-customers" cache on **NYC**.

```
<distributed-cache name="eu-customers">
  <backups>
    <backup site="LON" strategy="SYNC" />
  </backups>
  <backup-for remote-cache="customers" remote-site="LON" />
</distributed-cache>
```

2.4. Configuring Cross-Site Conflict Resolution

Specify the algorithm name of the implementation to use when conflict happens.

Procedure

- Use `merge-policy` to configure the conflict resolution algorithm.

Using Infinispan algorithm

```
<distributed-cache name="eu-customers">
   <backups merge-policy="ALWAYS_REMOVE">
      <backup site="LON" strategy="ASYNC"/>
   </backups>
</distributed-cache>
```

Using a custom implementation

```
<distributed-cache name="eu-customers">
   <backups merge-policy="org.mycompany.MyCustomXSiteEntryMergePolicy">
      <backup site="LON" strategy="ASYNC"/>
   </backups>
</distributed-cache>
```

Reference

- XSiteEntryMergePolicy
- XSiteMergePolicy
- Infinispan Configuration Schema

2.5. Verifying Cross-Site Views

After you configure Infinispan for cross-site replication, you should verify that Infinispan clusters successfully form cross-site views.

Procedure

- Check log messages for `ISPN000439: Received new x-site view` messages.

For example, if the Infinispan cluster in **LON** has formed a cross-site view with the Infinispan cluster in **NYC**, it provides the following messages:

```
INFO  [org.infinispan.XSITE] (jgroups-5,${server.hostname}) ISPN000439: Received new
x-site view: [NYC]
INFO  [org.infinispan.XSITE] (jgroups-7,${server.hostname}) ISPN000439: Received new
x-site view: [NYC, LON]
```

2.6. Configuring Hot Rod Clients for Cross-Site Replication

Configure Hot Rod clients to use Infinispan clusters at different sites.

`hotrod-client.properties`

```
# Servers at the active site
infinispan.client.hotrod.server_list = LON_host1:11222,LON_host2:11222,LON_host3:11222

# Servers at the backup site
infinispan.client.hotrod.cluster.NYC =
NYC_hostA:11222,NYC_hostB:11222,NYC_hostC:11222,NYC_hostD:11222
```

`ConfigurationBuilder`

```
ConfigurationBuilder builder = new ConfigurationBuilder();
builder.addServers("LON_host1:11222;LON_host2:11222;LON_host3:11222")
       .addCluster("NYC")
       .addClusterNodes(
"NYC_hostA:11222;NYC_hostB:11222;NYC_hostC:11222;NYC_hostD:11222")
```

Use the following methods to switch Hot Rod clients to the default cluster or to a cluster at a different site:

- `RemoteCacheManager.switchToDefaultCluster()`
- `RemoteCacheManager.switchToCluster(${site.name})`

Reference

- org.infinispan.client.hotrod.configuration package description
- org.infinispan.client.hotrod.configuration.ConfigurationBuilder
- org.infinispan.client.hotrod.RemoteCacheManager

Chapter 3. Performing Cross-Site Replication Operations

Bring sites online and offline. Transfer cache state to remote sites.

3.1. Performing Cross-Site Operations with the CLI

The Infinispan command line interface lets you remotely connect to Infinispan servers, manage sites, and push state transfer to backup locations.

Prerequisites

- Start the Infinispan CLI.
- Connect to a running Infinispan cluster.

3.1.1. Bringing Backup Locations Offline and Online

Take backup locations offline manually and bring them back online.

Procedure

1. Create a CLI connection to Infinispan.
2. Check if backup locations are online or offline with the `site status` command:

```
//containers/default]> site status --cache=cacheName --site=NYC
```

`--site` is an optional argument. If not set, the CLI returns all backup locations.

3. Manage backup locations as follows:
   - Bring backup locations online with the `bring-online` command:

```
//containers/default]> site bring-online --cache=customers --site=NYC
```

   - Take backup locations offline with the `take-offline` command:

```
//containers/default]> site take-offline --cache=customers --site=NYC
```

For more information and examples, run the `help site` command.

3.1.2. Pushing State to Backup Locations

Transfer cache state to remote backup locations.

Procedure

1. Create a CLI connection to Infinispan.
2. Use the `site` command to push state transfer, as in the following example:

```
//containers/default]> site push-site-state --cache=cacheName --site=NYC
```

For more information and examples, run the `help site` command.

Reference

Infinispan Command Line Interface

3.2. Performing Cross-Site Operations with the REST API

Infinispan servers provide a REST API that allows you to perform cross-site operations.

3.2.1. Getting Status of All Backup Locations

Retrieve the status of all backup locations with `GET` requests.

```
GET /v2/caches/{cacheName}/x-site/backups/
```

Infinispan responds with the status of each backup location in JSON format, as in the following example:

```
{
  "NYC": "online",
  "LON": "offline"
}
```

Table 1. Returned Status

Value	Description
`online`	All nodes in the local cluster have a cross-site view with the backup location.
`offline`	No nodes in the local cluster have a cross-site view with the backup location.
`mixed`	Some nodes in the local cluster have a cross-site view with the backup location, other nodes in the local cluster do not have a cross-site view. The response indicates status for each node.

3.2.2. Getting Status of Specific Backup Locations

Retrieve the status of a backup location with `GET` requests.

```
GET /v2/caches/{cacheName}/x-site/backups/{siteName}
```

Infinispan responds with the status of each node in the site in JSON format, as in the following example:

```
{
  "NodeA":"offline",
  "NodeB":"online"
}
```

Table 2. Returned Status

Value	Description
`online`	The node is online.
`offline`	The node is offline.
`failed`	Not possible to retrieve status. The remote cache could be shutting down or a network error occurred during the request.

3.2.3. Taking Backup Locations Offline

Take backup locations offline with `POST` requests and the `?action=take-offline` parameter.

```
POST /v2/caches/{cacheName}/x-site/backups/{siteName}?action=take-offline
```

3.2.4. Bringing Backup Locations Online

Bring backup locations online with the `?action=bring-online` parameter.

```
POST /v2/caches/{cacheName}/x-site/backups/{siteName}?action=bring-online
```

3.2.5. Pushing State to Backup Locations

Push cache state to a backup location with the `?action=start-push-state` parameter.

```
POST /v2/caches/{cacheName}/x-site/backups/{siteName}?action=start-push-state
```

3.2.6. Canceling State Transfer

Cancel state transfer operations with the `?action=cancel-push-state` parameter.

```
POST /v2/caches/{cacheName}/x-site/backups/{siteName}?action=cancel-push-state
```

3.2.7. Getting State Transfer Status

Retrieve status of state transfer operations with the `?action=push-state-status` parameter.

```
GET /v2/caches/{cacheName}/x-site/backups?action=push-state-status
```

Infinispan responds with the status of state transfer for each backup location in JSON format, as in the following example:

```
{
   "NYC":"CANCELED",
   "LON":"OK"
}
```

Table 3. Returned Status

Value	Description
`SENDING`	State transfer to the backup location is in progress.
`OK`	State transfer completed successfully.
`ERROR`	An error occurred with state transfer. Check log files.
`CANCELLING`	State transfer cancellation is in progress.

3.2.8. Clearing State Transfer Status

Clear state transfer status for sending sites with the `?action=clear-push-state-status` parameter.

```
POST /v2/caches/{cacheName}/x-site/local?action=clear-push-state-status
```

3.2.9. Modifying Take Offline Conditions

Sites go offline if certain conditions are met. Modify the take offline parameters to control when backup locations automatically go offline.

Procedure

1. Check configured take offline parameters with `GET` requests and the `take-offline-config`

parameter.

```
GET /v2/caches/{cacheName}/x-site/backups/{siteName}/take-offline-config
```

The Infinispan response includes `after_failures` and `min_wait` fields as follows:

```
{
  "after_failures": 2,
  "min_wait": 1000
}
```

2. Modify take offline parameters in the body of `PUT` requests.

```
PUT /v2/caches/{cacheName}/x-site/backups/{siteName}/take-offline-config
```

3.2.10. Canceling State Transfer from Receiving Sites

If the connection between two backup locations breaks, you can cancel state transfer on the site that is receiving the push.

Cancel state transfer from a remote site and keep the current state of the local cache with the `?action=cancel-receive-state` parameter.

```
POST /v2/caches/{cacheName}/x-site/backups/{siteName}?action=cancel-receive-state
```

3.2.11. Getting Status of Backup Locations

Retrieve the status of all backup locations from Cache Managers with `GET` requests.

```
GET /rest/v2/cache-managers/{cacheManagerName}/x-site/backups/
```

Infinispan responds with status in JSON format, as in the following example:

```
{
   "SFO-3":{
      "status":"online"
   },
   "NYC-2":{
      "status":"mixed",
      "online":[
         "CACHE_1"
      ],
      "offline":[
         "CACHE_2"
      ]
   }
}
```

Table 4. Returned Status

Value	Description
`online`	All nodes in the local cluster have a cross-site view with the backup location.
`offline`	No nodes in the local cluster have a cross-site view with the backup location.
`mixed`	Some nodes in the local cluster have a cross-site view with the backup location, other nodes in the local cluster do not have a cross-site view. The response indicates status for each node.

3.2.12. Taking Backup Locations Offline

Take backup locations offline with the `?action=take-offline` parameter.

```
POST /rest/v2/cache-managers/{cacheManagerName}/x-site/backups/{siteName}?action=take-offline
```

3.2.13. Bringing Backup Locations Online

Bring backup locations online with the `?action=bring-online` parameter.

```
POST /rest/v2/cache-managers/{cacheManagerName}/x-site/backups/{siteName}?action=bring-online
```

3.2.14. Starting State Transfer

Push state of all caches to remote sites with the `?action=start-push-state` parameter.

```
POST /rest/v2/cache-managers/{cacheManagerName}/x-
site/backups/{siteName}?action=start-push-state
```

3.2.15. Canceling State Transfer

Cancel ongoing state transfer operations with the `?action=cancel-push-state` parameter.

```
POST /rest/v2/cache-managers/{cacheManagerName}/x-
site/backups/{siteName}?action=cancel-push-state
```

3.3. Performing Cross-Site Operations with JMX

Infinispan provides JMX tooling to perfrom cross-site operations such as pushing state transfer and bringing sites online.

3.3.1. Configuring Infinispan to Register JMX MBeans

Infinispan can register JMX MBeans that you can use to collect statistics and perform administrative operations. However, you must enable statistics separately to JMX otherwise Infinispan provides `0` values for all statistic attributes.

Procedure

- Enable JMX declaratively or programmatically.

Declaratively

```
<cache-container>
  <jmx enabled="true" /> ①
</cache-container>
```

① Registers Infinispan JMX MBeans.

Programmatically

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .jmx().enable() ①
  .build();
```

① Registers Infinispan JMX MBeans.

3.3.2. Performing Cross-Site Operations

Perform cross-site operations via JMX clients.

Prerequisites

- Configure Infinispan to register JMX MBeans

Procedure

1. Connect to Infinispan with any JMX client.
2. Invoke operations from the following MBeans:
   - `XSiteAdmin` provides cross-site operations for caches.
   - `GlobalXSiteAdminOperations` provides cross-site operations for Cache Managers.

     For example, to bring sites back online, invoke `bringSiteOnline(siteName)`.

See the *Infinispan JMX Components* documentation for details about available cross-site operations.

Reference

- XSiteAdmin MBean
- GlobalXSiteAdminOperations MBean

Chapter 4. Monitoring and Troubleshooting Global Infinispan Clusters

Infinispan provides statistics for cross-site replication operations via JMX or the `/metrics` endpoint for Infinispan server.

Cross-site replication statistics are available at cache level so you must explicitly enable statistics for your caches. Likewise, if you want to collect statistics via JMX you must configure Infinispan to register MBeans.

Infinispan also includes an `org.infinispan.XSITE` logging category so you can monitor and troubleshoot common issues with networking and state transfer operations.

4.1. Enabling Infinispan Statistics

Infinispan lets you enable statistics for Cache Managers and caches. However, enabling statistics for a Cache Manager does not enable statistics for the caches that it controls. You must explicitly enable statistics for your caches.

Infinispan server enables statistics for Cache Managers by default.

Procedure

- Enable statistics declaratively or programmatically.

Declaratively

```
<cache-container statistics="true"> ①
  <local-cache name="mycache" statistics="true"/> ②
</cache-container>
```

① Enables statistics for the Cache Manager.

② Enables statistics for the named cache.

Programmatically

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .cacheContainer().statistics(true) ①
  .build();

 ...

Configuration config = new ConfigurationBuilder()
  .statistics().enable() ②
  .build();
```

① Enables statistics for the Cache Manager.

② Enables statistics for the named cache.

4.2. Enabling Infinispan Metrics

Configure Infinispan to export gauges and histograms.

Procedure

- Configure metrics declaratively or programmatically.

Declaratively

```
<cache-container statistics="true"> ①
  <metrics gauges="true" histograms="true" /> ②
</cache-container>
```

① Computes and collects statistics about the Cache Manager.

② Exports collected statistics as gauge and histogram metrics.

Programmatically

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .statistics().enable() ①
  .metrics().gauges(true).histograms(true) ②
  .build();
```

① Computes and collects statistics about the Cache Manager.

② Exports collected statistics as gauge and histogram metrics.

4.2.1. Collecting Infinispan Metrics

Collect Infinispan metrics with monitoring tools such as Prometheus.

Prerequisites

- Enable statistics. If you do not enable statistics, Infinispan provides `0` and `-1` values for metrics.
- Optionally enable histograms. By default Infinispan generates gauges but not histograms.

Procedure

- Get metrics in Prometheus (OpenMetrics) format:

```
$ curl -v http://localhost:11222/metrics
```

- Get metrics in MicroProfile JSON format:

```
$ curl --header "Accept: application/json" http://localhost:11222/metrics
```

Next steps

Configure monitoring applications to collect Infinispan metrics. For example, add the following to

`prometheus.yml`:

```
static_configs:
    - targets: ['localhost:11222']
```

Reference

- Prometheus Configuration
- Enabling Infinispan Statistics

4.3. Configuring Infinispan to Register JMX MBeans

Infinispan can register JMX MBeans that you can use to collect statistics and perform administrative operations. However, you must enable statistics separately to JMX otherwise Infinispan provides `0` values for all statistic attributes.

Procedure

- Enable JMX declaratively or programmatically.

Declaratively

```
<cache-container>
  <jmx enabled="true" /> ①
</cache-container>
```

① Registers Infinispan JMX MBeans.

Programmatically

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .jmx().enable() ①
  .build();
```

① Registers Infinispan JMX MBeans.

4.3.1. JMX MBeans for Cross-Site Replication

Infinispan provides JMX MBeans for cross-site replication that let you gather statistics and perform remote operations.

The `org.infinispan:type=Cache` component provides the following JMX MBeans:

- `XSiteAdmin` exposes cross-site operations that apply to specific cache instances.
- `StateTransferManager` provides statistics for state transfer operations.
- `InboundInvocationHandler` provides statistics and operations for asynchronous and synchronous cross-site requests.

The `org.infinispan:type=CacheManager` component includes the following JMX MBean:

- `GlobalXSiteAdminOperations` exposes cross-site operations that apply to all caches in a cache container.

For details about JMX MBeans along with descriptions of available operations and statistics, see the *Infinispan JMX Components* documentation.

Reference

Infinispan JMX Components

4.4. Collecting Logs and Troubleshooting Cross-Site Replication

Diagnose and resolve issues related to Infinispan cross-site replication. Use the Infinispan Command Line Interface (CLI) to adjust log levels at run-time and perform cross-site troubleshooting.

Procedure

1. Open a terminal in `$ISPN_HOME`.
2. Create a Infinispan CLI connection.
3. Adjust run-time logging levels to capture DEBUG messages if necessary.

   For example, the following command enables DEBUG log messages for the org.infinispan.XSITE category:

   ```
   [//containers/default]> logging set --level=DEBUG org.infinispan.XSITE
   ```

   You can then check the Infinispan log files for cross-site messages in the `${infinispan.server.root}/log` directory.
4. Use the `site` command to view status for backup locations and perform troubleshooting.

For example, check the status of the "customers" cache that uses "LON" as a backup location:

```
[//containers/default]> site status --cache=customers
{
  "LON" : "online"
}
```

Another scenario for using the Infinispan CLI to troubleshoot is when the network connection between backup locations is broken during a state transfer operation.

If this occurs, Infinispan clusters that receive state transfer continually wait for the operation to complete. In this case you should cancel the state transfer to the receiving site to return it to a normal operational state.

For example, cancel state transfer for "NYC" as follows:

```
[//containers/default]> site cancel-receive-state --cache=mycache --site=NYC`
```

Reference

- Infinispan Server Troubleshooting
- Working with Infinispan Server Logs

4.4.1. Cross-Site Log Messages

Find user actions for log messages related to cross-site replication.

Log level	Identifier	Message	Description
DEBUG	ISPN000400	Node null was suspected	Infinispan prints this message when it cannot reach backup locations. Ensure that sites are online and check network status.
INFO	ISPN000439	Received new x-site view: ${site.name}	Infinispan prints this message when sites join and leave the global cluster.
INFO	ISPN100005	Site ${site.name} is online.	Infinispan prints this message when a site comes online.
INFO	ISPN100006	Site ${site.name} is offline.	Infinispan prints this message when a site goes offline. If you did not take the site offline manually, this message could indicate a failure has occurred. Check network status and try to bring the site back online.
WARN	ISPN000202	Problems backing up data for cache ${cache.name} to site ${site.name}:	Infinispan prints this message when issues occur with state transfer operations along with the exception. If necessary adjust Infinispan logging to get more fine-grained logging messages.
WARN	ISPN000289	Unable to send X-Site state chunk to ${site.name}.	Indicates that Infinispan cannot transfer a batch of cache entries during a state transfer operation. Ensure that sites are online and check network status.

Log level	Identifier	Message	Description
WARN	ISPN000291	Unable to apply X-Site state chunk.	Indicates that Infinispan cannot apply a batch of cache entries during a state transfer operation. Ensure that sites are online and check network status.
WARN	ISPN000322	Unable to re-start x-site state transfer to site ${site.name}	Indicates that Infinispan cannot resume a state transfer operation to a backup location. Ensure that sites are online and check network status.
ERROR	ISPN000477	Unable to perform operation ${operation.name} for site ${site.name}	Indicates that Infinispan cannot successfully complete an operation on a backup location. If necessary adjust Infinispan logging to get more fine-grained logging messages.
FATAL	ISPN000449	XSite state transfer timeout must be higher or equals than 1 (one).	Results when the value of the `timeout` attribute is `0` or a negative number. Specify a value of at least `1` for the `timeout` attribute in the state transfer configuration for your cache definition.
FATAL	ISPN000450	XSite state transfer waiting time between retries must be higher or equals than 1 (one).	Results when the value of the `wait-time` attribute is `0` or a negative number. Specify a value of at least `1` for the `wait-time` attribute in the state transfer configuration for your cache definition.
FATAL	ISPN000576	Cross-site Replication not available for local cache.	Cross-site replication does not work with the local cache mode. Either remove the backup configuration from the local cache definition or use a distributed or replicated cache mode.