Adding Constraints to High Availability Cluster Resources

Resource constraints let you specify cluster node assignments, define the start order, and manage dependencies between resources. Because cluster resources sometimes depend on other resources or on a particular node configuration, they might need to run in a specific location or start in a specific order. Add resource constraints to specify exactly where and when High Availability cluster resources can run.

REQUIREMENTS

- An existing SUSE Linux Enterprise High Availability cluster
- Existing cluster resources

If you still need to configure cluster resources, see *Configuring High Availability Cluster Resources* (https://documentation.suse.com/sle-ha/16.0/html/HA-resources-configuring/).

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1 What are cluster resources?

In a High Availability cluster, the applications and services that need to be highly available are called *resources*. Cluster resources can include Web sites, e-mail servers, databases, file systems, virtual machines or any other applications or services that need to be available to users at all times. You can start, stop, monitor and move resources as needed. You can also specify whether resources should run together on the same node, or start and stop in sequential order. If a node fails, the resources running on it *fail over* (move) to another node instead of being lost.

In SUSE Linux Enterprise High Availability, the *cluster resource manager* (CRM) is *Pacemaker*, which manages and coordinates all cluster services. Pacemaker uses *resource agents* (RAs) to start, stop and monitor resources. A resource agent abstracts the resource and presents its status to the cluster. This means that Pacemaker only interacts with the resource agent, not with the actual application or service. SUSE Linux Enterprise High Availability supports many different resource agents that are designed to manage specific types of resources.

1.1 Primitive resources

Primitive resources represent the applications or services that need to be highly available. Configuring a primitive specifies the resource agent and any other information required for the cluster to manage a resource. To see the supported resource agent classes, run **`crm ra classes`**. To see the resource agents available within a class, run **`crm ra list`** *`CLASS`*.

Primitive resources can have the following settings:

Properties

Resource properties are the basic details required by the cluster: a unique name for the resource, and the resource agent that manages the application or service.

Parameters

Parameters are specific to each resource agent and determine the details and behavior of an application or service. To show all the parameters available for a resource agent, run **`crm ra info`** *`RESOURCE_AGENT`*.

Operations

Operations are actions that the cluster can perform on a resource, such as `start`, `stop` and `monitor`. To show the supported operations for a resource agent, run **`crm ra info`** *`RESOURCE_AGENT`* and scroll to the bottom of the output.

Meta attributes

Meta attributes change how the cluster treats a resource. To show all the meta attributes available for primitives, run **`crm_resource --list-options primitive`**.

Utilization attributes

If the cluster nodes have utilization attributes configured, you can add these attributes to cluster resources to help with load balancing. For more information, see https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/utilization.html.

1.2 Resource groups

Cluster resources might depend on other resources, such as a Web server that requires an IP address and a file system. You can combine these resources into a *resource group*. Groups contain multiple primitives that need to be located together, started sequentially and stopped in the reverse order.

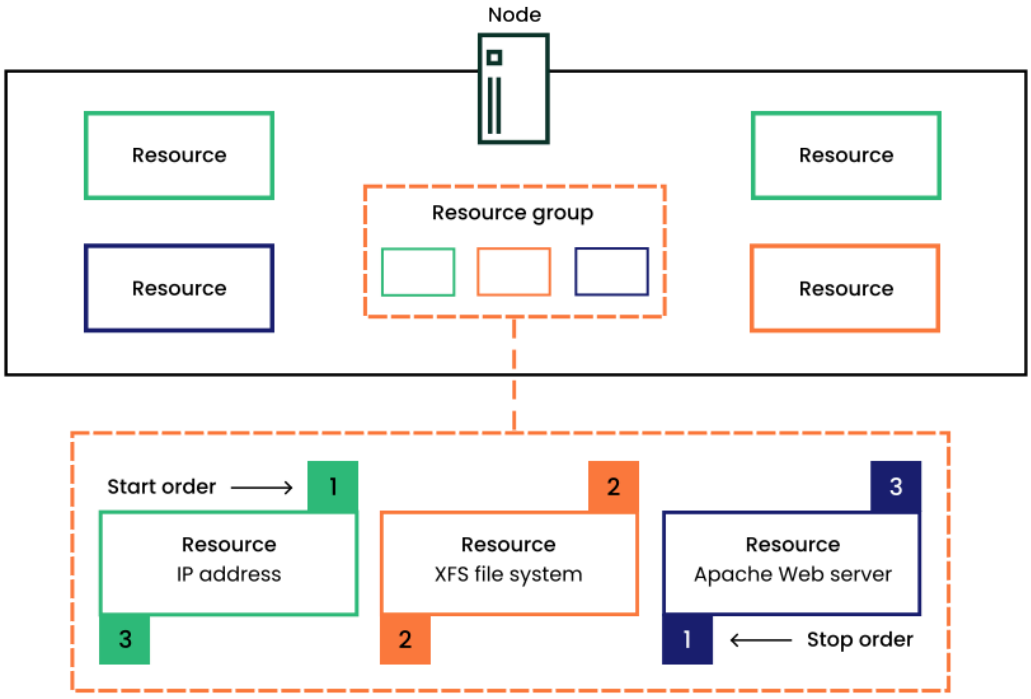

FIGURE 1: RESOURCE GROUP

Groups have the following properties:

Contents
: Groups can only contain primitive resources, not clones or other groups.

Starting and stopping
: Resources start in the order they appear and stop in the reverse order.

Location
: Resources in the group must all run on the same node.

Dependency
: If one of the resources can't run anywhere, then the resources that appear after it in the group can't run anywhere either.

Meta attributes
: The meta attributes `target-role`, `priority`, `maintenance` and `is-managed` can be added directly to the group. All other attributes are inherited from the group's resources.

Resource stickiness
: Stickiness in groups is additive. Every *active* resource in the group contributes its stickiness value to the group's total.

1.3 Resource clones

Resource clones can run simultaneously on multiple nodes. This is required for cluster file systems like GFS2, for example. You can clone a primitive or a group if the resource agent supports it. Clones can also have additional clone-specific meta attributes to change their behavior.

Clones can be one of the following types:

Anonymous clones
: Anonymous clones are the simplest type. All instances of the clone behave identically. Therefore, only one instance of an anonymous clone can be active on each node.

Globally unique clones
: Globally unique clones are distinct entities. An instance of the clone running on one node is not necessarily equivalent to another instance on another node.

Promotable clones

Promotable clones allow the instances to be in one of two operating modes: promoted or unpromoted (also known as primary and secondary, or active and passive). Promotable clones can be either anonymous or globally unique.

To make a clone promotable, the resource agent must support the *promote* and *demote* operations. The cluster determines which instance of the clone to promote using one of the following methods (or a combination of both):

- If a resource agent supports promotable clones, it might automatically set promotion scores based on its own preference for which instance to promote.
- You can manually set promotion rules or preferences by creating location or colocation constraints.

For more information, see https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/collective.html#determining-which-instance-is-promoted

1.4 For more information

- Primitive resources: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/resources.html
- Groups and clones: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/collective.html
- Resource operations: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/operations.html
- Utilization attributes: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/utilization.html

2 What are resource constraints?

Resource constraints let you specify cluster node assignments, define the start order, and manage dependencies between resources.

2.1 Types of constraints

Order

Order constraints tell the cluster to start resources in a specific order and stop them in the reverse order. You can also start or stop a resource right before or after a different resource performs a certain action, such as being promoted.

Location

Location constraints tell the cluster where resources can or cannot run. You can specify that a resource *must* or must *not* run on a particular node, or give the resource an optional preference for or against a node.

Colocation

Colocation constraints tell the cluster which resources can or cannot run together on the same node. You can specify that the resources *must* or must *not* run together, or give a resource an optional preference for or against another resource.

Important: Restrictions for constraints and primitive resources

- Don't add colocation constraints to primitives in a resource group. Add a colocation constraint to the group instead.
- Don't add any constraints to a primitive that has been cloned. Add constraints to the clone instead.

2.2 Scores and kinds

Location and colocation constraints must have a *score* to indicate how important the constraint is. A score of `INFINITY` (positive or negative) means that the constraint *must* be applied. The score can also be a non-infinite number (positive or negative), which means the constraint is only a preference. In this case, the constraint might not be applied if its score is outweighed by other factors, such as other constraints, resource stickiness, failure thresholds, etc.

For location constraints, a positive score means the resource should (or must) run on the specified node. A negative score means the resource should *not* (or must not) run on the specified node. You can also add multiple location constraints with different scores to prioritize node preferences.

For colocation constraints, a positive score means the resources should (or must) run together on the same node. A negative score means the resources should *not* (or must not) run together on the same node.

Instead of a score, order constraints must have a *kind*, which defines whether the constraint is mandatory or optional.

2.3 Resource sets

Resource sets let you group multiple resources in a single constraint instead of needing multiple constraints. The effect depends on the type of constraint:

- In a *location* constraint, a resource set applies the constraint to multiple resources instead of just one, without creating any dependency between the resources.
  Location constraints use curly brackets to group the resources.

- In an *order* constraint, a resource set gives multiple resources the same position in the order. For example, a simple order constraint says that `res1` must start first, then `res2`, then `res3`. However, if you put `res2` and `res3` in a resource set, the constraint would say that `res1` must start first, and then `res2` and `res3` can start in any order.
  Order constraints can use round brackets or square brackets to group the resources.

- In a *colocation* constraint, a resource set gives multiple resources the same relationship to the next resource. For example, a simple colocation constraint says that `res1` must run on the same node as `res2`, which must run on the same node as `res3`. However, if you put `res1` and `res2` in a resource set, the constraint would say that `res1` and `res2` must run on the same node as `res3`, but aren't otherwise dependent on each other.
  Colocation constraints can use round brackets or square brackets to group the resources.

The syntax for resource sets can be complex, so before using them in a production environment, we recommend testing them to make sure the resources behave as expected.

For more information about the syntax of resource sets and the difference between round and square brackets, run **`crm help Resourcesets`**.

2.4 For more information

- Constraints: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/constraints.html
- Constraints for clones: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/collective.html#clone-constraints
- Scores: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/local-options.html#scores
- Resource sets: https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/constraints.html#resource-sets

3 Adding order constraints

Order constraints tell the cluster to start resources in a specific order and stop them in the reverse order. You can also start or stop a resource right before or after a different resource performs a certain action, such as being promoted.

Instead of a score, order constraints have a *kind*. The kind can be one of the following:

- `Mandatory`: Resources *must* start in this order.
- `Optional`: The start order is only a preference.
- `Serialize`: A resource must finish starting before the next resource can begin starting. This is useful for resources that put a high load on the node during start-up, for example.

You can add order constraints with the CRM Shell (`crmsh`) or with the Hawk Web interface.

CRM Shell

You can perform this procedure on any node in the cluster.

1. Log in either as the `root` user or as a user with **`sudo`** privileges.
2. Add an order constraint. The basic command requires a name, a kind, and at least two resources:

   ```
   > sudo crm configure order ORDER_NAME KIND: RESOURCE1 RESOURCE2
   ```

   The *`KIND`* can be `Mandatory`, `Optional` or `Serialize`.

ADDITIONAL OPTIONS

Resource sets

You can use round brackets or square brackets to group resources in an order constraint. In this example, `res1` must start first, and then `res2` and `res3` can start in any order:

```
> sudo crm configure order res1-first Mandatory: res1 [ res2 res3 ]
```

Round brackets are treated as special characters in most shells, so for `crm` commands that aren't in interactive mode, you must escape the brackets with `\`:

```
> sudo crm configure order res1-first Mandatory: res1 \( res2 res3 \)
```

For more information about the difference between round and square brackets, run `crm help Resourcesets`.

Symmetry

In most cases, you should keep the default `symmetrical=true`, which means that resources stop in the reverse of their start order. However, if necessary, you can change it to `false`.

Actions

You can require a resource to perform an action (`start`, `stop`, `promote` or `demote`) before or after another resource starts. In this example, `res1` must start before `clone2` can be promoted:

```
> sudo crm configure order res1-pr-clone2 Mandatory: res1 clone2:promote
```

3. You can view all order constraints with the following command:

```
> sudo crm configure show type:order
```

Hawk

You can use Hawk on any machine with a Web browser and network access to the nodes.

1. In a Web browser, go to `https://HAWKSERVER:7630/` and log in.
2. From the left navigation bar, select *Configuration* › *Add Constraint*.
3. Click *Order*.
4. Enter a unique *Constraint ID*.

5. Select a *Kind* from the drop-down list.
6. In most cases, you should keep the option *Symmetrical* enabled. This means that resources stop in the reverse of their start order.
7. From the drop-down list in the *Resources* section, select a resource.
   A new drop-down list appears. Repeat this step to add more resources.
   The resources will start in the order shown on the screen. To change the order, click the up arrow icon to swap a resource with the one above it.
   To remove a resource from the constraint, click the minus icon.
8. *(Optional)* To create a resource set, click the chain icon to link a resource to the one above it. You can link multiple resources into a set or create multiple resource sets.
   To remove a resource from the set, click the scissors icon.
9. *(Optional)* If required, select an action (`Start`, `Stop`, `Promote` or `Demote`) from the drop-down list next to a resource. The resource must perform this action before or after another resource starts, depending on the order.
10. Click *Create* to finish the configuration.
    A message at the top of the screen shows if the action was successful.

FOR MORE INFORMATION

- **`crm configure help order`**
- **`crm help Resourcesets`**
- https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/constraints.html#specifying-the-order-in-which-resources-should-start-stop

4 Adding location constraints

Location constraints tell the cluster where resources can or cannot run. You can specify that a resource *must* or must *not* run on a particular node, or give the resource an optional preference for or against a node.

Location constraints use a *score* to indicate how important the constraint is. A score of `INFINITY` (positive or negative) means that the constraint *must* be applied. The score can also be a non-infinite number (positive or negative), which means the constraint is only a preference. You can also add multiple location constraints with different scores to prioritize node preferences.

You can add location constraints with the CRM Shell (`crmsh`) or with the Hawk Web interface.

CRM Shell

You can perform this procedure on any node in the cluster.

1. Log in either as the `root` user or as a user with **`sudo`** privileges.
2. Add a location constraint. The basic command requires a name, at least one resource, a score, and a node:

```
> sudo crm configure location LOCATION_NAME RESOURCE SCORE: NODE
```

The *`SCORE`* can be `inf`, `-inf` or a number (positive or negative).

ADDITIONAL OPTIONS

Resource sets

You can use curly brackets to include multiple resources in a location constraint. In this example, `res1` and `res2` must both run on node `alice`:

```
> sudo crm configure location res1-2-alice { res1 res2 } inf: alice
```

Resource patterns

You can use a resource pattern (a regular expression between two slashes) to refer to multiple resources. If you add new resources with the same name pattern, they will also be included in the location constraint. In this example, any resources beginning with `res` must run on node `alice`:

```
> sudo crm configure location all-res-alice /res.*/ inf: alice
```

Resource discovery

In most cases, you should keep the default `resource-discovery=always`. This means that the cluster checks whether the resource is already running, to help avoid unwanted instances of the resource. However, if necessary, you can change it to `never` or `exclusive`.

Rules

Instead of specifying a single node, you can use a rule to refer to multiple nodes. If you add more nodes that meet the rule, they will also be included in the location constraint. In this example, `res1` can't run on any node where the custom node attribute `memory` is less than `4096`:

```
> sudo crm configure location res1-no-small-nodes res1 \
  rule -inf: memory lt 4096
```

3. Check the status to see which node the resources are now running on:

```
> sudo crm status
```

Hawk

You can use Hawk on any machine with a Web browser and network access to the nodes.

1. In a Web browser, go to `https://HAWKSERVER:7630/` and log in.
2. From the left navigation bar, select *Configuration* › *Add Constraint*.
3. Click *Location*.
4. Enter a unique *Constraint ID*.
5. Select one or more *Resources* to apply the constraint to.
   To remove a resource from the constraint, press `Ctrl` and click the resource again.
6. Enter a numeric *Score* or select a value from the drop-down list:
   - `Always` sets the score to `INFINITY`, which means that the resources must run on the specified node.
   - `Never` sets the score to `-INFINITY`, which means that the resources must *not* run on the specified node.
   - `Advisory` sets the score to `0`, which disables the constraint. This can be useful when you want to set resource discovery but don't want to constrain the resources.
7. Select a *Node* to apply the constraint to.
8. *(Optional)* Click the *Advanced* tab if you need to set further parameters.

9. *(Optional)* In most cases, you should keep the option *Resource Discovery* enabled. This means that the cluster checks whether the resource is already running, to help avoid unwanted instances of the resource. If you do need to change this option, select a new value from the drop-down list.

10. *(Optional)* Instead of specifying a single node, you can use a *Rule* to refer to multiple nodes. If you add more nodes that meet the rule, they will also be included in the location constraint. Configure the rule with the following settings:

    - Add a *Score* for the rule.
    - Optionally, select a *Role* from the drop-down list. The rule will only apply when the resource is in this role.
    - If you intend to add multiple expressions, select a *Boolean Operator* from the drop-down list.
    - Add one or more *Expressions*. Select an expression type from the drop-down list, then click the plus icon.
      The required fields for that expression type appear. This could be a node's `uname`, or a custom node attribute and value. Fill in the fields and select an operation (such as `=`, `<`, `>`, etc.) to create the expression.

11. Click *Create* to finish the configuration.
    A message at the top of the screen shows if the action was successful.

FOR MORE INFORMATION

- **`crm configure help location`**
- **`crm help Resourcesets`**
- **`crm help RuleExpressions`**
- https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/constraints.html#deciding-which-nodes-a-resource-can-run-on
- https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/rules.html

5 Adding colocation constraints

Colocation constraints tell the cluster which resources can or cannot run together on the same node. You can specify that the resources *must* or must *not* run together, or give a resource an optional preference for or against another resource.

Colocation constraints use a *score* to indicate how important the constraint is. A score of `INFINITY` (positive or negative) means that the constraint *must* be applied. The score can also be a non-infinite number (positive or negative), which means the constraint is only a preference.

Important: Resource start order

Colocation constraints *don't* affect the order in which the resources start. If you want resources to run on the same node *and* start in a specific order, create a resource group.

You can add colocation constraints with the CRM Shell (`crmsh`) or with the Hawk Web interface.

CRM Shell

You can perform this procedure on any node in the cluster.

1. Log in either as the `root` user or as a user with **`sudo`** privileges.
2. Add a colocation constraint. The basic command requires a name, a score and at least two resources:

```
> sudo crm configure colocation COLOCATION_NAME SCORE: RESOURCE1 RESOURCE2
```

The *`SCORE`* can be `inf`, `-inf` or a number (positive or negative).
`RESOURCE2` is assigned to a node *first*, and *`RESOURCE1`* is placed relative to *`RESOURCE2`*.

ADDITIONAL OPTIONS

Resource sets

You can use round brackets or square brackets to group resources in a colocation constraint. In this example, `res1` and `res2` must run on the same node as `res3`, but aren't otherwise dependent on each other:

```
> sudo crm configure colocation res1-2-with-res3 \
  inf: [ res1 res2 ] res3
```

Round brackets are treated as special characters in most shells, so for `crm` commands that aren't in interactive mode, you must escape the brackets with `\`:

```
> sudo crm configure colocation res1-2-with-res3 \
  inf: \( res1 res2 \) res3
```

For more information about the difference between round and square brackets, run `crm help Resourcesets`.

Roles

You can require a role (`Started`, `Stopped`, `Promoted` or `Unpromoted`) for one or more resources. The colocation constraint only applies when the resource is in this role. In this example, `res1` must run on the same node where `clone2` is in the `Promoted` role:

```
> sudo crm configure colocation res1-with-pr-clone2 \
  inf: res1 clone2:Promoted
```

Node attributes

You can use a node attribute to colocate resources on a group of nodes instead of one node. In this example, `res1` and `res2` don't have to run on the same node, but must run on nodes with the same value for the `datacenter` node attribute:

```
> sudo crm configure colocation res1-2-same-dc \
  inf: res1 res2 node-attribute=datacenter
```

3. Check the status to see which node the resources are now running on:

```
> sudo crm status
```

Hawk

You can use Hawk on any machine with a Web browser and network access to the nodes.

1. In a Web browser, go to `https://HAWKSERVER:7630/` and log in.
2. From the left navigation bar, select *Configuration* › *Add Constraint*.
3. Click *Colocation*.
4. Enter a unique *Constraint ID*.

5. Enter a numeric *Score* or select a value from the drop-down list:

   - `Always` sets the score to `INFINITY`, which means that the resources must run on the same node.
   - `Never` sets the score to `-INFINITY`, which means that the resources must run on different nodes.

6. From the drop-down list in the *Resources* section, select a resource.
   A new drop-down list appears. Repeat this step to add more resources.
   The resource that appears *last* in the list is assigned to a node *first*, and the other resources are placed relative to that resource. To change the order of the resources, click the up arrow icon to swap a resource with the one above it.
   To remove a resource from the constraint, click the minus icon.

7. *(Optional)* To create a resource set, click the chain icon to link a resource to the one above it. You can link multiple resources into a set or create multiple resource sets.
   To remove a resource from the set, click the scissors icon.

8. *(Optional)* If required, select a role (`Started`, `Stopped`, `Promoted` or `Promotable`) from the drop-down list next to a resource. The colocation constraint only applies when the resource is in this role.

9. *(Optional)* You can add a *Node Attribute* to colocate the resources on a group of nodes instead of one specific node. If the nodes have an attribute assigned, the resources in this constraint will all be placed on nodes with the same value for that attribute.

10. Click *Create* to finish the configuration.
    A message at the top of the screen shows if the action was successful.

FOR MORE INFORMATION

- **`crm configure help colocation`**
- **`crm help Resourcesets`**
- https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/constraints.html#placing-resources-relative-to-other-resources
- https://clusterlabs.org/projects/pacemaker/doc/3.0/Pacemaker_Explained/html/constraints.html#colocating-sets-of-resources

6 Colocating resources without adding dependency

A colocation constraint creates dependency between the resources. If one resource fails, the cluster also restarts the other resource. However, sometimes you might need to place resources together *without* any dependency. You can do this with the CRM Shell's **`weak-bond`** command. This creates a `Dummy` resource, then creates a colocation constraint between the `Dummy` resource and the resources you specify.

You can perform this procedure on any node in the cluster.

1. Log in either as the `root` user or as a user with **`sudo`** privileges.
2. Run the following command, specifying two or more primitive resources:

```
> sudo crm configure assist weak-bond RESOURCE1 RESOURCE2
Create weak bond / independent colocation
The following elements will be created:
   * Colocation constraint, ID: place-constraint-1
   * Dummy resource, ID: place-dummy-1
Create resources (y/n)?
```

3. Enter `y` to create the `Dummy` resource and colocation constraint.
4. View the new constraint:

```
> sudo crm configure show place-constraint-1
```

5. Check which node the resources are running on:

```
> sudo crm status
```

FOR MORE INFORMATION

- **`crm assist weak-bond --help`**

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HA glossary

active/active, active/passive

How resources run on the nodes. Active/passive means that resources only run on the active node, but can move to the passive node if the active node fails. Active/active means that all nodes are active at once, and resources can run on (and move to) any node in the cluster.

arbitrator

An *arbitrator* is a machine running outside the cluster to provide an additional instance for cluster calculations. For example, *QNetd* provides a vote to help *QDevice* participate in *quorum* decisions.

CIB (cluster information base)

An XML representation of the whole cluster configuration and status (cluster options, nodes, resources, constraints, etc.). The CIB manager (`pacemaker-based`) keeps the CIB synchronized across the cluster nodes and handles requests to modify it.

clone

In the context of a cluster *resource*, a clone is a resource that can be active on multiple nodes. Any resource can be cloned if its resource agent supports it.

cluster

A *high-availability* cluster is a group of servers (physical or virtual) designed primarily to secure the highest possible availability of data, applications and services. Not to be confused with a *high-performance* cluster, which shares the application load to achieve faster results.

Cluster LVM (Cluster logical volume manager)

The term *Cluster LVM* indicates that LVM is being used in a cluster environment. This requires configuration adjustments to protect the LVM metadata on shared storage.

cluster partition

A cluster partition occurs when communication fails between one or more nodes and the rest of the cluster. The nodes are split into partitions but are still active. They can only communicate with nodes in the same partition and are unaware of the separated nodes. This is known as a *split brain* scenario.

cluster services

The services that run the cluster. Typically this refers to Pacemaker and Corosync, but might also include SBD and QDevice if those services are used.

cluster stack

The ensemble of software technologies and components that make up a cluster.

colocation constraint

A type of *resource constraint* that specifies which resources can or cannot run together on a node.

concurrency violation

A resource that should be running on only one node in the cluster is running on several nodes.

Corosync

Corosync provides reliable messaging, membership and quorum information about the cluster. This is handled by the Corosync Cluster Engine, a group communication system.

CRM (cluster resource manager)

The management entity responsible for coordinating all non-local interactions in a High Availability cluster. SUSE Linux Enterprise High Availability uses *Pacemaker* as the CRM. It interacts with several components: local executors on its own node and on the other nodes, non-local CRMs, administrative commands, the fencing functionality, and the membership layer.

`crmsh` (CRM Shell)

The command-line utility `crmsh` manages the cluster, nodes and resources.

Csync2

A synchronization tool for replicating configuration files across all nodes in the cluster.

DC (designated coordinator)

The `pacemaker-controld` daemon is the cluster controller, which coordinates all actions. This daemon has an instance on each cluster node, but only one instance is elected to act as the DC. The DC is elected when the cluster services start, or if the current DC fails or leaves the cluster. The DC decides whether a cluster-wide change must be performed, such as fencing a node or moving resources.

disaster

An unexpected interruption of critical infrastructure caused by nature, humans, hardware failure, or software bugs.

disaster recovery

The process by which a function is restored to the normal, steady state after a disaster.

Disaster Recovery Plan

A strategy to recover from a disaster with the minimum impact on IT infrastructure.

DLM (Distributed Lock Manager)

DLM coordinates accesses to shared resources in a cluster, for example, managing file locking in clustered file systems to increase performance and availability.

DRBD

DRBD® is a block device designed for building High Availability clusters. It replicates data on a primary device to secondary devices in a way that ensures all copies of the data remain identical.

existing cluster

The term *existing cluster* is used to refer to any cluster that consists of at least one node. An existing cluster has a basic *Corosync* configuration that defines the communication channels, but does not necessarily have resource configuration yet.

failover

Occurs when a resource or node fails on one machine and the affected resources move to another node.

failover domain

A named subset of cluster nodes that are eligible to run a resource if a node fails.

fencing

Prevents access to a shared resource by isolated or failing cluster members. There are two classes of fencing: *resource-level* fencing and *node-level* fencing. Resource-level fencing ensures exclusive access to a resource. Node-level fencing prevents a failed node from accessing shared resources and prevents resources from running on a node with an uncertain status. This is usually done by resetting or powering off the node.

GFS2

Global File System 2 (GFS2) is a shared disk file system for Linux computer clusters. GFS2 allows all nodes to have direct concurrent access to the same shared block storage. GFS2 has no disconnected operating mode, and no client or server roles. All nodes in a GFS2 cluster function as peers. GFS2 supports up to 32 cluster nodes. Using GFS2 in a cluster requires hardware to allow access to the shared storage, and a lock manager to control access to the storage.

group

Resource groups contain multiple resources that need to be located together, started sequentially and stopped in the reverse order.

Hawk (HA Web Konsole)

A user-friendly Web-based interface for monitoring and administering a High Availability cluster from Linux or non-Linux machines. Hawk can be accessed from any machine that can connect to the cluster nodes, using a graphical Web browser.

heuristics

QDevice supports using a set of commands (*heuristics*) that run locally on start-up of cluster services, cluster membership change, successful connection to the *QNetd* server, or optionally at regular times. The result is used in calculations to determine which partition should have *quorum*.

knet (kronosnet)

A network abstraction layer supporting redundancy, security, fault tolerance, and fast failover of network links. In SUSE Linux Enterprise High Availability 16, *knet* is the default transport protocol for the *Corosync* communication channels.

local cluster

A single cluster in one location (for example, all nodes are located in one data center). Network latency is minimal. Storage is typically accessed synchronously by all nodes.

local executor

The local executor is located between *Pacemaker* and the resources on each node. Through the `pacemaker-execd` daemon, Pacemaker can start, stop and monitor resources.

location

In the context of a whole cluster, *location* can refer to the physical location of nodes (for example, all nodes might be located in the same data center). In the context of a *location constraint*, *location* refers to the nodes on which a resource can or cannot run.

location constraint

A type of *resource constraint* that defines the nodes on which a resource can or cannot run.

meta attribute

Parameters that tell the *CRM (cluster resource manager)* how to treat a specific *resource*. For example, you might define a resource's priority or target role.

metro cluster

A single cluster that can stretch over multiple buildings or data centers, with all sites connected by Fibre Channel. Network latency is usually low. Storage is frequently replicated using mirroring or synchronous replication.

network device bonding

Network device bonding combines two or more network interfaces into a single bonded device to increase bandwidth and/or provide redundancy. When using *Corosync*, the bonded device is not managed by the cluster software. Therefore, the bonded device must be configured on every cluster node that might need to access it.

node

Any server (physical or virtual) that is a member of a cluster.

order constraint

A type of *resource constraint* that defines the sequence of actions.

Pacemaker

Pacemaker is the *CRM (cluster resource manager)* in SUSE Linux Enterprise High Availability, or the "brain" that reacts to events occurring in the cluster. Events might be nodes that join or leave the cluster, failure of resources, or scheduled activities such as maintenance, for example. The `pacemakerd` daemon launches and monitors all other related daemons.

parameters (instance attributes)

Parameters determine which instance of a service the *resource* controls.

primitive

A primitive resource is the most basic type of cluster resource.

promotable clone

Promotable clones are a special type of *clone* resource that can be promoted. Active instances of these resources are divided into two states: promoted and unpromoted (also known as "active and passive" or "primary and secondary").

QDevice

QDevice and *QNetd* participate in *quorum* decisions. The `corosync-qdevice` daemon runs on each cluster node and communicates with QNetd to provide a configurable number of votes, allowing a cluster to sustain more node failures than the standard quorum rules allow.

QNetd

QNetd is an *arbitrator* that runs outside the cluster. The `corosync-qnetd` daemon provides a vote to the `corosync-qdevice` daemon on each node to help it participate in quorum decisions.

quorum

A *cluster partition* is defined to have quorum (be *quorate*) if it has the majority of nodes (or "votes"). Quorum distinguishes exactly one partition. This is part of the algorithm to prevent several disconnected partitions or nodes ("split brain") from proceeding and causing data and service corruption. Quorum is a prerequisite for fencing, which then ensures that quorum is unique.

RA (resource agent)

A script acting as a proxy to manage a *resource* (for example, to start, stop or monitor a resource). SUSE Linux Enterprise High Availability supports different kinds of resource agents.

ReaR (Relax and Recover)

An administrator tool set for creating *disaster recovery* images.

resource

Any type of service or application that is known to *Pacemaker*, for example, an IP address, a file system, or a database. The term *resource* is also used for *DRBD*, where it names a set of block devices that use a common connection for replication.

resource constraint

Resource constraints specify which cluster nodes a resource can run on, what order the resources should start in, and which other resources a specific resource is dependent on.

See also *colocation constraint*, *location constraint* and *order constraint*.

resource set

As an alternative format for defining location, colocation or order constraints, you can use *resource sets*, where primitives are grouped together in one set. When creating a constraint, you can specify multiple resources for the constraint to apply to.

resource template

To help create many resources with similar configurations, you can define a resource template. After being defined, it can be referenced in primitives or in certain types of constraints. If a template is referenced in a primitive, the primitive inherits all operations, instance attributes (parameters), meta attributes and utilization attributes defined in the template.

SBD (STONITH Block Device)

SBD provides a node *fencing* mechanism through the exchange of messages via shared block storage. Alternatively, it can be used in diskless mode. In either case, it needs a hardware or software *watchdog* on each node to ensure that misbehaving nodes are really stopped.

scheduler

The scheduler is implemented as `pacemaker-schedulerd`. When a cluster transition is needed, `pacemaker-schedulerd` calculates the expected next state of the cluster and determines what actions need to be scheduled to achieve the next state.

split brain

A scenario in which the cluster nodes are divided into two or more groups that do not know about each other (either through a software or hardware failure). *STONITH* prevents a split-brain scenario from badly affecting the entire cluster. Also known as a *partitioned cluster* scenario.

The term *split brain* is also used in *DRBD* but means that the nodes contain different data.

SPOF (single point of failure)

Any component of a cluster that, if it fails, triggers the failure of the entire cluster.

stickiness

Resource stickiness is a *meta attribute* that determines how much a resource prefers to stay on its current node.

STONITH

Another term for the *fencing* mechanism that shuts down a misbehaving node to prevent it from causing trouble in a cluster. In a *Pacemaker* cluster, node fencing is managed by the fencing subsystem `pacemaker-fenced`.

switchover

The planned moving of resources to other nodes in a cluster. See also *failover*.

utilization

Tells the CRM what capacity a certain *resource* requires from a node.

watchdog

SBD (STONITH Block Device) needs a watchdog on each node to ensure that misbehaving nodes are really stopped. SBD "feeds" the watchdog by regularly writing a service pulse to it. If SBD stops feeding the watchdog, the hardware enforces a system restart. This protects against failures of the SBD process itself, such as becoming stuck on an I/O error.