Pacemaker 1.1

Configuration Explained

An A-Z guide to Pacemaker's Configuration Options

Andrew Beekhof

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Edition 1

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The purpose of this document is to definitively explain the concepts used to configure Pacemaker. To achieve this, it will focus exclusively on the XML syntax used to configure the CIB.

For those that are allergic to XML, there exist several unified shells and GUIs for Pacemaker. However these tools will not be covered at all in this document[1], precisely because they hide the XML.

Additionally, this document is NOT a step-by-step how-to guide for configuring a specific clustering scenario. Although such guides exist, the purpose of this document is to provide an understanding of the building blocks that can be used to construct any type of Pacemaker cluster. Try the *Clusters from Scratch*[2] document instead.

[3] An explanation of CC-BY-SA is available at *http://creativecommons.org/licenses/by-sa/3.0/*

[1] I hope, however, that the concepts explained here make the functionality of these tools more easily understood.

[2] http://www.clusterlabs.org/doc

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Preface

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1. Document Conventions

This manual uses several conventions to highlight certain words and phrases and draw attention to specific pieces of information.

In PDF and paper editions, this manual uses typefaces drawn from the *Liberation Fonts*[1] set. The Liberation Fonts set is also used in HTML editions if the set is installed on your system. If not, alternative but equivalent typefaces are displayed. Note: Red Hat Enterprise Linux 5 and later include the Liberation Fonts set by default.

1.1. Typographic Conventions

Four typographic conventions are used to call attention to specific words and phrases. These conventions, and the circumstances they apply to, are as follows.

`Mono-spaced Bold`

Used to highlight system input, including shell commands, file names and paths. Also used to highlight keys and key combinations. For example:

> To see the contents of the file **`my_next_bestselling_novel`** in your current working directory, enter the **`cat my_next_bestselling_novel`** command at the shell prompt and press **`Enter`** to execute the command.

The above includes a file name, a shell command and a key, all presented in mono-spaced bold and all distinguishable thanks to context.

Key combinations can be distinguished from an individual key by the plus sign that connects each part of a key combination. For example:

> Press **`Enter`** to execute the command.
>
> Press **`Ctrl`**+**`Alt`**+**`F2`** to switch to a virtual terminal.

The first example highlights a particular key to press. The second example highlights a key combination: a set of three keys pressed simultaneously.

If source code is discussed, class names, methods, functions, variable names and returned values mentioned within a paragraph will be presented as above, in **`mono-spaced bold`**. For example:

[1] https://fedorahosted.org/liberation-fonts/

File-related classes include **filesystem** for file systems, **file** for files, and **dir** for directories. Each class has its own associated set of permissions.

Proportional Bold

This denotes words or phrases encountered on a system, including application names; dialog box text; labeled buttons; check-box and radio button labels; menu titles and sub-menu titles. For example:

Choose **System** → **Preferences** → **Mouse** from the main menu bar to launch **Mouse Preferences**. In the **Buttons** tab, select the **Left-handed mouse** check box and click **Close** to switch the primary mouse button from the left to the right (making the mouse suitable for use in the left hand).

To insert a special character into a **gedit** file, choose **Applications** → **Accessories** → **Character Map** from the main menu bar. Next, choose **Search** → **Find…** from the **Character Map** menu bar, type the name of the character in the **Search** field and click **Next**. The character you sought will be highlighted in the **Character Table**. Double-click this highlighted character to place it in the **Text to copy** field and then click the **Copy** button. Now switch back to your document and choose **Edit** → **Paste** from the **gedit** menu bar.

The above text includes application names; system-wide menu names and items; application-specific menu names; and buttons and text found within a GUI interface, all presented in proportional bold and all distinguishable by context.

Mono-spaced Bold Italic or ***Proportional Bold Italic***

Whether mono-spaced bold or proportional bold, the addition of italics indicates replaceable or variable text. Italics denotes text you do not input literally or displayed text that changes depending on circumstance. For example:

To connect to a remote machine using ssh, type **ssh *username*@*domain.name*** at a shell prompt. If the remote machine is **example.com** and your username on that machine is john, type **ssh john@example.com**.

The **mount -o remount *file-system*** command remounts the named file system. For example, to remount the **/home** file system, the command is **mount -o remount /home**.

To see the version of a currently installed package, use the **rpm -q *package*** command. It will return a result as follows: ***package-version-release***.

Note the words in bold italics above — username, domain.name, file-system, package, version and release. Each word is a placeholder, either for text you enter when issuing a command or for text displayed by the system.

Aside from standard usage for presenting the title of a work, italics denotes the first use of a new and important term. For example:

Publican is a *DocBook* publishing system.

1.2. Pull-quote Conventions

Terminal output and source code listings are set off visually from the surrounding text.

Output sent to a terminal is set in **mono-spaced roman** and presented thus:

```
books        Desktop   documentation  drafts  mss    photos   stuff  svn
books_tests  Desktop1  downloads      images  notes  scripts  svgs
```

Source-code listings are also set in **mono-spaced roman** but add syntax highlighting as follows:

```
package org.jboss.book.jca.ex1;

import javax.naming.InitialContext;

public class ExClient
{
   public static void main(String args[])
       throws Exception
   {
      InitialContext iniCtx = new InitialContext();
      Object         ref    = iniCtx.lookup("EchoBean");
      EchoHome       home   = (EchoHome) ref;
      Echo           echo   = home.create();

      System.out.println("Created Echo");

      System.out.println("Echo.echo('Hello') = " + echo.echo("Hello"));
   }
}
```

1.3. Notes and Warnings

Finally, we use three visual styles to draw attention to information that might otherwise be overlooked.

Note

Notes are tips, shortcuts or alternative approaches to the task at hand. Ignoring a note should have no negative consequences, but you might miss out on a trick that makes your life easier.

Important

Important boxes detail things that are easily missed: configuration changes that only apply to the current session, or services that need restarting before an update will apply. Ignoring a box labeled 'Important' will not cause data loss but may cause irritation and frustration.

Warning

Warnings should not be ignored. Ignoring warnings will most likely cause data loss.

2. We Need Feedback!

If you find a typographical error in this manual, or if you have thought of a way to make this manual better, we would love to hear from you! Please submit a report in Bugzilla[2] against the product **Pacemaker.**

When submitting a bug report, be sure to mention the manual's identifier: *Pacemaker_Explained*

If you have a suggestion for improving the documentation, try to be as specific as possible when describing it. If you have found an error, please include the section number and some of the surrounding text so we can find it easily.

[2] *http://bugs.clusterlabs.org*

Read-Me-First

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1.1. The Scope of this Document

The purpose of this document is to definitively explain the concepts used to configure Pacemaker. To achieve this, it will focus exclusively on the XML syntax used to configure the CIB.

For those that are allergic to XML, there exist several unified shells and GUIs for Pacemaker. However these tools will not be covered at all in this document [1] , precisely because they hide the XML.

Additionally, this document is NOT a step-by-step how-to guide for configuring a specific clustering scenario.

Although such guides exist, the purpose of this document is to provide an understanding of the building blocks that can be used to construct any type of Pacemaker cluster.

1.2. What Is Pacemaker?

Pacemaker is a cluster resource manager.

It achieves maximum availability for your cluster services (aka. resources) by detecting and recovering from node and resource-level failures by making use of the messaging and membership capabilities provided by your preferred cluster infrastructure (either *Corosync*[2] or *Heartbeat*[3].

Pacemaker's key features include:

- Detection and recovery of node and service-level failures
- Storage agnostic, no requirement for shared storage
- Resource agnostic, anything that can be scripted can be clustered
- Supports *STONITH*[4] for ensuring data integrity
- Supports large and small clusters
- Supports both *quorate*[5] and *resource driven*[6] clusters

[1] I hope, however, that the concepts explained here make the functionality of these tools more easily understood.
[2] http://www.corosync.org/
[3] http://linux-ha.org/wiki/Heartbeat
[4] http://en.wikipedia.org/wiki/STONITH
[5] http://en.wikipedia.org/wiki/Quorum_(Distributed_Systems)
[6] http://devresources.linux-foundation.org/dev/clusters/docs/ResourceDrivenClusters.pdf

- Supports practically any *redundancy configuration*[7]
- Automatically replicated configuration that can be updated from any node
- Ability to specify cluster-wide service ordering, colocation and anti-colocation
- Support for advanced services type
  - Clones: for services which need to be active on multiple nodes
  - Multi-state: for services with multiple modes (eg. master/slave, primary/secondary)

1.3. Types of Pacemaker Clusters

Pacemaker makes no assumptions about your environment, this allows it to support practically any *redundancy configuration*[8] including Active/Active, Active/Passive, N+1, N+M, N-to-1 and N-to-N.

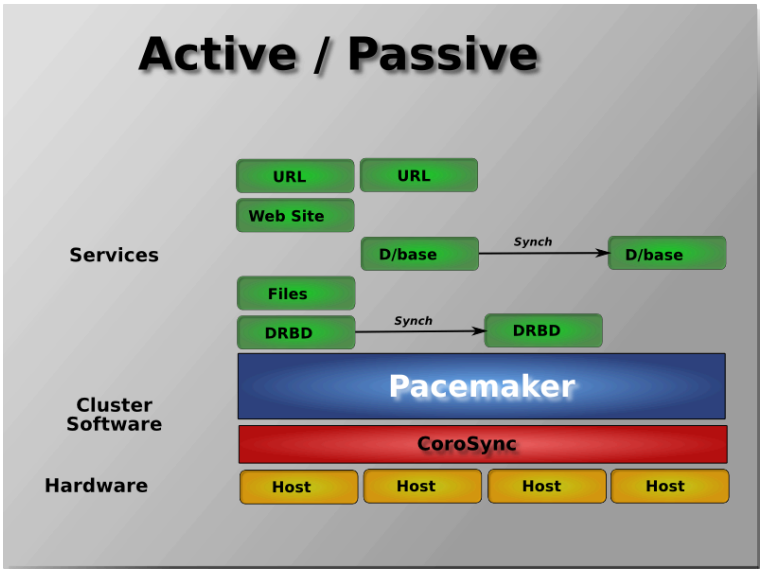

Figure 1.1. Active/Passive Redundancy

Two-node Active/Passive clusters using Pacemaker and DRBD are a cost-effective solution for many High Availability situations.

[7] http://en.wikipedia.org/wiki/High-availability_cluster#Node_configurations
[8] http://en.wikipedia.org/wiki/High-availability_cluster#Node_configurations

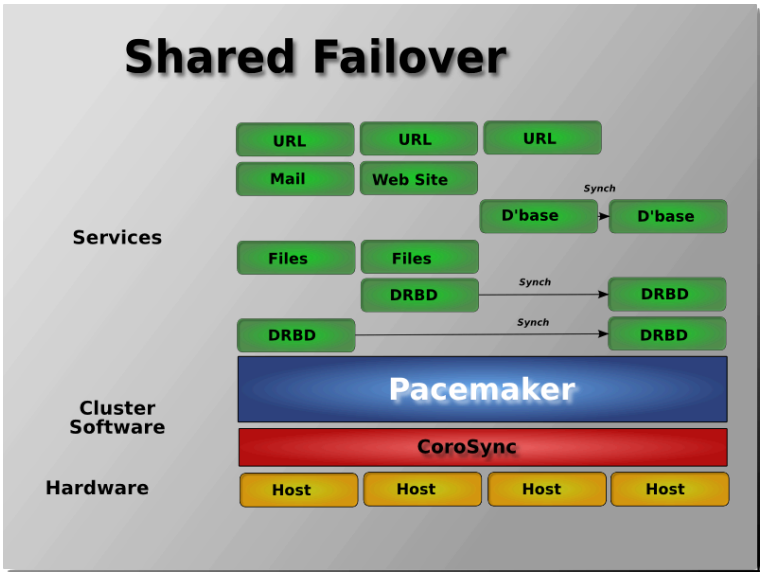

Figure 1.2. Shared Failover

By supporting many nodes, Pacemaker can dramatically reduce hardware costs by allowing several active/passive clusters to be combined and share a common backup node

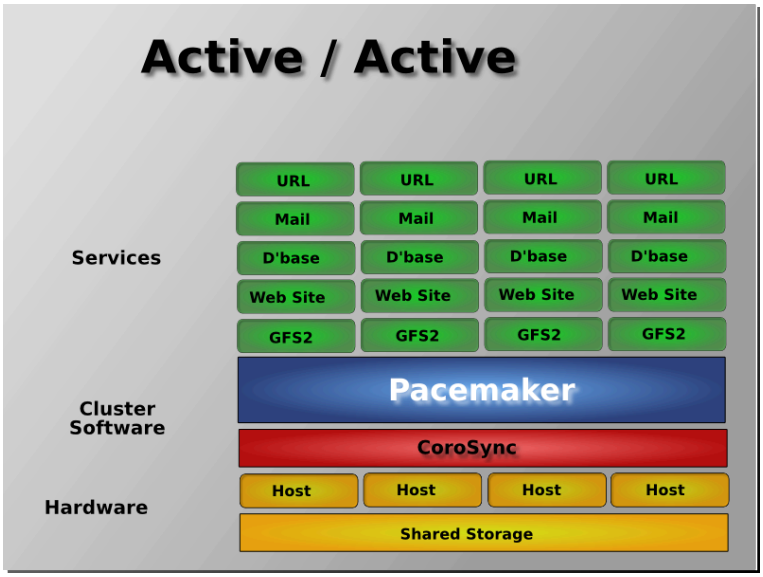

Figure 1.3. N to N Redundancy

When shared storage is available, every node can potentially be used for failover. Pacemaker can even run multiple copies of services to spread out the workload.

1.4. Pacemaker Architecture

At the highest level, the cluster is made up of three pieces:

- Core cluster infrastructure providing messaging and membership functionality (illustrated in red)
- Non-cluster aware components (illustrated in green).

  In a Pacemaker cluster, these pieces include not only the scripts that knows how to start, stop and monitor resources, but also a local daemon that masks the differences between the different standards these scripts implement.

- A brain (illustrated in blue)

  This component processes and reacts to events from the cluster (nodes leaving or joining) and resources (eg. monitor failures) as well as configuration changes from the administrator. In response to all of these events, Pacemaker will compute the ideal state of the cluster and plot a path to achieve it. This may include moving resources, stopping nodes and even forcing nodes offline with remote power switches.

1.4.1. Conceptual Stack Overview

Figure 1.4. Conceptual overview of the cluster stack

When combined with Corosync, Pacemaker also supports popular open source cluster filesystems. footnote:[Even though Pacemaker also supports Heartbeat, the filesystems need to use the stack for messaging and membership and Corosync seems to be what they're standardizing on.

Technically it would be possible for them to support Heartbeat as well, however there seems little interest in this.]

Due to recent standardization within the cluster filesystem community, they make use of a common distributed lock manager which makes use of Corosync for its messaging capabilities and Pacemaker for its membership (which nodes are up/down) and fencing services.

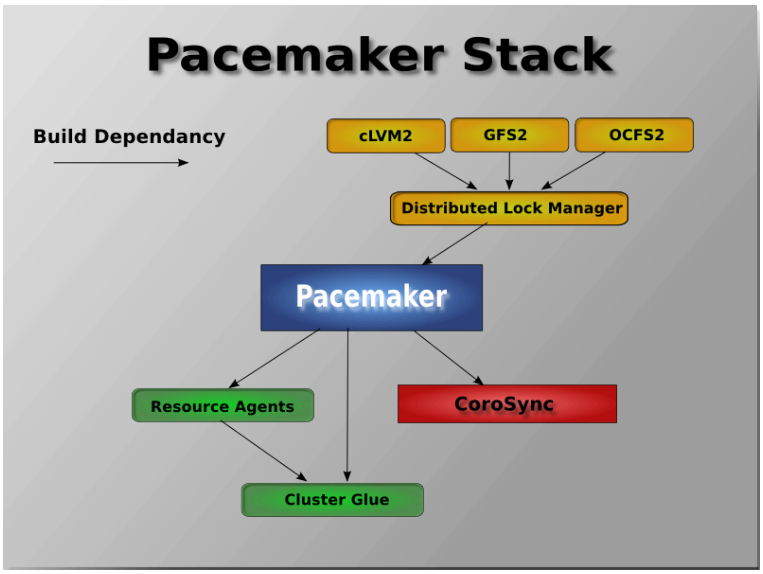

Figure 1.5. The Pacemaker stack when running on Corosync

1.4.2. Internal Components

Pacemaker itself is composed of four key components (illustrated below in the same color scheme as the previous diagram):

- CIB (aka. Cluster Information Base)
- CRMd (aka. Cluster Resource Management daemon)
- PEngine (aka. PE or Policy Engine)
- STONITHd

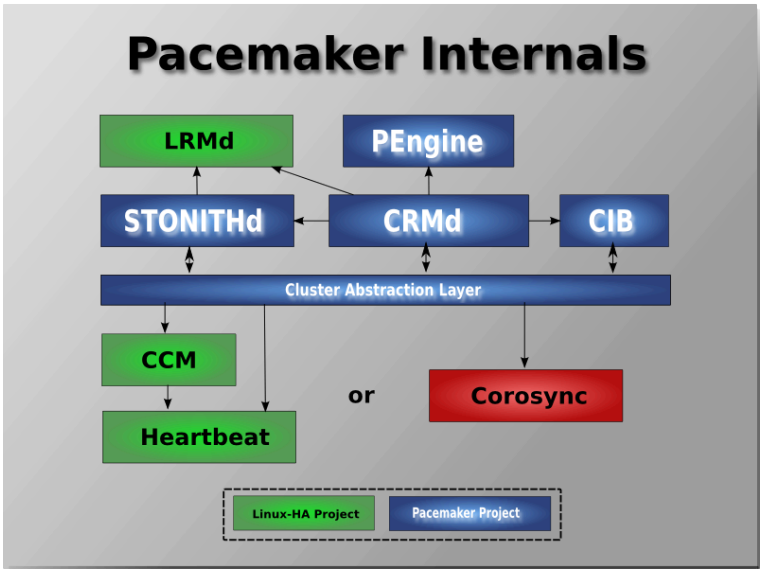

Figure 1.6. Subsystems of a Pacemaker cluster

The CIB uses XML to represent both the cluster's configuration and current state of all resources in the cluster. The contents of the CIB are automatically kept in sync across the entire cluster and are used by the PEngine to compute the ideal state of the cluster and how it should be achieved.

This list of instructions is then fed to the DC (Designated Controller). Pacemaker centralizes all cluster decision making by electing one of the CRMd instances to act as a master. Should the elected CRMd process (or the node it is on) fail… a new one is quickly established.

The DC carries out PEngine's instructions in the required order by passing them to either the LRMd (Local Resource Management daemon) or CRMd peers on other nodes via the cluster messaging infrastructure (which in turn passes them on to their LRMd process).

The peer nodes all report the results of their operations back to the DC and, based on the expected and actual results, will either execute any actions that needed to wait for the previous one to complete, or abort processing and ask the PEngine to recalculate the ideal cluster state based on the unexpected results.

In some cases, it may be necessary to power off nodes in order to protect shared data or complete resource recovery. For this Pacemaker comes with STONITHd.

STONITH is an acronym for Shoot-The-Other-Node-In-The-Head and is usually implemented with a remote power switch.

In Pacemaker, STONITH devices are modeled as resources (and configured in the CIB) to enable them to be easily monitored for failure, however STONITHd takes care of understanding the STONITH topology such that its clients simply request a node be fenced and it does the rest.

Configuration Basics

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2.1. Configuration Layout

The cluster is written using XML notation and divided into two main sections: configuration and status.

The status section contains the history of each resource on each node and based on this data, the cluster can construct the complete current state of the cluster. The authoritative source for the status section is the local resource manager (lrmd) process on each cluster node and the cluster will occasionally repopulate the entire section. For this reason it is never written to disk and administrators are advised against modifying it in any way.

The configuration section contains the more traditional information like cluster options, lists of resources and indications of where they should be placed. The configuration section is the primary focus of this document.

The configuration section itself is divided into four parts:

- Configuration options (called **`crm_config`**)
- Nodes
- Resources
- Resource relationships (called **`constraints`**)

> Example 2.1. An empty configuration

```
<cib admin_epoch="0" epoch="0" num_updates="0" have-quorum="false">
   <configuration>
      <crm_config/>
      <nodes/>
      <resources/>
      <constraints/>
   </configuration>
   <status/>
</cib>
```

2.2. The Current State of the Cluster

Before one starts to configure a cluster, it is worth explaining how to view the finished product. For this purpose we have created the **crm_mon** utility that will display the current state of an active cluster. It can show the cluster status by node or by resource and can be used in either single-shot or dynamically-updating mode. There are also modes for displaying a list of the operations performed (grouped by node and resource) as well as information about failures.

Using this tool, you can examine the state of the cluster for irregularities and see how it responds when you cause or simulate failures.

Details on all the available options can be obtained using the **crm_mon --help** command.

Example 2.2. Sample output from crm_mon

```
============
Last updated: Fri Nov 23 15:26:13 2007
Current DC: sles-3 (2298606a-6a8c-499a-9d25-76242f7006ec)
3 Nodes configured.
5 Resources configured.
============

Node: sles-1 (1186dc9a-324d-425a-966e-d757e693dc86): online
    192.168.100.181    (heartbeat::ocf:IPaddr):    Started sles-1
    192.168.100.182    (heartbeat:IPaddr):         Started sles-1
    192.168.100.183    (heartbeat::ocf:IPaddr):    Started sles-1
    rsc_sles-1         (heartbeat::ocf:IPaddr):    Started sles-1
    child_DoFencing:2  (stonith:external/vmware):  Started sles-1
Node: sles-2 (02fb99a8-e30e-482f-b3ad-0fb3ce27d088): standby
Node: sles-3 (2298606a-6a8c-499a-9d25-76242f7006ec): online
    rsc_sles-2    (heartbeat::ocf:IPaddr):    Started sles-3
    rsc_sles-3    (heartbeat::ocf:IPaddr):    Started sles-3
    child_DoFencing:0    (stonith:external/vmware):    Started sles-3
```

Example 2.3. Sample output from crm_mon -n

```
============
Last updated: Fri Nov 23 15:26:13 2007
Current DC: sles-3 (2298606a-6a8c-499a-9d25-76242f7006ec)
3 Nodes configured.
5 Resources configured.
============

Node: sles-1 (1186dc9a-324d-425a-966e-d757e693dc86): online
Node: sles-2 (02fb99a8-e30e-482f-b3ad-0fb3ce27d088): standby
Node: sles-3 (2298606a-6a8c-499a-9d25-76242f7006ec): online

Resource Group: group-1
  192.168.100.181    (heartbeat::ocf:IPaddr):    Started sles-1
  192.168.100.182    (heartbeat:IPaddr):        Started sles-1
  192.168.100.183    (heartbeat::ocf:IPaddr):    Started sles-1
rsc_sles-1    (heartbeat::ocf:IPaddr):    Started sles-1
rsc_sles-2    (heartbeat::ocf:IPaddr):    Started sles-3
rsc_sles-3    (heartbeat::ocf:IPaddr):    Started sles-3
Clone Set: DoFencing
  child_DoFencing:0    (stonith:external/vmware):    Started sles-3
  child_DoFencing:1    (stonith:external/vmware):    Stopped
  child_DoFencing:2    (stonith:external/vmware):    Started sles-1
```

The DC (Designated Controller) node is where all the decisions are made and if the current DC fails a new one is elected from the remaining cluster nodes. The choice of DC is of no significance to an administrator beyond the fact that its logs will generally be more interesting.

2.3. How Should the Configuration be Updated?

There are three basic rules for updating the cluster configuration:

- Rule 1 - Never edit the cib.xml file manually. Ever. I'm not making this up.
- Rule 2 - Read Rule 1 again.
- Rule 3 - The cluster will notice if you ignored rules 1 & 2 and refuse to use the configuration.

Now that it is clear how NOT to update the configuration, we can begin to explain how you should.

The most powerful tool for modifying the configuration is the **`cibadmin`** command which talks to a running cluster. With **`cibadmin`**, the user can query, add, remove, update or replace any part of the configuration; all changes take effect immediately, so there is no need to perform a reload-like operation.

The simplest way of using cibadmin is to use it to save the current configuration to a temporary file, edit that file with your favorite text or XML editor and then upload the revised configuration.

Example 2.4. Safely using an editor to modify the cluster configuration

```
# cibadmin --query > tmp.xml
# vi tmp.xml
# cibadmin --replace --xml-file tmp.xml
```

Some of the better XML editors can make use of a Relax NG schema to help make sure any changes you make are valid. The schema describing the configuration can normally be found in */usr/lib/heartbeat/pacemaker.rng* on most systems.

If you only wanted to modify the resources section, you could instead do

Example 2.5. Safely using an editor to modify a subsection of the cluster configuration

```
# cibadmin --query --obj_type resources > tmp.xml
# vi tmp.xml
# cibadmin --replace --obj_type resources --xml-file tmp.xml
```

to avoid modifying any other part of the configuration.

2.4. Quickly Deleting Part of the Configuration

Identify the object you wish to delete. Eg. run

Example 2.6. Searching for STONITH related configuration items

```
# cibadmin -Q | grep stonith
```

```
 <nvpair id="cib-bootstrap-options-stonith-action" name="stonith-action" value="reboot"/>
 <nvpair id="cib-bootstrap-options-stonith-enabled" name="stonith-enabled" value="1"/>
```

```
<primitive id="child_DoFencing" class="stonith" type="external/vmware">
<lrm_resource id="child_DoFencing:0" type="external/vmware" class="stonith">
<lrm_resource id="child_DoFencing:0" type="external/vmware" class="stonith">
<lrm_resource id="child_DoFencing:1" type="external/vmware" class="stonith">
<lrm_resource id="child_DoFencing:0" type="external/vmware" class="stonith">
<lrm_resource id="child_DoFencing:2" type="external/vmware" class="stonith">
<lrm_resource id="child_DoFencing:0" type="external/vmware" class="stonith">
<lrm_resource id="child_DoFencing:3" type="external/vmware" class="stonith">
```

Next identify the resource's tag name and id (in this case we'll choose **primitive** and **child_DoFencing**). Then simply execute:

```
# cibadmin --delete --crm_xml '<primitive id="child_DoFencing"/>'
```

2.5. Updating the Configuration Without Using XML

Some common tasks can also be performed with one of the higher level tools that avoid the need to read or edit XML.

To enable stonith for example, one could run:

```
# crm_attribute --attr-name stonith-enabled --attr-value true
```

Or, to see if **somenode** is allowed to run resources, there is:

```
# crm_standby --get-value --node-uname somenode
```

Or, to find the current location of **my-test-rsc**, one can use:

```
# crm_resource --locate --resource my-test-rsc
```

2.6. Making Configuration Changes in a Sandbox

Often it is desirable to preview the effects of a series of changes before updating the configuration atomically. For this purpose we have created **crm_shadow** which creates a "shadow" copy of the configuration and arranges for all the command line tools to use it.

To begin, simply invoke **crm_shadow** and give it the name of a configuration to create [1] ; be sure to follow the simple on-screen instructions.

Warning

Read the above carefully, failure to do so could result in you destroying the cluster's active configuration!

Example 2.7. Creating and displaying the active sandbox

```
# crm_shadow --create test
```

[1] Shadow copies are identified with a name, making it possible to have more than one.

```
Setting up shadow instance
Type Ctrl-D to exit the crm_shadow shell
shadow[test]:
shadow[test] # crm_shadow --which
test
```

From this point on, all cluster commands will automatically use the shadow copy instead of talking to the cluster's active configuration. Once you have finished experimenting, you can either commit the changes, or discard them as shown below. Again, be sure to follow the on-screen instructions carefully.

For a full list of **crm_shadow** options and commands, invoke it with the <parameter>--help</parameter> option.

Example 2.8. Using a sandbox to make multiple changes atomically

```
shadow[test] # crm_failcount -G -r rsc_c001n01
 name=fail-count-rsc_c001n01 value=0
shadow[test] # crm_standby -v on -n c001n02
shadow[test] # crm_standby -G -n c001n02
name=c001n02 scope=nodes value=on
shadow[test] # cibadmin --erase --force
shadow[test] # cibadmin --query
 <cib cib_feature_revision="1" validate-
with="pacemaker-1.0" admin_epoch="0" crm_feature_set="3.0" have-quorum="1" epoch="112"
      dc-uuid="c001n01" num_updates="1" cib-last-written="Fri Jun 27 12:17:10 2008">
    <configuration>
       <crm_config/>
       <nodes/>
       <resources/>
       <constraints/>
    </configuration>
    <status/>
 </cib>
 shadow[test] # crm_shadow --delete test --force
 Now type Ctrl-D to exit the crm_shadow shell
 shadow[test] # exit
 # crm_shadow --which
 No shadow instance provided
 # cibadmin -Q
 <cib cib_feature_revision="1" validate-
with="pacemaker-1.0" admin_epoch="0" crm_feature_set="3.0" have-quorum="1" epoch="110"
       dc-uuid="c001n01" num_updates="551">
    <configuration>
       <crm_config>
          <cluster_property_set id="cib-bootstrap-options">
             <nvpair id="cib-bootstrap-1" name="stonith-enabled" value="1"/>
             <nvpair id="cib-bootstrap-2" name="pe-input-series-max" value="30000"/>
```

Making changes in a sandbox and verifying the real configuration is untouched

2.7. Testing Your Configuration Changes

We saw previously how to make a series of changes to a "shadow" copy of the configuration. Before loading the changes back into the cluster (eg. **crm_shadow --commit mytest --force**), it is often advisable to simulate the effect of the changes with **crm_simulate**, eg.

```
# crm_simulate --live-check -VVVVV --save-graph tmp.graph --save-dotfile tmp.dot
```

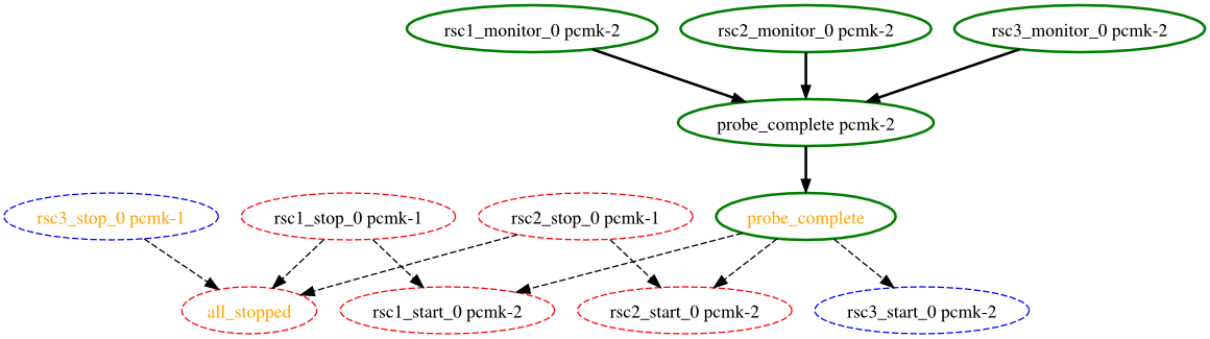
The tool uses the same library as the live cluster to show what it would have done given the supplied input. It's output, in addition to a significant amount of logging, is stored in two files **`tmp.graph`** and **`tmp.dot`**, both are representations of the same thing — the cluster's response to your changes.

In the graph file is stored the complete transition, containing a list of all the actions, their parameters and their pre-requisites. Because the transition graph is not terribly easy to read, the tool also generates a Graphviz dot-file representing the same information.

2.8. Interpreting the Graphviz output

- Arrows indicate ordering dependencies
- Dashed-arrows indicate dependencies that are not present in the transition graph
- Actions with a dashed border of any color do not form part of the transition graph
- Actions with a green border form part of the transition graph
- Actions with a red border are ones the cluster would like to execute but cannot run
- Actions with a blue border are ones the cluster does not feel need to be executed
- Actions with orange text are pseudo/pretend actions that the cluster uses to simplify the graph
- Actions with black text are sent to the LRM
- Resource actions have text of the form *`rsc_action_interval node`*
- Any action depending on an action with a red border will not be able to execute.
- Loops are *really* bad. Please report them to the development team.

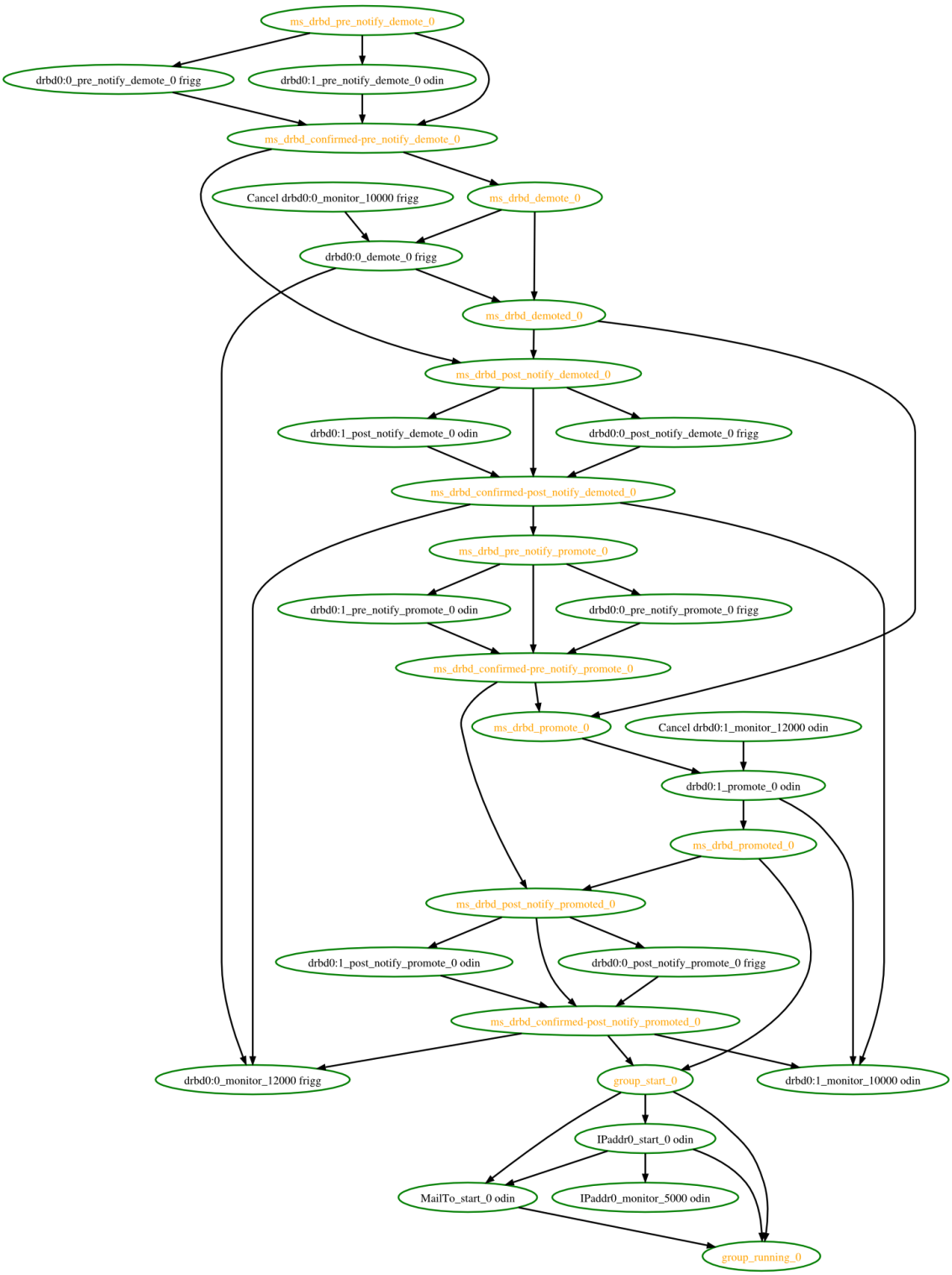
2.8.1. Small Cluster Transition



In the above example, it appears that a new node, **`node2`**, has come online and that the cluster is checking to make sure **`rsc1`**, **`rsc2`** and **`rsc3`** are not already running there (Indicated by the **`*_monitor_0`** entries). Once it did that, and assuming the resources were not active there, it would have liked to stop **`rsc1`** and **`rsc2`** on **`node1`** and move them to **`node2`**. However, there appears to be some problem and the cluster cannot or is not permitted to perform the stop actions which implies it also cannot perform the start actions. For some reason the cluster does not want to start **`rsc3`** anywhere.

For information on the options supported by **`crm_simulate`**, use the **`--help`** option.

2.8.2. Complex Cluster Transition



2.9. Do I Need to Update the Configuration on all Cluster Nodes?

No. Any changes are immediately synchronized to the other active members of the cluster.

To reduce bandwidth, the cluster only broadcasts the incremental updates that result from your changes and uses MD5 checksums to ensure that each copy is completely consistent.

Cluster Options

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3.1. Special Options

The reason for these fields to be placed at the top level instead of with the rest of cluster options is simply a matter of parsing. These options are used by the configuration database which is, by design, mostly ignorant of the content it holds. So the decision was made to place them in an easy to find location.

3.2. Configuration Version

When a node joins the cluster, the cluster will perform a check to see who has the best configuration based on the fields below. It then asks the node with the highest (**`admin_epoch`**, **`epoch`**, **`num_updates`**) tuple to replace the configuration on all the nodes - which makes setting them, and setting them correctly, very important.

Table 3.1. Configuration Version Properties

Field	Description
`admin_epoch`	Never modified by the cluster. Use this to make the configurations on any inactive nodes obsolete. *Never set this value to zero*, in such cases the cluster cannot tell the difference between your configuration and the "empty" one used when nothing is found on disk.
`epoch`	Incremented every time the configuration is updated (usually by the admin)
`num_updates`	Incremented every time the configuration or status is updated (usually by the cluster)

3.3. Other Fields

Table 3.2. Properties Controlling Validation

Field	Description
`validate-with`	Determines the type of validation being done on the configuration. If set to "none", the cluster will not verify that updates conform to

Field	Description
	the DTD (nor reject ones that don't). This option can be useful when operating a mixed version cluster during an upgrade.

3.4. Fields Maintained by the Cluster

Table 3.3. Properties Maintained by the Cluster

Field	Description
cib-last-written	Indicates when the configuration was last written to disk. Informational purposes only.
dc-uuid	Indicates which cluster node is the current leader. Used by the cluster when placing resources and determining the order of some events.
have-quorum	Indicates if the cluster has quorum. If false, this may mean that the cluster cannot start resources or fence other nodes. See **no-quorum-policy** below.

Note that although these fields can be written to by the admin, in most cases the cluster will overwrite any values specified by the admin with the "correct" ones. To change the **admin_epoch**, for example, one would use:

```
# cibadmin --modify --crm_xml '<cib admin_epoch="42"/>'
```

A complete set of fields will look something like this:

Example 3.1. An example of the fields set for a cib object

```
<cib have-quorum="true" validate-with="pacemaker-1.0"
  admin_epoch="1" epoch="12" num_updates="65"
  dc-uuid="ea7d39f4-3b94-4cfa-ba7a-952956daabee">
```

3.5. Cluster Options

Cluster options, as you might expect, control how the cluster behaves when confronted with certain situations.

They are grouped into sets and, in advanced configurations, there may be more than one. [1] For now we will describe the simple case where each option is present at most once.

3.6. Available Cluster Options

Table 3.4. Cluster Options

Option	Default	Description
batch-limit	30	The number of jobs that the TE is allowed to execute in parallel. The "correct" value will depend on the speed and load of your network and cluster nodes.

[1] This will be described later in the section on *Chapter 8, Rules* where we will show how to have the cluster use different sets of options during working hours (when downtime is usually to be avoided at all costs) than it does during the weekends (when resources can be moved to the their preferred hosts without bothering end users)

Option	Default	Description
migration-limit	-1 (unlimited)	The number of migration jobs that the TE is allowed to execute in parallel on a node.
no-quorum-policy	stop	What to do when the cluster does not have quorum. Allowed values: * ignore - continue all resource management * freeze - continue resource management, but don't recover resources from nodes not in the affected partition * stop - stop all resources in the affected cluster partition * suicide - fence all nodes in the affected cluster partition
symmetric-cluster	TRUE	Can all resources run on any node by default?
stonith-enabled	TRUE	Should failed nodes and nodes with resources that can't be stopped be shot? If you value your data, set up a STONITH device and enable this. If true, or unset, the cluster will refuse to start resources unless one or more STONITH resources have been configured also.
stonith-action	reboot	Action to send to STONITH device. Allowed values: reboot, off. The value *poweroff* is also allowed, but is only used for legacy devices.
cluster-delay	60s	Round trip delay over the network (excluding action execution). The "correct" value will depend on the speed and load of your network and cluster nodes.
stop-orphan-resources	TRUE	Should deleted resources be stopped?
stop-orphan-actions	TRUE	Should deleted actions be cancelled?
start-failure-is-fatal	TRUE	When set to FALSE, the cluster will instead use the resource's **failcount** and value for **resource-failure-stickiness**.
pe-error-series-max	-1 (all)	The number of PE inputs resulting in ERRORs to save. Used when reporting problems.
pe-warn-series-max	-1 (all)	The number of PE inputs resulting in WARNINGs to save. Used when reporting problems.
pe-input-series-max	-1 (all)	The number of "normal" PE inputs to save. Used when reporting problems.

You can always obtain an up-to-date list of cluster options, including their default values, by running the **pengine metadata** command.

3.7. Querying and Setting Cluster Options

Cluster options can be queried and modified using the **crm_attribute** tool. To get the current value of **cluster-delay**, simply use:

```
# crm_attribute --attr-name cluster-delay --get-value
```

which is more simply written as

```
# crm_attribute --get-value -n cluster-delay
```

If a value is found, you'll see a result like this:

```
# crm_attribute --get-value -n cluster-delay
 name=cluster-delay value=60s
```

However, if no value is found, the tool will display an error:

```
# crm_attribute --get-value -n clusta-deway`
name=clusta-deway value=(null)
Error performing operation: The object/attribute does not exist
```

To use a different value, eg. **30**, simply run:

```
# crm_attribute --attr-name cluster-delay --attr-value 30s
```

To go back to the cluster's default value you can delete the value, for example with this command:

```
# crm_attribute --attr-name cluster-delay --delete-attr
```

3.8. When Options are Listed More Than Once

If you ever see something like the following, it means that the option you're modifying is present more than once.

Example 3.2. Deleting an option that is listed twice

```
# crm_attribute --attr-name batch-limit --delete-attr

Multiple attributes match name=batch-limit in crm_config:
Value: 50          (set=cib-bootstrap-options, id=cib-bootstrap-options-batch-limit)
Value: 100         (set=custom, id=custom-batch-limit)
Please choose from one of the matches above and supply the 'id' with --attr-id
```

In such cases follow the on-screen instructions to perform the requested action. To determine which value is currently being used by the cluster, please refer to *Chapter 8, Rules*.

Cluster Nodes

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4.1. Defining a Cluster Node

Each node in the cluster will have an entry in the nodes section containing its UUID, uname, and type.

Example 4.1. Example Heartbeat cluster node entry

```
<node id="1186dc9a-324d-425a-966e-d757e693dc86" uname="pcmk-1" type="normal"/>
```

Example 4.2. Example Corosync cluster node entry

```
<node id="101" uname="pcmk-1" type="normal"/>
```

In normal circumstances, the admin should let the cluster populate this information automatically from the communications and membership data. However for Heartbeat, one can use the **crm_uuid** tool to read an existing UUID or define a value before the cluster starts.

4.2. Where Pacemaker Gets the Node Name

Traditionally, Pacemaker required nodes to be referred to by the value returned by **uname -n**. This can be problematic for services that require the **uname -n** to be a specific value (ie. for a licence file).

Since version 2.0.0 of Pacemaker, this requirement has been relaxed for clusters using Corosync 2.0 or later. The name Pacemaker uses is:

1. The value stored in *corosync.conf* under **ring0_addr** in the **nodelist**, if it does not contain an IP address; otherwise
2. The value stored in *corosync.conf* under **name** in the **nodelist**; otherwise
3. The value of **uname -n**

Pacemaker provides the **crm_node -n** command which displays the name used by a running cluster.

If a Corosync nodelist is used, **crm_node --name-for-id $number** is also available to display the name used by the node with the corosync **nodeid** of *$number*, for example: **crm_node --name-for-id 2**.

4.3. Describing a Cluster Node

Beyond the basic definition of a node the administrator can also describe the node's attributes, such as how much RAM, disk, what OS or kernel version it has, perhaps even its physical location. This information can then be used by the cluster when deciding where to place resources. For more information on the use of node attributes, see *Chapter 8, Rules*.

Node attributes can be specified ahead of time or populated later, when the cluster is running, using **crm_attribute**.

Below is what the node's definition would look like if the admin ran the command:

Example 4.3. The result of using crm_attribute to specify which kernel pcmk-1 is running

```
# crm_attribute --type nodes --node-uname pcmk-1 --attr-name kernel --attr-value `uname -
r`
```

```
<node uname="pcmk-1" type="normal" id="101">
   <instance_attributes id="nodes-101">
     <nvpair id="kernel-101" name="kernel" value="2.6.16.46-0.4-default"/>
   </instance_attributes>
</node>
```

A simpler way to determine the current value of an attribute is to use **crm_attribute** command again:

```
# crm_attribute --type nodes --node-uname pcmk-1 --attr-name kernel --get-value
```

By specifying **--type nodes** the admin tells the cluster that this attribute is persistent. There are also transient attributes which are kept in the status section which are "forgotten" whenever the node rejoins the cluster. The cluster uses this area to store a record of how many times a resource has failed on that node but administrators can also read and write to this section by specifying **--type status**.

4.4. Corosync

4.4.1. Adding a New Corosync Node

Adding a new node is as simple as installing Corosync and Pacemaker, and copying */etc/corosync/corosync.conf* and */etc/corosync/authkey* (if it exists) from an existing node. You may need to modify the **mcastaddr** option to match the new node's IP address.

If a log message containing "Invalid digest" appears from Corosync, the keys are not consistent between the machines.

4.4.2. Removing a Corosync Node

Because the messaging and membership layers are the authoritative source for cluster nodes, deleting them from the CIB is not a reliable solution. First one must arrange for corosync to forget about the node (*pcmk-1* in the example below).

On the host to be removed:

1. Stop the cluster: **`/etc/init.d/corosync stop`**

Next, from one of the remaining active cluster nodes:

1. Tell Pacemaker to forget about the removed host:

   ```
   # crm_node -R pcmk-1
   ```

   This includes deleting the node from the CIB

Note

This proceedure only works for versions after 1.1.8

4.4.3. Replacing a Corosync Node

The five-step guide to replacing an existing cluster node:

1. Make sure the old node is completely stopped
2. Give the new machine the same hostname and IP address as the old one
3. Install the cluster software :-)
4. Copy */etc/corosync/corosync.conf* and */etc/corosync/authkey* (if it exists) to the new node
5. Start the new cluster node

If a log message containing "Invalid digest" appears from Corosync, the keys are not consistent between the machines.

4.5. CMAN

4.5.1. Adding a New CMAN Node

4.5.2. Removing a CMAN Node

4.6. Heartbeat

4.6.1. Adding a New Heartbeat Node

Provided you specified **`autojoin any`** in *ha.cf*, adding a new node is as simple as installing heartbeat and copying *ha.cf* and *authkeys* from an existing node.

If you don't want to use **`autojoin`**, then after setting up *ha.cf* and *authkeys*, you must use **`hb_addnode`** before starting the new node.

4.6.2. Removing a Heartbeat Node

Because the messaging and membership layers are the authoritative source for cluster nodes, deleting them from the CIB is not a reliable solution.

First one must arrange for Heartbeat to forget about the node (pcmk-1 in the example below).

On the host to be removed:

1. Stop the cluster: **`/etc/init.d/corosync stop`**

Next, from one of the remaining active cluster nodes:

1. Tell Heartbeat the node should be removed

```
# hb_delnode pcmk-1
```

1. Tell Pacemaker to forget about the removed host:

```
# crm_node -R pcmk-1
```

Note

This proceedure only works for versions after 1.1.8

4.6.3. Replacing a Heartbeat Node

The seven-step guide to replacing an existing cluster node:

1. Make sure the old node is completely stopped
2. Give the new machine the same hostname as the old one
3. Go to an active cluster node and look up the UUID for the old node in */var/lib/heartbeat/hostcache*
4. Install the cluster software
5. Copy *ha.cf* and *authkeys* to the new node

6. On the new node, populate it's UUID using **`crm_uuid -w`** and the UUID from step 2
7. Start the new cluster node

Cluster Resources

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5.1. What is a Cluster Resource

The role of a resource agent is to abstract the service it provides and present a consistent view to the cluster, which allows the cluster to be agnostic about the resources it manages.

The cluster doesn't need to understand how the resource works because it relies on the resource agent to do the right thing when given a **`start`**, **`stop`** or **`monitor`** command.

For this reason it is crucial that resource agents are well tested.

Typically resource agents come in the form of shell scripts, however they can be written using any technology (such as C, Python or Perl) that the author is comfortable with.

5.2. Supported Resource Classes

There are five classes of agents supported by Pacemaker:

- OCF
- LSB
- Upstart
- Systemd
- Fencing
- Service

Version 1 of Heartbeat came with its own style of resource agents and it is highly likely that many people have written their own agents based on its conventions. [1]

Although deprecated with the release of Heartbeat v2, they were supported by Pacemaker up until the release of 1.1.8 to enable administrators to continue to use these agents.

5.2.1. Open Cluster Framework

The OCF standard [2] [3] is basically an extension of the Linux Standard Base conventions for init scripts to:

- support parameters,
- make them self describing and
- extensible

OCF specs have strict definitions of the exit codes that actions must return. [4]

The cluster follows these specifications exactly, and giving the wrong exit code will cause the cluster to behave in ways you will likely find puzzling and annoying. In particular, the cluster needs to distinguish a completely stopped resource from one which is in some erroneous and indeterminate state.

Parameters are passed to the script as environment variables, with the special prefix **`OCF_RESKEY_`**. So, a parameter which the user thinks of as ip it will be passed to the script as **`OCF_RESKEY_ip`**. The number and purpose of the parameters is completely arbitrary, however your script should advertise any that it supports using the **`meta-data`** command.

The OCF class is the most preferred one as it is an industry standard, highly flexible (allowing parameters to be passed to agents in a non-positional manner) and self-describing.

For more information, see the *reference*[5] and *Appendix B, More About OCF Resource Agents*.

5.2.2. Linux Standard Base

LSB resource agents are those found in */etc/init.d*.

Generally they are provided by the OS/distribution and, in order to be used with the cluster, they must conform to the LSB Spec. [6]

Many distributions claim LSB compliance but ship with broken init scripts. For details on how to check if your init script is LSB-compatible, see *Appendix G, init-Script LSB Compliance*. The most common problems are:

- Not implementing the status operation at all

[1] See *http://wiki.linux-ha.org/HeartbeatResourceAgent* for more information
[2] *http://www.opencf.org/cgi-bin/viewcvs.cgi/specs/ra/resource-agent-api.txt?rev=HEAD* - at least as it relates to resource agents.
[3] The Pacemaker implementation has been somewhat extended from the OCF Specs, but none of those changes are incompatible with the original OCF specification.
[4] Included with the cluster is the ocf-tester script, which can be useful in this regard.
[5] http://www.linux-ha.org/wiki/OCF_Resource_Agents
[6] See *http://refspecs.linux-foundation.org/LSB_3.0.0/LSB-Core-generic/LSB-Core-generic/iniscrptact.html* for the LSB Spec (as it relates to init scripts).

- Not observing the correct exit status codes for start/stop/status actions
- Starting a started resource returns an error (this violates the LSB spec)
- Stopping a stopped resource returns an error (this violates the LSB spec)

5.2.3. Systemd

Some newer distributions have replaced the old *SYS-V*[7] style of initialization daemons (and scripts) with an alternative called *Systemd*[8].

Pacemaker is able to manage these services *if they are present*.

Instead of **`init scripts`**, systemd has **`unit files`**. Generally the services (or unit files) are provided by the OS/distribution but there are some instructions for converting from init scripts at: *http://0pointer.de/blog/projects/systemd-for-admins-3.html*

Note

Remember to make sure the computer is **`not`** configured to start any services at boot time that should be controlled by the cluster.

5.2.4. Upstart

Some newer distributions have replaced the old *SYS-V*[9] style of initialization daemons (and scripts) with an alternative called *Upstart*[10].

Pacemaker is able to manage these services *if they are present*.

Instead of **`init scripts`**, upstart has **`jobs`**. Generally the services (or jobs) are provided by the OS/distribution.

Note

Remember to make sure the computer is **`not`** configured to start any services at boot time that should be controlled by the cluster.

5.2.5. System Services

[7] http://en.wikipedia.org/wiki/Init#SysV-style
[8] http://www.freedesktop.org/wiki/Software/systemd
[9] http://en.wikipedia.org/wiki/Init#SysV-style
[10] http://upstart.ubuntu.com

Since there are now many "common" types of system services (**systemd**, **upstart**, and **lsb**), Pacemaker supports a special alias which intelligently figures out which one applies to a given cluster node.

This is particularly useful when the cluster contains a mix of **systemd**, **upstart**, and **lsb**.

In order, Pacemaker will try to find the named service as:

1. an LSB (SYS-V) init script
2. a Systemd unit file
3. an Upstart job

5.2.6. STONITH

There is also an additional class, STONITH, which is used exclusively for fencing related resources. This is discussed later in *Chapter 13, STONITH*.

5.3. Resource Properties

These values tell the cluster which script to use for the resource, where to find that script and what standards it conforms to.

Table 5.1. Properties of a Primitive Resource

Field	Description
id	Your name for the resource
class	The standard the script conforms to. Allowed values: **ocf**, **service**, **upstart**, **systemd**, **lsb**, **stonith**
type	The name of the Resource Agent you wish to use. Eg. *IPaddr* or *Filesystem*
provider	The OCF spec allows multiple vendors to supply the same ResourceAgent. To use the OCF resource agents supplied with Heartbeat, you should specify **heartbeat** here.

Resource definitions can be queried with the **crm_resource** tool. For example

```
# crm_resource --resource Email --query-xml
```

might produce:

Example 5.1. An example system resource

```
<primitive id="Email" class="service" type="exim"/>
```

Note

One of the main drawbacks to system services (such as LSB, Systemd and Upstart) resources is that they do not allow any parameters!

Example 5.2. An example OCF resource

```
<primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
   <instance_attributes id="params-public-ip">
      <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
   </instance_attributes>
</primitive>
```

5.4. Resource Options

Options are used by the cluster to decide how your resource should behave and can be easily set using the **--meta** option of the **crm_resource** command.

Table 5.2. Options for a Primitive Resource

Field	Default	Description
priority	**0**	If not all resources can be active, the cluster will stop lower priority resources in order to keep higher priority ones active.
target-role	**Started**	What state should the cluster attempt to keep this resource in? Allowed values: * *Stopped* - Force the resource to be stopped * *Started* - Allow the resource to be started (In the case of *multi-state* resources, they will not promoted to master) * *Master* - Allow the resource to be started and, if appropriate, promoted
is-managed	**TRUE**	Is the cluster allowed to start and stop the resource? Allowed values: **true**, **false**
resource-stickiness	Calculated	How much does the resource prefer to stay where it is? Defaults to the value of **resource-stickiness** in the **rsc_defaults** section
requires	Calculated	Under what conditions can the resource be started. (*Since 1.1.8*) Defaults to **fencing** unless **stonith-enabled** is *false* or **class** is *stonith* - under those conditions the default is **quorum**. Possible values: * *nothing* - can always be started * *quorum* - The cluster can only start this resource if a majority of the configured nodes are active * *fencing* - The cluster can only start this resource if a majority of the configured nodes are active *and* any failed or unknown nodes have been powered off. * *unfencing* - The cluster can only start this resource if a majority of the configured nodes are active *and* any failed or unknown nodes have been powered off *and* only on nodes that have been *unfenced* indexterm: Option[requires,Resource]

Field	Default	Description
migration-threshold	**INFINITY** (disabled)	How many failures may occur for this resource on a node, before this node is marked ineligible to host this resource.
failure-timeout	**0** (disabled)	How many seconds to wait before acting as if the failure had not occurred, and potentially allowing the resource back to the node on which it failed.
multiple-active	**stop_start**	What should the cluster do if it ever finds the resource active on more than one node. Allowed values: * *block* - mark the resource as unmanaged * *stop_only* - stop all active instances and leave them that way * *stop_start* - stop all active instances and start the resource in one location only

If you performed the following commands on the previous LSB Email resource

```
# crm_resource --meta --resource Email --set-parameter priority --property-value 100
# crm_resource --meta --resource Email --set-parameter multiple-active --property-value block
```

the resulting resource definition would be

Example 5.3. An LSB resource with cluster options

```
<primitive id="Email" class="lsb" type="exim">
   <meta_attributes id="meta-email">
      <nvpair id="email-priority" name="priority" value="100"/>
      <nvpair id="email-active" name="multiple-active" value="block"/>
   </meta_attributes>
</primitive>
```

5.5. Setting Global Defaults for Resource Options

To set a default value for a resource option, simply add it to the **rsc_defaults** section with **crm_attribute**. Thus,

```
# crm_attribute --type rsc_defaults --attr-name is-managed --attr-value false
```

would prevent the cluster from starting or stopping any of the resources in the configuration (unless of course the individual resources were specifically enabled and had **is-managed** set to **true**).

5.6. Instance Attributes

The scripts of some resource classes (LSB not being one of them) can be given parameters which determine how they behave and which instance of a service they control.

If your resource agent supports parameters, you can add them with the **crm_resource** command. For instance

```
# crm_resource --resource Public-IP --set-parameter ip --property-value 1.2.3.4
```

would create an entry in the resource like this:

Example 5.4. An example OCF resource with instance attributes

```
<primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
   <instance_attributes id="params-public-ip">
      <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
   </instance_attributes>
</primitive>
```

For an OCF resource, the result would be an environment variable called **OCF_RESKEY_ip** with a value of **1.2.3.4**.

The list of instance attributes supported by an OCF script can be found by calling the resource script with the **meta-data** command. The output contains an XML description of all the supported attributes, their purpose and default values.

Example 5.5. Displaying the metadata for the Dummy resource agent template

```
# export OCF_ROOT=/usr/lib/ocf
# $OCF_ROOT/resource.d/pacemaker/Dummy meta-data
```

```
<?xml version="1.0"?>
  <!DOCTYPE resource-agent SYSTEM "ra-api-1.dtd">
  <resource-agent name="Dummy" version="0.9">
    <version>1.0</version>

    <longdesc lang="en-US">
      This is a Dummy Resource Agent. It does absolutely nothing except
      keep track of whether its running or not.
      Its purpose in life is for testing and to serve as a template for RA writers.
    </longdesc>
    <shortdesc lang="en-US">Dummy resource agent</shortdesc>

    <parameters>
      <parameter name="state" unique="1">
        <longdesc lang="en-US">
          Location to store the resource state in.
        </longdesc>
        <shortdesc lang="en-US">State file</shortdesc>
        <content type="string" default="/var/run/Dummy-{OCF_RESOURCE_INSTANCE}.state" />
      </parameter>

      <parameter name="dummy" unique="0">
        <longdesc lang="en-US">
          Dummy attribute that can be changed to cause a reload
        </longdesc>
        <shortdesc lang="en-US">Dummy attribute that can be changed to cause a reload</
shortdesc>
        <content type="string" default="blah" />
      </parameter>
    </parameters>

    <actions>
      <action name="start"        timeout="90" />
      <action name="stop"         timeout="100" />
      <action name="monitor"      timeout="20" interval="10",height="0" start-delay="0" />
      <action name="reload"       timeout="90" />
      <action name="migrate_to"   timeout="100" />
      <action name="migrate_from" timeout="90" />
      <action name="meta-data"    timeout="5" />
      <action name="validate-all" timeout="30" />
```

```
    </actions>
  </resource-agent>
```

5.7. Resource Operations

5.7.1. Monitoring Resources for Failure

By default, the cluster will not ensure your resources are still healthy. To instruct the cluster to do this, you need to add a **monitor** operation to the resource's definition.

Example 5.6. An OCF resource with a recurring health check

```
<primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
  <operations>
     <op id="public-ip-check" name="monitor" interval="60s"/>
  </operations>
  <instance_attributes id="params-public-ip">
     <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
  </instance_attributes>
</primitive>
```

Table 5.3. Properties of an Operation

Field	Description
id	Your name for the action. Must be unique.
name	The action to perform. Common values: **monitor**, **start**, **stop**
interval	How frequently (in seconds) to perform the operation. Default value: **0**, meaning never.
timeout	How long to wait before declaring the action has failed.
on-fail	The action to take if this action ever fails. Allowed values: * *ignore* - Pretend the resource did not fail * *block* - Don't perform any further operations on the resource * *stop* - Stop the resource and do not start it elsewhere * *restart* - Stop the resource and start it again (possibly on a different node) * *fence* - STONITH the node on which the resource failed * *standby* - Move *all* resources away from the node on which the resource failed The default for the **stop** operation is **fence** when STONITH is enabled and **block** otherwise. All other operations default to **stop**.
enabled	If **false**, the operation is treated as if it does not exist. Allowed values: **true**, **false**

5.7.2. Setting Global Defaults for Operations

To set a default value for a operation option, simply add it to the **op_defaults** section with **crm_attribute**. Thus,

```
# crm_attribute --type op_defaults --attr-name timeout --attr-value 20s
```

would default each operation's **timeout** to 20 seconds. If an operation's definition also includes a value for **timeout**, then that value would be used instead (for that operation only).

5.7.2.1. When Resources Take a Long Time to Start/Stop

There are a number of implicit operations that the cluster will always perform - **start**, **stop** and a non-recurring **monitor** operation (used at startup to check the resource isn't already active). If one of these is taking too long, then you can create an entry for them and simply specify a new value.

Example 5.7. An OCF resource with custom timeouts for its implicit actions

```
<primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
  <operations>
     <op id="public-ip-startup" name="monitor" interval="0" timeout="90s"/>
     <op id="public-ip-start" name="start" interval="0" timeout="180s"/>
     <op id="public-ip-stop" name="stop" interval="0" timeout="15min"/>
  </operations>
  <instance_attributes id="params-public-ip">
     <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
  </instance_attributes>
</primitive>
```

5.7.2.2. Multiple Monitor Operations

Provided no two operations (for a single resource) have the same name and interval you can have as many monitor operations as you like. In this way you can do a superficial health check every minute and progressively more intense ones at higher intervals.

To tell the resource agent what kind of check to perform, you need to provide each monitor with a different value for a common parameter. The OCF standard creates a special parameter called **OCF_CHECK_LEVEL** for this purpose and dictates that it is *"made available to the resource agent without the normal **OCF_RESKEY** prefix"*.

Whatever name you choose, you can specify it by adding an **instance_attributes** block to the op tag. Note that it is up to each resource agent to look for the parameter and decide how to use it.

Example 5.8. An OCF resource with two recurring health checks, performing different levels of checks - specified via **OCF_CHECK_LEVEL**.

```
<primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
   <operations>
      <op id="public-ip-health-60" name="monitor" interval="60">
         <instance_attributes id="params-public-ip-depth-60">
            <nvpair id="public-ip-depth-60" name="OCF_CHECK_LEVEL" value="10"/>
         </instance_attributes>
      </op>
      <op id="public-ip-health-300" name="monitor" interval="300">
         <instance_attributes id="params-public-ip-depth-300">
            <nvpair id="public-ip-depth-300" name="OCF_CHECK_LEVEL" value="20"/>
       </instance_attributes>
     </op>
   </operations>
   <instance_attributes id="params-public-ip">
       <nvpair id="public-ip-level" name="ip" value="1.2.3.4"/>
   </instance_attributes>
</primitive>
```

5.7.2.3. Disabling a Monitor Operation

The easiest way to stop a recurring monitor is to just delete it. However, there can be times when you only want to disable it temporarily. In such cases, simply add **`enabled="false"`** to the operation's definition.

Example 5.9. Example of an OCF resource with a disabled health check

```
<primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
   <operations>
      <op id="public-ip-check" name="monitor" interval="60s" enabled="false"/>
   </operations>
   <instance_attributes id="params-public-ip">
      <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
   </instance_attributes>
</primitive>
```

This can be achieved from the command-line by executing

```
# cibadmin -M -X '<op id="public-ip-check" enabled="false"/>'
```

Once you've done whatever you needed to do, you can then re-enable it with

Resource Constraints

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6.1. Scores

Scores of all kinds are integral to how the cluster works. Practically everything from moving a resource to deciding which resource to stop in a degraded cluster is achieved by manipulating scores in some way.

Scores are calculated on a per-resource basis and any node with a negative score for a resource can't run that resource. After calculating the scores for a resource, the cluster then chooses the node with the highest one.

6.1.1. Infinity Math

INFINITY is currently defined as 1,000,000 and addition/subtraction with it follows these three basic rules:

- Any value + **INFINITY** = **INFINITY**
- Any value - **INFINITY** = -**INFINITY**
- **INFINITY** - **INFINITY** = -**INFINITY**

6.2. Deciding Which Nodes a Resource Can Run On

There are two alternative strategies for specifying which nodes a resources can run on. One way is to say that by default they can run anywhere and then create location constraints for nodes that are not

allowed. The other option is to have nodes "opt-in"… to start with nothing able to run anywhere and selectively enable allowed nodes.

6.2.1. Options

Table 6.1. Options for Simple Location Constraints

Field	Description
id	A unique name for the constraint
rsc	A resource name
node	A node's name
score	Positive values indicate the resource should run on this node. Negative values indicate the resource should not run on this node. Values of +/- **INFINITY** change "should"/"should not" to "must"/"must not".

6.2.2. Asymmetrical "Opt-In" Clusters

To create an opt-in cluster, start by preventing resources from running anywhere by default:

```
# crm_attribute --attr-name symmetric-cluster --attr-value false
```

Then start enabling nodes. The following fragment says that the web server prefers **sles-1**, the database prefers **sles-2** and both can fail over to **sles-3** if their most preferred node fails.

Example 6.1. Example set of opt-in location constraints

```
<constraints>
    <rsc_location id="loc-1" rsc="Webserver" node="sles-1" score="200"/>
    <rsc_location id="loc-2" rsc="Webserver" node="sles-3" score="0"/>
    <rsc_location id="loc-3" rsc="Database" node="sles-2" score="200"/>
    <rsc_location id="loc-4" rsc="Database" node="sles-3" score="0"/>
</constraints>
```

6.2.3. Symmetrical "Opt-Out" Clusters

To create an opt-out cluster, start by allowing resources to run anywhere by default:

```
# crm_attribute --attr-name symmetric-cluster --attr-value true
```

Then start disabling nodes. The following fragment is the equivalent of the above opt-in configuration.

Example 6.2. Example set of opt-out location constraints

```
<constraints>
    <rsc_location id="loc-1" rsc="Webserver" node="sles-1" score="200"/>
    <rsc_location id="loc-2-dont-run" rsc="Webserver" node="sles-2" score="-INFINITY"/>
```

```
    <rsc_location id="loc-3-dont-run" rsc="Database" node="sles-1" score="-INFINITY"/>
    <rsc_location id="loc-4" rsc="Database" node="sles-2" score="200"/>
</constraints>
```

Whether you should choose opt-in or opt-out depends both on your personal preference and the make-up of your cluster. If most of your resources can run on most of the nodes, then an opt-out arrangement is likely to result in a simpler configuration. On the other-hand, if most resources can only run on a small subset of nodes an opt-in configuration might be simpler.

6.2.4. What if Two Nodes Have the Same Score

If two nodes have the same score, then the cluster will choose one. This choice may seem random and may not be what was intended, however the cluster was not given enough information to know any better.

Example 6.3. Example of two resources that prefer two nodes equally

```
<constraints>
    <rsc_location id="loc-1" rsc="Webserver" node="sles-1" score="INFINITY"/>
    <rsc_location id="loc-2" rsc="Webserver" node="sles-2" score="INFINITY"/>
    <rsc_location id="loc-3" rsc="Database" node="sles-1" score="500"/>
    <rsc_location id="loc-4" rsc="Database" node="sles-2" score="300"/>
    <rsc_location id="loc-5" rsc="Database" node="sles-2" score="200"/>
</constraints>
```

In the example above, assuming no other constraints and an inactive cluster, Webserver would probably be placed on sles-1 and Database on sles-2. It would likely have placed Webserver based on the node's uname and Database based on the desire to spread the resource load evenly across the cluster. However other factors can also be involved in more complex configurations.

6.3. Specifying in which Order Resources Should Start/Stop

The way to specify the order in which resources should start is by creating **`rsc_order`** constraints.

Table 6.2. Properties of an Ordering Constraint

Field	Description
`id`	A unique name for the constraint
`first`	The name of a resource that must be started before the **`then`** resource is allowed to.
`then`	The name of a resource. This resource will start after the **`first`** resource.
`kind`	How to enforce the constraint. (*Since 1.1.2*) * Optional - Just a suggestion. Only applies if both resources are starting/stopping. * Mandatory - Always. If *first* is stopping or cannot be started, *then* must be stopped. * Serialize - Ensure that no two stop/start actions occur concurrently for a set of resources.

Field	Description
symmetrical	If true, which is the default, stop the resources in the reverse order. Default value: *true*

6.3.1. Mandatory Ordering

When the **then** resource cannot run without the **first** resource being active, one should use mandatory constraints. To specify a constraint is mandatory, use scores greater than zero. This will ensure that the then resource will react when the first resource changes state.

- If the **first** resource was running and is stopped, the **then** resource will also be stopped (if it is running).
- If the **first** resource was not running and cannot be started, the **then** resource will be stopped (if it is running).
- If the **first** resource is (re)started while the **then** resource is running, the **then** resource will be stopped and restarted.

6.3.2. Advisory Ordering

On the other hand, when **score="0"** is specified for a constraint, the constraint is considered optional and only has an effect when both resources are stopping and/or starting. Any change in state by the **first** resource will have no effect on the **then** resource.

Example 6.4. Example of an optional and mandatory ordering constraint

```
<constraints>
    <rsc_order id="order-1" first="Database" then="Webserver" />
    <rsc_order id="order-2" first="IP" then="Webserver" score="0"/>
</constraints>
```

Some additional information on ordering constraints can be found in the document *Ordering Explained*[1].

6.4. Placing Resources Relative to other Resources

When the location of one resource depends on the location of another one, we call this colocation.

There is an important side-effect of creating a colocation constraint between two resources: it affects the order in which resources are assigned to a node. If you think about it, it's somewhat obvious. You can't place A relative to B unless you know where B is. [2]

So when you are creating colocation constraints, it is important to consider whether you should colocate A with B or B with A.

Another thing to keep in mind is that, assuming A is collocated with B, the cluster will also take into account A's preferences when deciding which node to choose for B.

[1] http://www.clusterlabs.org/mediawiki/images/d/d6/Ordering_Explained.pdf
[2] While the human brain is sophisticated enough to read the constraint in any order and choose the correct one depending on the situation, the cluster is not quite so smart. Yet.

For a detailed look at exactly how this occurs, see the *Colocation Explained*[3] document.

6.4.1. Options

Table 6.3. Properties of a Collocation Constraint

Field	Description
id	A unique name for the constraint.
rsc	The colocation source. If the constraint cannot be satisfied, the cluster may decide not to allow the resource to run at all.
with-rsc	The colocation target. The cluster will decide where to put this resource first and then decide where to put the resource in the **rsc** field.
score	Positive values indicate the resource should run on the same node. Negative values indicate the resources should not run on the same node. Values of +/- **INFINITY** change "should" to "must".

6.4.2. Mandatory Placement

Mandatory placement occurs any time the constraint's score is **+INFINITY** or **-INFINITY**. In such cases, if the constraint can't be satisfied, then the **rsc** resource is not permitted to run. For **score=INFINITY**, this includes cases where the **with-rsc** resource is not active.

If you need **resource1** to always run on the same machine as **resource2**, you would add the following constraint:

An example colocation constraint

```
<rsc_colocation id="colocate" rsc="resource1" with-rsc="resource2" score="INFINITY"/>
```

Remember, because **INFINITY** was used, if **resource2** can't run on any of the cluster nodes (for whatever reason) then **resource1** will not be allowed to run.

Alternatively, you may want the opposite… that **resource1** cannot run on the same machine as **resource2**. In this case use **score="-INFINITY"**

An example anti-colocation constraint

```
<rsc_colocation id="anti-colocate" rsc="resource1" with-rsc="resource2" score="-INFINITY"/>
```

Again, by specifying **-INFINTY**, the constraint is binding. So if the only place left to run is where **resource2** already is, then **resource1** may not run anywhere.

6.4.3. Advisory Placement

If mandatory placement is about "must" and "must not", then advisory placement is the "I'd prefer if" alternative. For constraints with scores greater than **-INFINITY** and less than **INFINITY**, the cluster will try and accommodate your wishes but may ignore them if the alternative is to stop some of the cluster resources.

[3] http://www.clusterlabs.org/mediawiki/images/6/61/Colocation_Explained.pdf

Like in life, where if enough people prefer something it effectively becomes mandatory, advisory colocation constraints can combine with other elements of the configuration to behave as if they were mandatory.

An example advisory-only colocation constraint

```
<rsc_colocation id="colocate-maybe" rsc="resource1" with-rsc="resource2" score="500"/>
```

6.5. Ordering Sets of Resources

A common situation is for an administrator to create a chain of ordered resources, such as:

Example 6.5. A chain of ordered resources

```
<constraints>
    <rsc_order id="order-1" first="A" then="B" />
    <rsc_order id="order-2" first="B" then="C" />
    <rsc_order id="order-3" first="C" then="D" />
</constraints>
```

6.6. Ordered Set

Figure 6.1. Visual representation of the four resources' start order for the above constraints

To simplify this situation, there is an alternate format for ordering constraints:

Example 6.6. A chain of ordered resources expressed as a set

```
<constraints>
    <rsc_order id="order-1">
      <resource_set id="ordered-set-example" sequential="true">
        <resource_ref id="A"/>
        <resource_ref id="B"/>
        <resource_ref id="C"/>
        <resource_ref id="D"/>
      </resource_set>
    </rsc_order>
</constraints>
```

Note

Resource sets have the same ordering semantics as groups.

Example 6.7. A group resource with the equivalent ordering rules

```
<group id="dummy">
    <primitive id="A" .../>
    <primitive id="B" .../>
    <primitive id="C" .../>
    <primitive id="D" .../>
</group>
```

While the set-based format is not less verbose, it is significantly easier to get right and maintain. It can also be expanded to allow ordered sets of (un)ordered resources. In the example below, **`rscA`** and **`rscB`** can both start in parallel, as can **`rscC`** and **`rscD`**, however **`rscC`** and **`rscD`** can only start once *both* **`rscA`** *and* **`rscB`** are active.

Example 6.8. Ordered sets of unordered resources

```
<constraints>
    <rsc_order id="order-1">
      <resource_set id="ordered-set-1" sequential="false">
        <resource_ref id="A"/>
        <resource_ref id="B"/>
      </resource_set>
      <resource_set id="ordered-set-2" sequential="false">
        <resource_ref id="C"/>
        <resource_ref id="D"/>
      </resource_set>
    </rsc_order>
  </constraints>
```

6.7. Two Sets of Unordered Resources

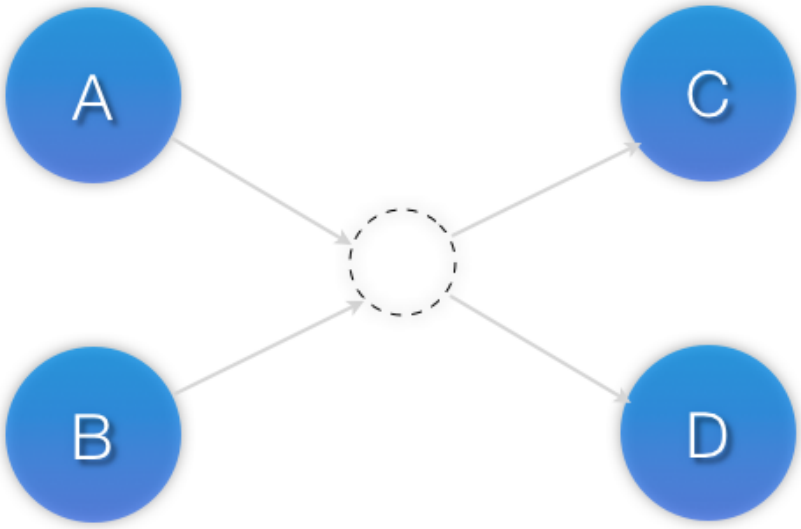

Figure 6.2. Visual representation of the start order for two ordered sets of unordered resources

Of course either set — or both sets — of resources can also be internally ordered (by setting **`sequential="true"`**) and there is no limit to the number of sets that can be specified.

Example 6.9. Advanced use of set ordering - Three ordered sets, two of which are internally unordered

```
<constraints>
    <rsc_order id="order-1">
      <resource_set id="ordered-set-1" sequential="false">
        <resource_ref id="A"/>
        <resource_ref id="B"/>
      </resource_set>
      <resource_set id="ordered-set-2" sequential="true">
        <resource_ref id="C"/>
        <resource_ref id="D"/>
      </resource_set>
      <resource_set id="ordered-set-3" sequential="false">
        <resource_ref id="E"/>
        <resource_ref id="F"/>
      </resource_set>
    </rsc_order>
</constraints>
```

6.8. Three Resources Sets

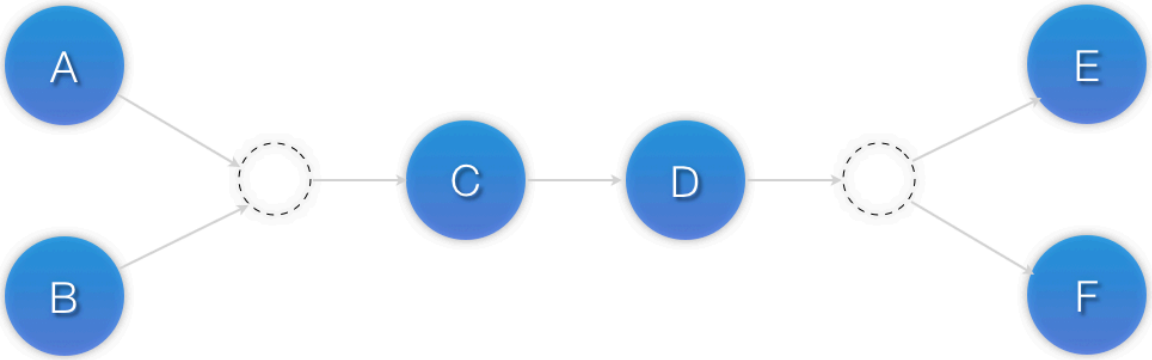

Figure 6.3. Visual representation of the start order for the three sets defined above

6.9. Collocating Sets of Resources

Another common situation is for an administrator to create a set of collocated resources. Previously this was possible either by defining a resource group (See *Section 10.1, "Groups - A Syntactic Shortcut"*) which could not always accurately express the design; or by defining each relationship as an individual constraint, causing a constraint explosion as the number of resources and combinations grew.

Example 6.10. A chain of collocated resources

```
<constraints>
    <rsc_colocation id="coloc-1" rsc="B" with-rsc="A" score="INFINITY"/>
    <rsc_colocation id="coloc-2" rsc="C" with-rsc="B" score="INFINITY"/>
    <rsc_colocation id="coloc-3" rsc="D" with-rsc="C" score="INFINITY"/>
</constraints>
```

To make things easier, we allow an alternate form of colocation constraints using **`resource_sets`**. Just like the expanded version, a resource that can't be active also prevents any resource that must

be collocated with it from being active. For example, if **B was** not able to run, then both **C (+and by inference +D)** must also remain stopped.

Example 6.11. The equivalent colocation chain expressed using **resource_sets**

```
<constraints>
    <rsc_colocation id="coloc-1" score="INFINITY" >
      <resource_set id="collocated-set-example" sequential="true">
        <resource_ref id="A"/>
        <resource_ref id="B"/>
        <resource_ref id="C"/>
        <resource_ref id="D"/>
      </resource_set>
    </rsc_colocation>
</constraints>
```

Note

Resource sets have the same colocation semantics as groups.

A group resource with the equivalent colocation rules

```
<group id="dummy">
    <primitive id="A" .../>
    <primitive id="B" .../>
    <primitive id="C" .../>
    <primitive id="D" .../>
</group>
```

This notation can also be used in this context to tell the cluster that a set of resources must all be located with a common peer, but have no dependencies on each other. In this scenario, unlike the previous, **B would** be allowed to remain active even if **A or C** (or both) were inactive.

Example 6.12. Using colocation sets to specify a common peer.

```
<constraints>
    <rsc_colocation id="coloc-1" score="INFINITY" >
      <resource_set id="collocated-set-1" sequential="false">
        <resource_ref id="A"/>
        <resource_ref id="B"/>
        <resource_ref id="C"/>
      </resource_set>
      <resource_set id="collocated-set-2" sequential="true">
        <resource_ref id="D"/>
      </resource_set>
    </rsc_colocation>
</constraints>
```

Of course there is no limit to the number and size of the sets used. The only thing that matters is that in order for any member of set N to be active, all the members of set N+1 must also be active (and naturally on the same node); and if a set has **sequential="true"**, then in order for member M to be active, member M+1 must also be active. You can even specify the role in which the members of a set must be in using the set's role attribute.

Example 6.13. A colocation chain where the members of the middle set have no inter-dependencies and the last has master status.

```
<constraints>
    <rsc_colocation id="coloc-1" score="INFINITY" >
      <resource_set id="collocated-set-1" sequential="true">
        <resource_ref id="A"/>
        <resource_ref id="B"/>
      </resource_set>
      <resource_set id="collocated-set-2" sequential="false">
        <resource_ref id="C"/>
        <resource_ref id="D"/>
        <resource_ref id="E"/>
      </resource_set>
      <resource_set id="collocated-set-2" sequential="true" role="Master">
        <resource_ref id="F"/>
        <resource_ref id="G"/>
      </resource_set>
    </rsc_colocation>
</constraints>
```

6.10. Another Three Resources Sets

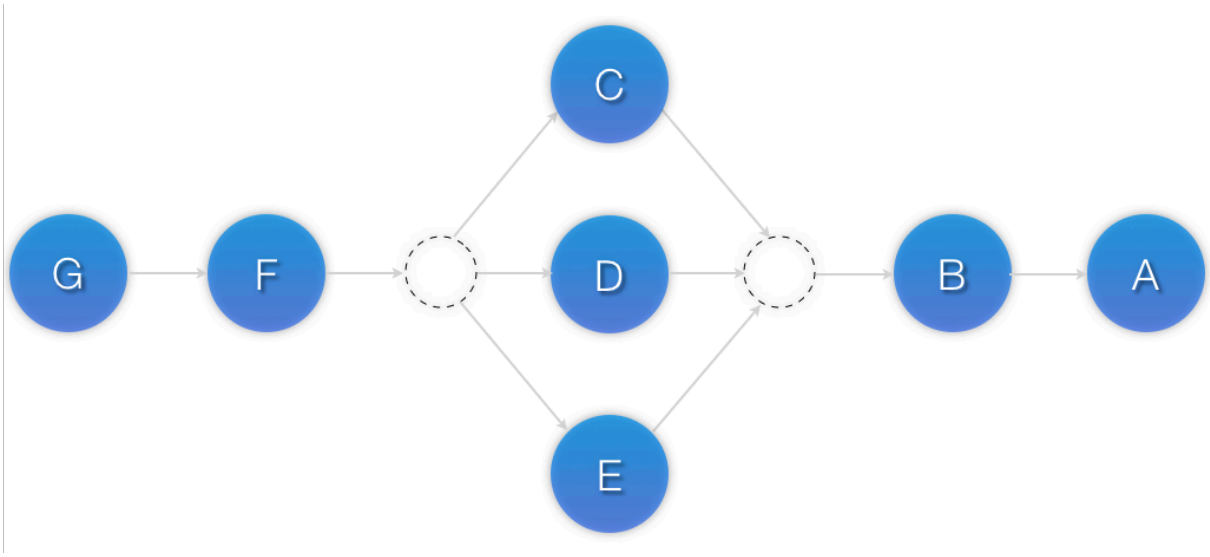

Figure 6.4. Visual representation of a colocation chain where the members of the middle set have no inter-dependencies

Receiving Notification for Cluster Events

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A Pacemaker cluster is an event driven system. In this context, an event is a resource failure or configuration change (not exhaustive).

The **`ocf:pacemaker:ClusterMon`** resource can monitor the cluster status and triggers alerts on each cluster event. This resource runs **`crm_mon`** in the background at regular intervals (configurable) and uses **`crm_mon`** capabilities to send emails (SMTP), SNMP traps or to execute an external program via the **`extra_options`** parameter.

Note

Depending on your system settings and compilation settings, SNMP or email alerts might be unavailable. Check **`crm_mon --help`** output to see if these options are available to you. In any case, executing an external agent will always be available, and you can have this agent to send emails, SNMP traps, or whatever action you develop.

7.1. Configuring SNMP Notifications

Requires an IP to send SNMP traps to, and a SNMP community. Pacemaker MIB is found in */usr/share/snmp/mibs/PCMK-MIB.txt*

Example 7.1. Configuring ClusterMon to send SNMP traps

```
<clone id="ClusterMon-clone">
    <primitive class="ocf" id="ClusterMon-SNMP" provider="pacemaker" type="ClusterMon">
        <instance_attributes id="ClusterMon-instance_attributes">
            <nvpair id="ClusterMon-instance_attributes-user" name="user" value="root"/>
            <nvpair id="ClusterMon-instance_attributes-update" name="update" value="30"/>
            <nvpair id="ClusterMon-instance_attributes-extra_options" name="extra_options"
 value="-S snmphost.example.com -C public"/>
        </instance_attributes>
    </primitive>
</clone>
```

7.2. Configuring Email Notifications

Requires a user to send mail alerts to. "Mail-From", SMTP relay and Subject prefix can also be configured.

Example 7.2. Configuring ClusterMon to send email alerts

```
<clone id="ClusterMon-clone">
    <primitive class="ocf" id="ClusterMon-SMTP" provider="pacemaker" type="ClusterMon">
        <instance_attributes id="ClusterMon-instance_attributes">
            <nvpair id="ClusterMon-instance_attributes-user" name="user" value="root"/>
            <nvpair id="ClusterMon-instance_attributes-update" name="update" value="30"/>
            <nvpair id="ClusterMon-instance_attributes-extra_options" name="extra_options"
 value="-T pacemaker@example.com -F pacemaker@node2.example.com -P PACEMAKER -H
 mail.example.com"/>
        </instance_attributes>
    </primitive>
</clone>
```

7.3. Configuring Notifications via External-Agent

Requires a program (external-agent) to run when resource operations take place, and an external-recipient (IP address, Email address, URI). When triggered, the external-agent is fed with dynamically filled environnement variables describing precisely the cluster event that occurred. By making smart usage of these variables in your external-agent code, you can trigger any action.

Example 7.3. Configuring ClusterMon to execute an external-agent

```
<clone id="ClusterMon-clone">
    <primitive class="ocf" id="ClusterMon" provider="pacemaker" type="ClusterMon">
        <instance_attributes id="ClusterMon-instance_attributes">
            <nvpair id="ClusterMon-instance_attributes-user" name="user" value="root"/>
            <nvpair id="ClusterMon-instance_attributes-update" name="update" value="30"/>
            <nvpair id="ClusterMon-instance_attributes-extra_options" name="extra_options"
 value="-E /usr/local/bin/example.sh -e 192.168.12.1"/>
        </instance_attributes>
    </primitive>
</clone>
```

Table 7.1. Environment Variables Passed to the External Agent

Environment Variable	Description
CRM_notify_recipient	The static external-recipient from the resource definition.
CRM_notify_node	The node on which the status change happened.
CRM_notify_rsc	The name of the resource that changed the status.
CRM_notify_task	The operation that caused the status change.
CRM_notify_desc	The textual output relevant error code of the operation (if any) that caused the status change.
CRM_notify_rc	The return code of the operation.
CRM_notify_target_rc	The expected return code of the operation.
CRM_notify_status	The numerical representation of the status of the operation.

Rules

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Rules can be used to make your configuration more dynamic. One common example is to set one value for **resource-stickiness** during working hours, to prevent resources from being moved back to their most preferred location, and another on weekends when no-one is around to notice an outage.

Another use of rules might be to assign machines to different processing groups (using a node attribute) based on time and to then use that attribute when creating location constraints.

Each rule can contain a number of expressions, date-expressions and even other rules. The results of the expressions are combined based on the rule's **boolean-op** field to determine if the rule ultimately evaluates to **true** or **false**. What happens next depends on the context in which the rule is being used.

Table 8.1. Properties of a Rule

Field	Description
role	Limits the rule to apply only when the resource is in that role. Allowed values: *Started*, **Slave**, and **Master**. NOTE: A rule with **role="Master"** can not determine the initial location of a clone instance. It will only affect which of the active instances will be promoted.
score	The score to apply if the rule evaluates to **true**. Limited to use in rules that are part of location constraints.
score-attribute	The node attribute to look up and use as a score if the rule evaluates to **true**. Limited to use in rules that are part of location constraints.
boolean-op	How to combine the result of multiple expression objects. Allowed values: *and* and **or**.

8.1. Node Attribute Expressions

Expression objects are used to control a resource based on the attributes defined by a node or nodes. In addition to any attributes added by the administrator, each node has a built-in node attribute called **#uname** that can also be used.

Table 8.2. Properties of an Expression

Field	Description
value	User supplied value for comparison
attribute	The node attribute to test
type	Determines how the value(s) should be tested. Allowed values: *string*, **integer**, **version**
operation	The comparison to perform. Allowed values: * *lt* - True if the node attribute's value is less than **value** * *gt* - True if the node attribute's value is greater than **value** * *lte* - True if the node attribute's value is less than or equal to **value** * *gte* - True if the node attribute's value is greater than or equal to **value** * *eq* - True if the node attribute's value is equal to **value** * *ne* - True if the node attribute's value is not equal to **value** * *defined* - True if the node has the named attribute * *not_defined* - True if the node does not have the named attribute

8.2. Time/Date Based Expressions

As the name suggests, **date_expressions** are used to control a resource or cluster option based on the current date/time. They can contain an optional **date_spec** and/or **duration** object depending on the context.

Table 8.3. Properties of a Date Expression

Field	Description
start	A date/time conforming to the ISO8601 specification.
end	A date/time conforming to the ISO8601 specification. Can be inferred by supplying a value for **start** and a **duration**.
operation	Compares the current date/time with the start and/or end date, depending on the context. Allowed values: * *gt* - True if the current date/time is after **start** * *lt* - True if the current date/time is before **end** * *in-range* - True if the current date/time is after **start** and before **end** * *date-spec* - performs a cron-like comparison to the current date/time

Note

As these comparisons (except for **date_spec**) include the time, the **eq**, **neq**, **gte** and **lte** operators have not been implemented since they would only be valid for a single second.

8.2.1. Date Specifications

date_spec objects are used to create cron-like expressions relating to time. Each field can contain a single number or a single range. Instead of defaulting to zero, any field not supplied is ignored.

For example, **monthdays="1"** matches the first day of every month and **hours="09-17"** matches the hours between 9am and 5pm (inclusive). However, at this time one cannot specify **weekdays="1,2"** or **weekdays="1-2,5-6"** since they contain multiple ranges. Depending on demand, this may be implemented in a future release.

Table 8.4. Properties of a Date Spec

Field	Description
id	A unique name for the date
hours	Allowed values: 0-23
monthdays	Allowed values: 0-31 (depending on month and year)
weekdays	Allowed values: 1-7 (1=Monday, 7=Sunday)
yeardays	Allowed values: 1-366 (depending on the year)
months	Allowed values: 1-12
weeks	Allowed values: 1-53 (depending on weekyear)
years	Year according the Gregorian calendar
weekyears	May differ from Gregorian years; Eg. **2005-001 Ordinal** is also **2005-01-01 Gregorian** is also **2004-W53-6 Weekly**
moon	Allowed values: 0-7 (0 is new, 4 is full moon). Seriously, you can use this. This was implemented to demonstrate the ease with which new comparisons could be added.

8.2.2. Durations

Durations are used to calculate a value for **end** when one is not supplied to in_range operations. They contain the same fields as **date_spec** objects but without the limitations (ie. you can have a duration of 19 months). Like **date_specs**, any field not supplied is ignored.

8.3. Sample Time Based Expressions

A small sample of how time based expressions can be used.

Example 8.1. True if now is any time in the year 2005

```
<rule id="rule1">
```

```
   <date_expression id="date_expr1" start="2005-001" operation="in_range">
    <duration years="1"/>
   </date_expression>
</rule>
```

Example 8.2. Equivalent expression

```
<rule id="rule2">
   <date_expression id="date_expr2" operation="date_spec">
    <date_spec years="2005"/>
   </date_expression>
</rule>
```

Example 8.3. 9am-5pm, Mon-Friday

```
<rule id="rule3">
   <date_expression id="date_expr3" operation="date_spec">
    <date_spec hours="9-16" days="1-5"/>
   </date_expression>
</rule>
```

Please note that the **16** matches up to **16:59:59**, as the numeric value (hour) still matches!

Example 8.4. 9am-6pm, Mon-Friday, or all day saturday

```
<rule id="rule4" boolean_op="or">
   <date_expression id="date_expr4-1" operation="date_spec">
    <date_spec hours="9-16" days="1-5"/>
   </date_expression>
   <date_expression id="date_expr4-2" operation="date_spec">
    <date_spec days="6"/>
   </date_expression>
</rule>
```

Example 8.5. 9am-5pm or 9pm-12pm, Mon-Friday

```
<rule id="rule5" boolean_op="and">
   <rule id="rule5-nested1" boolean_op="or">
    <date_expression id="date_expr5-1" operation="date_spec">
     <date_spec hours="9-16"/>
    </date_expression>
    <date_expression id="date_expr5-2" operation="date_spec">
     <date_spec hours="21-23"/>
    </date_expression>
   </rule>
   <date_expression id="date_expr5-3" operation="date_spec">
    <date_spec days="1-5"/>
   </date_expression>
  </rule>
```

Example 8.6. Mondays in March 2005

```
<rule id="rule6" boolean_op="and">
   <date_expression id="date_expr6-1" operation="date_spec">
    <date_spec weekdays="1"/>
```

```
    </date_expression>
    <date_expression id="date_expr6-2" operation="in_range"
      start="2005-03-01" end="2005-04-01"/>
  </rule>
```

Note

Because no time is specified, 00:00:00 is implied.

This means that the range includes all of 2005-03-01 but none of 2005-04-01. You may wish to write **`end="2005-03-31T23:59:59"`** to avoid confusion.

Example 8.7. A full moon on Friday the 13th

```
<rule id="rule7" boolean_op="and">
   <date_expression id="date_expr7" operation="date_spec">
    <date_spec weekdays="5" monthdays="13" moon="4"/>
   </date_expression>
</rule>
```

8.4. Using Rules to Determine Resource Location

If the constraint's outer-most rule evaluates to **`false`**, the cluster treats the constraint as if it was not there. When the rule evaluates to **`true`**, the node's preference for running the resource is updated with the score associated with the rule.

If this sounds familiar, its because you have been using a simplified syntax for location constraint rules already. Consider the following location constraint:

Example 8.8. Prevent myApacheRsc from running on c001n03

```
<rsc_location id="dont-run-apache-on-c001n03" rsc="myApacheRsc"
              score="-INFINITY" node="c001n03"/>
```

This constraint can be more verbosely written as:

Example 8.9. Prevent myApacheRsc from running on c001n03 - expanded version

```
<rsc_location id="dont-run-apache-on-c001n03" rsc="myApacheRsc">
    <rule id="dont-run-apache-rule" score="-INFINITY">
      <expression id="dont-run-apache-expr" attribute="#uname"
        operation="eq" value="c00n03"/>
    </rule>
</rsc_location>
```

The advantage of using the expanded form is that one can then add extra clauses to the rule, such as limiting the rule such that it only applies during certain times of the day or days of the week (this is discussed in subsequent sections).

It also allows us to match on node properties other than its name. If we rated each machine's CPU power such that the cluster had the following nodes section:

Example 8.10. A sample nodes section for use with score-attribute

```
<nodes>
   <node id="uuid1" uname="c001n01" type="normal">
      <instance_attributes id="uuid1-custom_attrs">
        <nvpair id="uuid1-cpu_mips" name="cpu_mips" value="1234"/>
      </instance_attributes>
   </node>
   <node id="uuid2" uname="c001n02" type="normal">
      <instance_attributes id="uuid2-custom_attrs">
        <nvpair id="uuid2-cpu_mips" name="cpu_mips" value="5678"/>
      </instance_attributes>
   </node>
</nodes>
```

then we could prevent resources from running on underpowered machines with the rule

```
<rule id="need-more-power-rule" score="-INFINITY">
   <expression id=" need-more-power-expr" attribute="cpu_mips"
               operation="lt" value="3000"/>
</rule>
```

8.4.1. Using `score-attribute` Instead of `score`

When using **`score-attribute`** instead of **`score`**, each node matched by the rule has its score adjusted differently, according to its value for the named node attribute. Thus, in the previous example, if a rule used **`score-attribute="cpu_mips"`**, **`c001n01`** would have its preference to run the resource increased by **`1234`** whereas **`c001n02`** would have its preference increased by **`5678`**.

8.5. Using Rules to Control Resource Options

Often some cluster nodes will be different from their peers; sometimes these differences (the location of a binary or the names of network interfaces) require resources to be configured differently depending on the machine they're hosted on.

By defining multiple **`instance_attributes`** objects for the resource and adding a rule to each, we can easily handle these special cases.

In the example below, **`mySpecialRsc`** will use eth1 and port 9999 when run on **`node1`**, eth2 and port 8888 on **`node2`** and default to eth0 and port 9999 for all other nodes.

Example 8.11. Defining different resource options based on the node name

```
<primitive id="mySpecialRsc" class="ocf" type="Special" provider="me">
   <instance_attributes id="special-node1" score="3">
    <rule id="node1-special-case" score="INFINITY" >
     <expression id="node1-special-case-expr" attribute="#uname"
       operation="eq" value="node1"/>
    </rule>
    <nvpair id="node1-interface" name="interface" value="eth1"/>
   </instance_attributes>
   <instance_attributes id="special-node2" score="2" >
    <rule id="node2-special-case" score="INFINITY">
     <expression id="node2-special-case-expr" attribute="#uname"
       operation="eq" value="node2"/>
```

```
    </rule>
    <nvpair id="node2-interface" name="interface" value="eth2"/>
    <nvpair id="node2-port" name="port" value="8888"/>
   </instance_attributes>
   <instance_attributes id="defaults" score="1" >
    <nvpair id="default-interface" name="interface" value="eth0"/>
    <nvpair id="default-port" name="port" value="9999"/>
   </instance_attributes>
</primitive>
```

The order in which **instance_attributes** objects are evaluated is determined by their score (highest to lowest). If not supplied, score defaults to zero and objects with an equal score are processed in listed order. If the **instance_attributes** object does not have a **rule** or has a **rule** that evaluates to **true**, then for any parameter the resource does not yet have a value for, the resource will use the parameter values defined by the **instance_attributes** object.

8.6. Using Rules to Control Cluster Options

Controlling cluster options is achieved in much the same manner as specifying different resource options on different nodes.

The difference is that because they are cluster options, one cannot (or should not, because they won't work) use attribute based expressions. The following example illustrates how to set a different **resource-stickiness** value during and outside of work hours. This allows resources to automatically move back to their most preferred hosts, but at a time that (in theory) does not interfere with business activities.

Example 8.12. Change **resource-stickiness** during working hours

```
<rsc_defaults>
   <meta_attributes id="core-hours" score="2">
      <rule id="core-hour-rule" score="0">
        <date_expression id="nine-to-five-Mon-to-Fri" operation="date_spec">
          <date_spec id="nine-to-five-Mon-to-Fri-spec" hours="9-16" weekdays="1-5"/>
        </date_expression>
      </rule>
      <nvpair id="core-stickiness" name="resource-stickiness" value="INFINITY"/>
   </meta_attributes>
   <meta_attributes id="after-hours" score="1" >
      <nvpair id="after-stickiness" name="resource-stickiness" value="0"/>
   </meta_attributes>
</rsc_defaults>
```

8.7. Ensuring Time Based Rules Take Effect

A Pacemaker cluster is an event driven system. As such, it won't recalculate the best place for resources to run in unless something (like a resource failure or configuration change) happens. This can mean that a location constraint that only allows resource X to run between 9am and 5pm is not enforced.

If you rely on time based rules, it is essential that you set the **cluster-recheck-interval** option. This tells the cluster to periodically recalculate the ideal state of the cluster. For example, if you set **cluster-recheck-interval=5m**, then sometime between 9:00 and 9:05 the cluster would notice that it needs to start resource X, and between 17:00 and 17:05 it would realize that X needed to be stopped.

Note that the timing of the actual start and stop actions depends on what else needs to be performed first .

Advanced Configuration

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9.1. Connecting from a Remote Machine

Provided Pacemaker is installed on a machine, it is possible to connect to the cluster even if the machine itself is not in the same cluster. To do this, one simply sets up a number of environment variables and runs the same commands as when working on a cluster node.

Table 9.1. Environment Variables Used to Connect to Remote Instances of the CIB

Environment Variable	Description
CIB_user	The user to connect as. Needs to be part of the **hacluster** group on the target host. Defaults to *$USER*.
CIB_passwd	The user's password. Read from the command line if unset.
CIB_server	The host to contact. Defaults to *localhost*.
CIB_port	The port on which to contact the server; required.
CIB_encrypted	Encrypt network traffic; defaults to *true*.

So, if **c001n01** is an active cluster node and is listening on **1234** for connections, and **someguy** is a member of the **hacluster** group, then the following would prompt for **someguy**'s password and return the cluster's current configuration:

```
# export CIB_port=1234; export CIB_server=c001n01; export CIB_user=someguy;
# cibadmin -Q
```

For security reasons, the cluster does not listen for remote connections by default. If you wish to allow remote access, you need to set the **remote-tls-port** (encrypted) or **remote-clear-port** (unencrypted) top-level options (ie., those kept in the cib tag, like **num_updates** and **epoch**).

Table 9.2. Extra top-level CIB options for remote access

Field	Description
remote-tls-port	Listen for encrypted remote connections on this port. Default: *none*
remote-clear-port	Listen for plaintext remote connections on this port. Default: *none*

9.2. Specifying When Recurring Actions are Performed

By default, recurring actions are scheduled relative to when the resource started. So if your resource was last started at 14:32 and you have a backup set to be performed every 24 hours, then the backup will always run at in the middle of the business day - hardly desirable.

To specify a date/time that the operation should be relative to, set the operation's **`interval-origin`**. The cluster uses this point to calculate the correct **`start-delay`** such that the operation will occur at *origin + (interval * N)*.

So, if the operation's interval is 24h, it's interval-origin is set to **`02:00`** and it is currently **`14:32`**, then the cluster would initiate the operation with a start delay of 11 hours and 28 minutes. If the resource is moved to another node before 2am, then the operation is of course cancelled.

The value specified for interval and **`interval-origin`** can be any date/time conforming to the *ISO8601 standard*[1]. By way of example, to specify an operation that would run on the first Monday of 2009 and every Monday after that you would add:

Example 9.1. Specifying a Base for Recurring Action Intervals

```
<op id="my-weekly-action" name="custom-action" interval="P7D" interval-origin="2009-
W01-1"/>
```

9.3. Moving Resources

9.3.1. Manual Intervention

There are primarily two occasions when you would want to move a resource from it's current location: when the whole node is under maintenance, and when a single resource needs to be moved.

Since everything eventually comes down to a score, you could create constraints for every resource to prevent them from running on one node. While the configuration can seem convoluted at times, not even we would require this of administrators.

Instead one can set a special node attribute which tells the cluster "don't let anything run here". There is even a helpful tool to help query and set it, called **`crm_standby`**. To check the standby status of the current machine, simply run:

```
# crm_standby --get-value
```

A value of **`true`** indicates that the node is *NOT* able to host any resources, while a value of **`false`** says that it *CAN*.

You can also check the status of other nodes in the cluster by specifying the **`--node-uname`** option:

```
# crm_standby --get-value --node-uname sles-2
```

To change the current node's standby status, use **`--attr-value`** instead of **`--get-value`**.

```
# crm_standby --attr-value
```

[1] http://en.wikipedia.org/wiki/ISO_8601

Again, you can change another host's value by supplying a host name with **--node-uname**.

When only one resource is required to move, we do this by creating location constraints. However, once again we provide a user friendly shortcut as part of the **crm_resource** command, which creates and modifies the extra constraints for you. If **Email** was running on **sles-1** and you wanted it moved to a specific location, the command would look something like:

```
# crm_resource -M -r Email -H sles-2
```

Behind the scenes, the tool will create the following location constraint:

```
<rsc_location rsc="Email" node="sles-2" score="INFINITY"/>
```

It is important to note that subsequent invocations of **crm_resource -M** are not cumulative. So, if you ran these commands

```
# crm_resource -M -r Email -H sles-2
# crm_resource -M -r Email -H sles-3
```

then it is as if you had never performed the first command.

To allow the resource to move back again, use:

```
# crm_resource -U -r Email
```

Note the use of the word *allow*. The resource can move back to its original location but, depending on **resource-stickiness**, it might stay where it is. To be absolutely certain that it moves back to **sles-1**, move it there before issuing the call to **crm_resource -U**:

```
# crm_resource -M -r Email -H sles-1
# crm_resource -U -r Email
```

Alternatively, if you only care that the resource should be moved from its current location, try

```
# crm_resource -M -r Email`
```

Which will instead create a negative constraint, like

```
<rsc_location rsc="Email" node="sles-1" score="-INFINITY"/>
```

This will achieve the desired effect, but will also have long-term consequences. As the tool will warn you, the creation of a **-INFINITY** constraint will prevent the resource from running on that node until **crm_resource -U** is used. This includes the situation where every other cluster node is no longer available!

In some cases, such as when **resource-stickiness** is set to **INFINITY**, it is possible that you will end up with the problem described in *Section 6.2.4, "What if Two Nodes Have the Same Score"*. The tool can detect some of these cases and deals with them by also creating both a positive and negative constraint. Eg.

Email prefers **sles-1** with a score of **-INFINITY**

Email prefers **sles-2** with a score of **INFINITY**

which has the same long-term consequences as discussed earlier.

9.3.2. Moving Resources Due to Failure

New in 1.0 is the concept of a migration threshold. [2]

Simply define **migration-threshold=N** for a resource and it will migrate to a new node after N failures. There is no threshold defined by default. To determine the resource's current failure status and limits, use **crm_mon --failcounts**.

By default, once the threshold has been reached, this node will no longer be allowed to run the failed resource until the administrator manually resets the resource's failcount using **crm_failcount** (after hopefully first fixing the failure's cause). However it is possible to expire them by setting the resource's **failure-timeout** option.

So a setting of **migration-threshold=2** and **failure-timeout=60s** would cause the resource to move to a new node after 2 failures, and allow it to move back (depending on the stickiness and constraint scores) after one minute.

There are two exceptions to the migration threshold concept; they occur when a resource either fails to start or fails to stop. Start failures cause the failcount to be set to **INFINITY** and thus always cause the resource to move immediately.

Stop failures are slightly different and crucial. If a resource fails to stop and STONITH is enabled, then the cluster will fence the node in order to be able to start the resource elsewhere. If STONITH is not enabled, then the cluster has no way to continue and will not try to start the resource elsewhere, but will try to stop it again after the failure timeout.

Important

Please read *Section 8.7, "Ensuring Time Based Rules Take Effect"* before enabling this option.

9.3.3. Moving Resources Due to Connectivity Changes

Setting up the cluster to move resources when external connectivity is lost is a two-step process.

9.3.3.1. Tell Pacemaker to monitor connectivity

To do this, you need to add a **ping** resource to the cluster. The **ping** resource uses the system utility of the same name to a test if list of machines (specified by DNS hostname or IPv4/IPv6 address) are reachable and uses the results to maintain a node attribute normally called **pingd**. [3]

Note

Older versions of Heartbeat required users to add ping nodes to *ha.cf* - this is no longer required.

[2] The naming of this option was perhaps unfortunate as it is easily confused with true migration, the process of moving a resource from one node to another without stopping it. Xen virtual guests are the most common example of resources that can be migrated in this manner.

[3] The attribute name is customizable; that allows multiple ping groups to be defined.

Important

Older versions of Pacemaker used a custom binary called *pingd* for this functionality; this is now deprecated in favor of *ping*.

If your version of Pacemaker does not contain the ping agent, you can download the latest version from *https://github.com/ClusterLabs/pacemaker/tree/master/extra/resources/ping*

Normally the resource will run on all cluster nodes, which means that you'll need to create a clone. A template for this can be found below along with a description of the most interesting parameters.

Table 9.3. Common Options for a *ping* Resource

Field	Description
dampen	The time to wait (dampening) for further changes to occur. Use this to prevent a resource from bouncing around the cluster when cluster nodes notice the loss of connectivity at slightly different times.
multiplier	The number of connected ping nodes gets multiplied by this value to get a score. Useful when there are multiple ping nodes configured.
host_list	The machines to contact in order to determine the current connectivity status. Allowed values include resolvable DNS host names, IPv4 and IPv6 addresses.

Example 9.2. An example ping cluster resource that checks node connectivity once every minute

```
<clone id="Connected">
   <primitive id="ping" provider="pacemaker" class="ocf" type="ping">
    <instance_attributes id="ping-attrs">
      <nvpair id="pingd-dampen" name="dampen" value="5s"/>
      <nvpair id="pingd-multiplier" name="multiplier" value="1000"/>
      <nvpair id="pingd-hosts" name="host_list" value="my.gateway.com www.bigcorp.com"/>
    </instance_attributes>
    <operations>
      <op id="ping-monitor-60s" interval="60s" name="monitor"/>
    </operations>
   </primitive>
</clone>
```

Important

You're only half done. The next section deals with telling Pacemaker how to deal with the connectivity status that **ocf:pacemaker:ping** is recording.

9.3.3.2. Tell Pacemaker how to interpret the connectivity data

Note

Before reading the following, please make sure you have read and understood *Chapter 8, Rules* above.

There are a number of ways to use the connectivity data provided by Heartbeat. The most common setup is for people to have a single ping node, to prevent the cluster from running a resource on any unconnected node.

Example 9.3. Don't run on unconnected nodes

```
<rsc_location id="WebServer-no-connectivity" rsc="Webserver">
   <rule id="ping-exclude-rule" score="-INFINITY" >
    <expression id="ping-exclude" attribute="pingd" operation="not_defined"/>
   </rule>
</rsc_location>
```

A more complex setup is to have a number of ping nodes configured. You can require the cluster to only run resources on nodes that can connect to all (or a minimum subset) of them.

Example 9.4. Run only on nodes connected to three or more ping nodes; this assumes **`multiplier`** is set to 1000:

```
<rsc_location id="WebServer-connectivity" rsc="Webserver">
   <rule id="ping-prefer-rule" score="-INFINITY" >
    <expression id="ping-prefer" attribute="pingd" operation="lt" value="3000"/>
   </rule>
</rsc_location>
```

Instead you can tell the cluster only to *prefer* nodes with the best connectivity. Just be sure to set **`multiplier`** to a value higher than that of **`resource-stickiness`** (and don't set either of them to **`INFINITY`**).

Example 9.5. Prefer the node with the most connected ping nodes

```
<rsc_location id="WebServer-connectivity" rsc="Webserver">
   <rule id="ping-prefer-rule" score-attribute="pingd" >
    <expression id="ping-prefer" attribute="pingd" operation="defined"/>
   </rule>
</rsc_location>
```

It is perhaps easier to think of this in terms of the simple constraints that the cluster translates it into. For example, if **`sles-1`** is connected to all 5 ping nodes but **`sles-2`** is only connected to 2, then it would be as if you instead had the following constraints in your configuration:

Example 9.6. How the cluster translates the pingd constraint

```
<rsc_location id="ping-1" rsc="Webserver" node="sles-1" score="5000"/>
<rsc_location id="ping-2" rsc="Webserver" node="sles-2" score="2000"/>
```

The advantage is that you don't have to manually update any constraints whenever your network connectivity changes.

You can also combine the concepts above into something even more complex. The example below shows how you can prefer the node with the most connected ping nodes provided they have connectivity to at least three (again assuming that **`multiplier`** is set to 1000).

Example 9.7. A more complex example of choosing a location based on connectivity

```
<rsc_location id="WebServer-connectivity" rsc="Webserver">
   <rule id="ping-exclude-rule" score="-INFINITY" >
    <expression id="ping-exclude" attribute="pingd" operation="lt" value="3000"/>
   </rule>
   <rule id="ping-prefer-rule" score-attribute="pingd" >
    <expression id="ping-prefer" attribute="pingd" operation="defined"/>
   </rule>
</rsc_location>
```

9.3.4. Resource Migration

Some resources, such as Xen virtual guests, are able to move to another location without loss of state. We call this resource migration; this is different from the normal practice of stopping the resource on the first machine and starting it elsewhere.

Not all resources are able to migrate, see the Migration Checklist below, and those that can, won't do so in all situations. Conceptually there are two requirements from which the other prerequisites follow:

- the resource must be active and healthy at the old location
- everything required for the resource to run must be available on both the old and new locations

The cluster is able to accommodate both push and pull migration models by requiring the resource agent to support two new actions: **`migrate_to`** (performed on the current location) and **`migrate_from`** (performed on the destination).

In push migration, the process on the current location transfers the resource to the new location where is it later activated. In this scenario, most of the work would be done in the **`migrate_to`** action and, if anything, the activation would occur during **`migrate_from`**.

Conversely for pull, the **`migrate_to`** action is practically empty and **`migrate_from`** does most of the work, extracting the relevant resource state from the old location and activating it.

There is no wrong or right way to implement migration for your service, as long as it works.

9.3.4.1. Migration Checklist

- The resource may not be a clone.
- The resource must use an OCF style agent.
- The resource must not be in a failed or degraded state.

- The resource must not, directly or indirectly, depend on any primitive or group resources.
- The resource must support two new actions: **migrate_to** and **migrate_from**, and advertise them in its metadata.
- The resource must have the **allow-migrate** meta-attribute set to **true** (which is not the default).

If the resource depends on a clone, and at the time the resource needs to be move, the clone has instances that are stopping and instances that are starting, then the resource will be moved in the traditional manner. The Policy Engine is not yet able to model this situation correctly and so takes the safe (yet less optimal) path.

9.4. Reusing Rules, Options and Sets of Operations

Sometimes a number of constraints need to use the same set of rules, and resources need to set the same options and parameters. To simplify this situation, you can refer to an existing object using an **id-ref** instead of an id.

So if for one resource you have

```
<rsc_location id="WebServer-connectivity" rsc="Webserver">
   <rule id="ping-prefer-rule" score-attribute="pingd" >
    <expression id="ping-prefer" attribute="pingd" operation="defined"/>
   </rule>
</rsc_location>
```

Then instead of duplicating the rule for all your other resources, you can instead specify:

Example 9.8. Referencing rules from other constraints

```
<rsc_location id="WebDB-connectivity" rsc="WebDB">
      <rule id-ref="ping-prefer-rule"/>
</rsc_location>
```

Important

The cluster will insist that the **rule** exists somewhere. Attempting to add a reference to a non-existing rule will cause a validation failure, as will attempting to remove a **rule** that is referenced elsewhere.

The same principle applies for **meta_attributes** and **instance_attributes** as illustrated in the example below:

Example 9.9. Referencing attributes, options, and operations from other resources

```
<primitive id="mySpecialRsc" class="ocf" type="Special" provider="me">
   <instance_attributes id="mySpecialRsc-attrs" score="1" >
     <nvpair id="default-interface" name="interface" value="eth0"/>
     <nvpair id="default-port" name="port" value="9999"/>
   </instance_attributes>
   <meta_attributes id="mySpecialRsc-options">
     <nvpair id="failure-timeout" name="failure-timeout" value="5m"/>
```

```
      <nvpair id="migration-threshold" name="migration-threshold" value="1"/>
      <nvpair id="stickiness" name="resource-stickiness" value="0"/>
    </meta_attributes>
    <operations id="health-checks">
      <op id="health-check" name="monitor" interval="60s"/>
      <op id="health-check" name="monitor" interval="30min"/>
    </operations>
</primitive>
<primitive id="myOtherlRsc" class="ocf" type="Other" provider="me">
    <instance_attributes id-ref="mySpecialRsc-attrs"/>
    <meta_attributes id-ref="mySpecialRsc-options"/>
    <operations id-ref="health-checks"/>
</primitive>
```

9.5. Reloading Services After a Definition Change

The cluster automatically detects changes to the definition of services it manages. However, the normal response is to stop the service (using the old definition) and start it again (with the new definition). This works well, but some services are smarter and can be told to use a new set of options without restarting.

To take advantage of this capability, your resource agent must:

1. Accept the **`reload`** operation and perform any required actions. *The steps required here depend completely on your application!*

   Example 9.10. The DRBD Agent's Control logic for Supporting the **`reload`** Operation

   ```
   case $1 in
       start)
           drbd_start
           ;;
       stop)
           drbd_stop
           ;;
       reload)
           drbd_reload
           ;;
       monitor)
           drbd_monitor
           ;;
       *)
           drbd_usage
           exit $OCF_ERR_UNIMPLEMENTED
           ;;
   esac
   exit $?
   ```

2. Advertise the **`reload`** operation in the **`actions`** section of its metadata

   Example 9.11. The DRBD Agent Advertising Support for the **`reload`** Operation

   ```
   <?xml version="1.0"?>
     <!DOCTYPE resource-agent SYSTEM "ra-api-1.dtd">
     <resource-agent name="drbd">
       <version>1.1</version>

       <longdesc>
         Master/Slave OCF Resource Agent for DRBD
       </longdesc>
   ```

```
    ...

    <actions>
      <action name="start"   timeout="240" />
      <action name="reload"  timeout="240" />
      <action name="promote" timeout="90" />
      <action name="demote"  timeout="90" />
      <action name="notify"  timeout="90" />
      <action name="stop"    timeout="100" />
      <action name="meta-data"    timeout="5" />
      <action name="validate-all" timeout="30" />
    </actions>
  </resource-agent>
```

3. Advertise one or more parameters that can take effect using **`reload`**.

   Any parameter with the **`unique`** set to 0 is eligible to be used in this way.

Example 9.12. Parameter that can be changed using reload

```
<parameter name="drbdconf" unique="0">
    <longdesc>Full path to the drbd.conf file.</longdesc>
    <shortdesc>Path to drbd.conf</shortdesc>
    <content type="string" default="${OCF_RESKEY_drbdconf_default}"/>
</parameter>
```

Once these requirements are satisfied, the cluster will automatically know to reload the resource (instead of restarting) when a non-unique fields changes.

Note

The metadata is re-read when the resource is started. This may mean that the resource will be restarted the first time, even though you changed a parameter with **`unique=0`**

Note

If both a unique and non-unique field are changed simultaneously, the resource will still be restarted.

Advanced Resource Types

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10.1. Groups - A Syntactic Shortcut

One of the most common elements of a cluster is a set of resources that need to be located together, start sequentially, and stop in the reverse order. To simplify this configuration we support the concept of groups.

Example 10.1. An example group

```
<group id="shortcut">
   <primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
    <instance_attributes id="params-public-ip">
       <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
    </instance_attributes>
   </primitive>
   <primitive id="Email" class="lsb" type="exim"/>
  </group>
```

Although the example above contains only two resources, there is no limit to the number of resources a group can contain. The example is also sufficient to explain the fundamental properties of a group:

- Resources are started in the order they appear in (**`Public-IP`** first, then **`Email`**)
- Resources are stopped in the reverse order to which they appear in (**`Email`** first, then **`Public-IP`**)

If a resource in the group can't run anywhere, then nothing after that is allowed to run, too.

- If **`Public-IP`** can't run anywhere, neither can **`Email`**;
- but if **`Email`** can't run anywhere, this does not affect **`Public-IP`** in any way

The group above is logically equivalent to writing:

Example 10.2. How the cluster sees a group resource

```
<configuration>
   <resources>
    <primitive id="Public-IP" class="ocf" type="IPaddr" provider="heartbeat">
     <instance_attributes id="params-public-ip">
        <nvpair id="public-ip-addr" name="ip" value="1.2.3.4"/>
     </instance_attributes>
    </primitive>
    <primitive id="Email" class="lsb" type="exim"/>
   </resources>
   <constraints>
      <rsc_colocation id="xxx" rsc="Email" with-rsc="Public-IP" score="INFINITY"/>
      <rsc_order id="yyy" first="Public-IP" then="Email"/>
   </constraints>
</configuration>
```

Obviously as the group grows bigger, the reduced configuration effort can become significant.

Another (typical) example of a group is a DRBD volume, the filesystem mount, an IP address, and an application that uses them.

10.1.1. Group Properties

Table 10.1. Properties of a Group Resource

Field	Description
`id`	Your name for the group

10.1.2. Group Options

Options inherited from *primitive* resources: **`priority, target-role, is-managed`**

10.1.3. Group Instance Attributes

Groups have no instance attributes, however any that are set here will be inherited by the group's children.

10.1.4. Group Contents

Groups may only contain a collection of *Section 5.3, "Resource Properties"* cluster resources. To refer to the child of a group resource, just use the child's id instead of the group's.

10.1.5. Group Constraints

Although it is possible to reference the group's children in constraints, it is usually preferable to use the group's name instead.

Example 10.3. Example constraints involving groups

```
<constraints>
    <rsc_location id="group-prefers-node1" rsc="shortcut" node="node1" score="500"/>
    <rsc_colocation id="webserver-with-group" rsc="Webserver" with-rsc="shortcut"/>
    <rsc_order id="start-group-then-webserver" first="Webserver" then="shortcut"/>
</constraints>
```

10.1.6. Group Stickiness

Stickiness, the measure of how much a resource wants to stay where it is, is additive in groups. Every active resource of the group will contribute its stickiness value to the group's total. So if the default **`resource-stickiness`** is 100, and a group has seven members, five of which are active, then the group as a whole will prefer its current location with a score of 500.

10.2. Clones - Resources That Get Active on Multiple Hosts

Clones were initially conceived as a convenient way to start N instances of an IP resource and have them distributed throughout the cluster for load balancing. They have turned out to quite useful for a number of purposes including integrating with Red Hat's DLM, the fencing subsystem, and OCFS2.

You can clone any resource, provided the resource agent supports it.

Three types of cloned resources exist:

- Anonymous
- Globally Unique
- Stateful

Anonymous clones are the simplest type. These resources behave completely identically everywhere they are running. Because of this, there can only be one copy of an anonymous clone active per machine.

Globally unique clones are distinct entities. A copy of the clone running on one machine is not equivalent to another instance on another node. Nor would any two copies on the same node be equivalent.

Stateful clones are covered later in *Section 10.3, "Multi-state - Resources That Have Multiple Modes"*.

Example 10.4. An example clone

```
<clone id="apache-clone">
    <meta_attributes id="apache-clone-meta">
       <nvpair id="apache-unique" name="globally-unique" value="false"/>
    </meta_attributes>
    <primitive id="apache" class="lsb" type="apache"/>
</clone>
```

10.2.1. Clone Properties

Table 10.2. Properties of a Clone Resource

Field	Description
id	Your name for the clone

10.2.2. Clone Options

Options inherited from *primitive* resources: **priority, target-role, is-managed**

Table 10.3. Clone specific configuration options

Field	Description
clone-max	How many copies of the resource to start. Defaults to the number of nodes in the cluster.
clone-node-max	How many copies of the resource can be started on a single node; default *1*.
notify	When stopping or starting a copy of the clone, tell all the other copies beforehand and when the action was successful. Allowed values: *false*, **true**
globally-unique	Does each copy of the clone perform a different function? Allowed values: *false*, **true**
ordered	Should the copies be started in series (instead of in parallel). Allowed values: *false*, **true**
interleave	Changes the behavior of ordering constraints (between clones/masters) so that instances can start/stop as soon as their peer instance has (rather than waiting for every instance of the other clone has). Allowed values: *false*, **true**

10.2.3. Clone Instance Attributes

Clones have no instance attributes; however, any that are set here will be inherited by the clone's children.

10.2.4. Clone Contents

Clones must contain exactly one group or one regular resource.

Warning

You should never reference the name of a clone's child. If you think you need to do this, you probably need to re-evaluate your design.

10.2.5. Clone Constraints

In most cases, a clone will have a single copy on each active cluster node. If this is not the case, you can indicate which nodes the cluster should preferentially assign copies to with resource location

constraints. These constraints are written no differently to those for regular resources except that the clone's id is used.

Ordering constraints behave slightly differently for clones. In the example below, **apache-stats** will wait until all copies of the clone that need to be started have done so before being started itself. Only if *no* copies can be started **apache-stats** will be prevented from being active. Additionally, the clone will wait for **apache-stats** to be stopped before stopping the clone.

Colocation of a regular (or group) resource with a clone means that the resource can run on any machine with an active copy of the clone. The cluster will choose a copy based on where the clone is running and the resource's own location preferences.

Colocation between clones is also possible. In such cases, the set of allowed locations for the clone is limited to nodes on which the clone is (or will be) active. Allocation is then performed as normally.

Example 10.5. Example constraints involving clones

```
<constraints>
    <rsc_location id="clone-prefers-node1" rsc="apache-clone" node="node1" score="500"/>
    <rsc_colocation id="stats-with-clone" rsc="apache-stats" with="apache-clone"/>
    <rsc_order id="start-clone-then-stats" first="apache-clone" then="apache-stats"/>
</constraints>
```

10.2.6. Clone Stickiness

To achieve a stable allocation pattern, clones are slightly sticky by default. If no value for **resource-stickiness** is provided, the clone will use a value of 1. Being a small value, it causes minimal disturbance to the score calculations of other resources but is enough to prevent Pacemaker from needlessly moving copies around the cluster.

10.2.7. Clone Resource Agent Requirements

Any resource can be used as an anonymous clone, as it requires no additional support from the resource agent. Whether it makes sense to do so depends on your resource and its resource agent.

Globally unique clones do require some additional support in the resource agent. In particular, it must only respond with other probes for instances of the clone should result in they should return one of the other OCF error codes.

Copies of a clone are identified by appending a colon and a numerical offset, eg. **apache:2**.

Resource agents can find out how many copies there are by examining the **OCF_RESKEY_CRM_meta_clone_max** environment variable and which copy it is by examining **OCF_RESKEY_CRM_meta_clone**.

You should not make any assumptions (based on **OCF_RESKEY_CRM_meta_clone**) about which copies are active. In particular, the list of active copies will not always be an unbroken sequence, nor always start at 0.

10.2.7.1. Clone Notifications

Supporting notifications requires the **notify** action to be implemented. Once supported, the notify action will be passed a number of extra variables which, when combined with additional context, can be used to calculate the current state of the cluster and what is about to happen to it.

Table 10.4. Environment variables supplied with Clone notify actions

Variable	Description
OCF_RESKEY_CRM_meta_notify_type	Allowed values: **pre**, **post**
OCF_RESKEY_CRM_meta_notify_operation	Allowed values: **start**, **stop**
OCF_RESKEY_CRM_meta_notify_start_resource	Resources to be started
OCF_RESKEY_CRM_meta_notify_stop_resource	Resources to be stopped
OCF_RESKEY_CRM_meta_notify_active_resource	Resources that are running
OCF_RESKEY_CRM_meta_notify_inactive_resource	Resources that are not running
OCF_RESKEY_CRM_meta_notify_start_uname	Nodes on which resources will be started
OCF_RESKEY_CRM_meta_notify_stop_uname	Nodes on which resources will be stopped
OCF_RESKEY_CRM_meta_notify_active_uname	Nodes on which resources are running
OCF_RESKEY_CRM_meta_notify_inactive_uname	Nodes on which resources are not running

The variables come in pairs, such as **OCF_RESKEY_CRM_meta_notify_start_resource** and **OCF_RESKEY_CRM_meta_notify_start_uname** and should be treated as an array of whitespace separated elements.

Thus in order to indicate that **clone:0** will be started on **sles-1**, **clone:2** will be started on **sles-3**, and **clone:3** will be started on **sles-2**, the cluster would set

Example 10.6. Example notification variables

```
OCF_RESKEY_CRM_meta_notify_start_resource="clone:0 clone:2 clone:3"
OCF_RESKEY_CRM_meta_notify_start_uname="sles-1 sles-3 sles-2"
```

10.2.7.2. Proper Interpretation of Notification Environment Variables

Pre-notification (stop):

- Active resources: **$OCF_RESKEY_CRM_meta_notify_active_resource**
- Inactive resources: **$OCF_RESKEY_CRM_meta_notify_inactive_resource**
- Resources to be started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**

Post-notification (stop) / Pre-notification (start):

- Active resources
  - **$OCF_RESKEY_CRM_meta_notify_active_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Inactive resources
  - **$OCF_RESKEY_CRM_meta_notify_inactive_resource**

  - plus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Resources that were started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources that were stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**

Post-notification (start):
- Active resources:
  - **$OCF_RESKEY_CRM_meta_notify_active_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Inactive resources:
  - **$OCF_RESKEY_CRM_meta_notify_inactive_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources that were started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources that were stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**

10.3. Multi-state - Resources That Have Multiple Modes

Multi-state resources are a specialization of Clone resources; please ensure you understand the section on clones before continuing! They allow the instances to be in one of two operating modes; these are called **Master** and **Slave**, but can mean whatever you wish them to mean. The only limitation is that when an instance is started, it must come up in the **Slave** state.

10.3.1. Multi-state Properties

Table 10.5. Properties of a Multi-State Resource

Field	Description
id	Your name for the multi-state resource

10.3.2. Multi-state Options

Options inherited from *primitive* resources: **priority**, **target-role**, **is-managed**

Options inherited from *clone* resources: **clone-max**, **clone-node-max**, **notify**, **globally-unique**, **ordered**, **interleave**

Table 10.6. Multi-state specific resource configuration options

Field	Description
master-max	How many copies of the resource can be promoted to **master** status; default 1.
master-node-max	How many copies of the resource can be promoted to **master** status on a single node; default 1.

10.3.3. Multi-state Instance Attributes

Multi-state resources have no instance attributes; however, any that are set here will be inherited by master's children.

10.3.4. Multi-state Contents

Masters must contain exactly one group or one regular resource.

Warning

You should never reference the name of a master's child. If you think you need to do this, you probably need to re-evaluate your design.

10.3.5. Monitoring Multi-State Resources

The normal type of monitor actions are not sufficient to monitor a multi-state resource in the **`Master`** state. To detect failures of the **`Master`** instance, you need to define an additional monitor action with **`role="Master"`**.

Important

It is crucial that *every* monitor operation has a different interval!

This is because Pacemaker currently differentiates between operations only by resource and interval; so if eg. a master/slave resource has the same monitor interval for both roles, Pacemaker would ignore the role when checking the status - which would cause unexpected return codes, and therefore unnecessary complications.

Example 10.7. Monitoring both states of a multi-state resource

```
<master id="myMasterRsc">
   <primitive id="myRsc" class="ocf" type="myApp" provider="myCorp">
    <operations>
     <op id="public-ip-slave-check" name="monitor" interval="60"/>
     <op id="public-ip-master-check" name="monitor" interval="61" role="Master"/>
    </operations>
   </primitive>
</master>
```

10.3.6. Multi-state Constraints

In most cases, a multi-state resources will have a single copy on each active cluster node. If this is not the case, you can indicate which nodes the cluster should preferentially assign copies to with resource location constraints. These constraints are written no differently to those for regular resources except that the master's id is used.

When considering multi-state resources in constraints, for most purposes it is sufficient to treat them as clones. The exception is when the **`rsc-role`** and/or **`with-rsc-role`** fields (for colocation constraints) and **`first-action`** and/or **`then-action`** fields (for ordering constraints) are used.

Table 10.7. Additional constraint options relevant to multi-state resources

Field	Description
rsc-role	An additional attribute of colocation constraints that specifies the role that **rsc** must be in. Allowed values: *Started*, **Master**, **Slave**.
with-rsc-role	An additional attribute of colocation constraints that specifies the role that **with-rsc** must be in. Allowed values: *Started*, **Master**, **Slave**.
first-action	An additional attribute of ordering constraints that specifies the action that the **first** resource must complete before executing the specified action for the **then** resource. Allowed values: *start*, **stop**, **promote**, **demote**.
then-action	An additional attribute of ordering constraints that specifies the action that the **then** resource can only execute after the **first-action** on the **first** resource has completed. Allowed values: **start**, **stop**, **promote**, **demote**. Defaults to the value (specified or implied) of **first-action**.

In the example below, **myApp** will wait until one of the database copies has been started and promoted to master before being started itself. Only if no copies can be promoted will **apache-stats** be prevented from being active. Additionally, the database will wait for **myApp** to be stopped before it is demoted.

Example 10.8. Example constraints involving multi-state resources

```
<constraints>
   <rsc_location id="db-prefers-node1" rsc="database" node="node1" score="500"/>
   <rsc_colocation id="backup-with-db-slave" rsc="backup"
     with-rsc="database" with-rsc-role="Slave"/>
   <rsc_colocation id="myapp-with-db-master" rsc="myApp"
     with-rsc="database" with-rsc-role="Master"/>
   <rsc_order id="start-db-before-backup" first="database" then="backup"/>
   <rsc_order id="promote-db-then-app" first="database" first-action="promote"
     then="myApp" then-action="start"/>
</constraints>
```

Colocation of a regular (or group) resource with a multi-state resource means that it can run on any machine with an active copy of the multi-state resource that is in the specified state (**Master** or **Slave**). In the example, the cluster will choose a location based on where database is running as a **Master**, and if there are multiple **Master** instances it will also factor in **myApp**'s own location preferences when deciding which location to choose.

Colocation with regular clones and other multi-state resources is also possible. In such cases, the set of allowed locations for the **rsc** clone is (after role filtering) limited to nodes on which the **with-rsc** multi-state resource is (or will be) in the specified role. Allocation is then performed as-per-normal.

10.3.7. Multi-state Stickiness

To achieve a stable allocation pattern, multi-state resources are slightly sticky by default. If no value for **resource-stickiness** is provided, the multi-state resource will use a value of 1. Being a small value, it causes minimal disturbance to the score calculations of other resources but is enough to prevent Pacemaker from needlessly moving copies around the cluster.

10.3.8. Which Resource Instance is Promoted

During the start operation, most Resource Agent scripts should call the **crm_master** utility. This tool automatically detects both the resource and host and should be used to set a preference for being promoted. Based on this, **master-max**, and **master-node-max**, the instance(s) with the highest preference will be promoted.

The other alternative is to create a location constraint that indicates which nodes are most preferred as masters.

Example 10.9. Manually specifying which node should be promoted

```
<rsc_location id="master-location" rsc="myMasterRsc">
    <rule id="master-rule" score="100" role="Master">
      <expression id="master-exp" attribute="#uname" operation="eq" value="node1"/>
    </rule>
</rsc_location>
```

10.3.9. Multi-state Resource Agent Requirements

Since multi-state resources are an extension of cloned resources, all the requirements of Clones are also requirements of multi-state resources. Additionally, multi-state resources require two extra actions: **demote** and **promote**; these actions are responsible for changing the state of the resource. Like **start** and **stop**, they should return **OCF_SUCCESS** if they completed successfully or a relevant error code if they did not.

The states can mean whatever you wish, but when the resource is started, it must come up in the mode called **Slave**. From there the cluster will then decide which instances to promote to **Master**.

In addition to the Clone requirements for monitor actions, agents must also *accurately* report which state they are in. The cluster relies on the agent to report its status (including role) accurately and does not indicate to the agent what role it currently believes it to be in.

Table 10.8. Role implications of OCF return codes

Monitor Return Code	Description
OCF_NOT_RUNNING	Stopped
OCF_SUCCESS	Running (Slave)
OCF_RUNNING_MASTER	Running (Master)
OCF_FAILED_MASTER	Failed (Master)
Other	Failed (Slave)

10.3.10. Multi-state Notifications

Like clones, supporting notifications requires the **notify** action to be implemented. Once supported the notify action will be passed a number of extra variables which, when combined with additional context, can be used to calculate the current state of the cluster and what is about to happen to it.

Table 10.9. Environment variables supplied with Master notify actions [1]

Variable	Description
OCF_RESKEY_CRM_meta_notify_type	Allowed values: **pre**, **post**
OCF_RESKEY_CRM_meta_notify_operation	Allowed values: **start**, **stop**
OCF_RESKEY_CRM_meta_notify_active_resource	Resources the that are running

Variable	Description
OCF_RESKEY_CRM_meta_notify_inactive_resource	Resources the that are not running
OCF_RESKEY_CRM_meta_notify_master_resource	Resources that are running in **`Master`** mode
OCF_RESKEY_CRM_meta_notify_slave_resource	Resources that are running in **`Slave`** mode
OCF_RESKEY_CRM_meta_notify_start_resource	Resources to be started
OCF_RESKEY_CRM_meta_notify_stop_resource	Resources to be stopped
OCF_RESKEY_CRM_meta_notify_promote_resource	Resources to be promoted
OCF_RESKEY_CRM_meta_notify_demote_resource	Resources to be demoted
OCF_RESKEY_CRM_meta_notify_start_uname	Nodes on which resources will be started
OCF_RESKEY_CRM_meta_notify_stop_uname	Nodes on which resources will be stopped
OCF_RESKEY_CRM_meta_notify_promote_uname	Nodes on which resources will be promote
OCF_RESKEY_CRM_meta_notify_demote_uname	Nodes on which resources will be demoted
OCF_RESKEY_CRM_meta_notify_active_uname	Nodes on which resources are running
OCF_RESKEY_CRM_meta_notify_inactive_uname	Nodes on which resources are not running
OCF_RESKEY_CRM_meta_notify_master_uname	Nodes on which resources are running in **`Master`** mode
OCF_RESKEY_CRM_meta_notify_slave_uname	Nodes on which resources are running in **`Slave`** mode

[1] Emphasized variables are specific to **`Master`** resources and all behave in the same manner as described for Clone resources.

10.3.11. Multi-state - Proper Interpretation of Notification Environment Variables

Pre-notification (demote):

- **`Active`** resources: **`$OCF_RESKEY_CRM_meta_notify_active_resource`**
- **`Master`** resources: **`$OCF_RESKEY_CRM_meta_notify_master_resource`**
- **`Slave`** resources: **`$OCF_RESKEY_CRM_meta_notify_slave_resource`**
- Inactive resources: **`$OCF_RESKEY_CRM_meta_notify_inactive_resource`**
- Resources to be started: **`$OCF_RESKEY_CRM_meta_notify_start_resource`**
- Resources to be promoted: **`$OCF_RESKEY_CRM_meta_notify_promote_resource`**
- Resources to be demoted: **`$OCF_RESKEY_CRM_meta_notify_demote_resource`**
- Resources to be stopped: **`$OCF_RESKEY_CRM_meta_notify_stop_resource`**

Post-notification (demote) / Pre-notification (stop):

- **Active** resources: **$OCF_RESKEY_CRM_meta_notify_active_resource**
- **Master** resources:
  - **$OCF_RESKEY_CRM_meta_notify_master_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- **Slave** resources: **$OCF_RESKEY_CRM_meta_notify_slave_resource**
- Inactive resources: **$OCF_RESKEY_CRM_meta_notify_inactive_resource**
- Resources to be started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be promoted: **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- Resources to be demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources to be stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Resources that were demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**

Post-notification (stop) / Pre-notification (start)

- **Active** resources:
  - **$OCF_RESKEY_CRM_meta_notify_active_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- **Master** resources:
  - **$OCF_RESKEY_CRM_meta_notify_master_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- **Slave** resources:
  - **$OCF_RESKEY_CRM_meta_notify_slave_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Inactive resources:
  - **$OCF_RESKEY_CRM_meta_notify_inactive_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Resources to be started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be promoted: **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- Resources to be demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources to be stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Resources that were demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources that were stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**

Post-notification (start) / Pre-notification (promote)

- **Active** resources:
  - **$OCF_RESKEY_CRM_meta_notify_active_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- **Master** resources:
  - **$OCF_RESKEY_CRM_meta_notify_master_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- **Slave** resources:
  - **$OCF_RESKEY_CRM_meta_notify_slave_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Inactive resources:
  - **$OCF_RESKEY_CRM_meta_notify_inactive_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be promoted: **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- Resources to be demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources to be stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Resources that were started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources that were demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources that were stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**

Post-notification (promote)

- **Active** resources:
  - **$OCF_RESKEY_CRM_meta_notify_active_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- **Master** resources:
  - **$OCF_RESKEY_CRM_meta_notify_master_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_demote_resource**

  - plus **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- **Slave** resources:
  - **$OCF_RESKEY_CRM_meta_notify_slave_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_start_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- Inactive resources:
  - **$OCF_RESKEY_CRM_meta_notify_inactive_resource**
  - plus **$OCF_RESKEY_CRM_meta_notify_stop_resource**
  - minus **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources to be promoted: **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- Resources to be demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources to be stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**
- Resources that were started: **$OCF_RESKEY_CRM_meta_notify_start_resource**
- Resources that were promoted: **$OCF_RESKEY_CRM_meta_notify_promote_resource**
- Resources that were demoted: **$OCF_RESKEY_CRM_meta_notify_demote_resource**
- Resources that were stopped: **$OCF_RESKEY_CRM_meta_notify_stop_resource**

Utilization and Placement Strategy

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11.1. Background

Pacemaker decides where to place a resource according to the resource allocation scores on every node. The resource will be allocated to the node where the resource has the highest score. If the resource allocation scores on all the nodes are equal, by the **`default`** placement strategy, Pacemaker will choose a node with the least number of allocated resources for balancing the load. If the number of resources on each node is equal, the first eligible node listed in cib will be chosen to run the resource.

Though resources are different. They may consume different amounts of the capacities of the nodes. Actually, we cannot ideally balance the load just according to the number of resources allocated to a node. Besides, if resources are placed such that their combined requirements exceed the provided capacity, they may fail to start completely or run with degraded performance.

To take these into account, Pacemaker allows you to specify the following configurations:

1. The **`capacity`** a certain **`node provides`**.
2. The **`capacity`** a certain **`resource requires`**.
3. An overall **`strategy`** for placement of resources.

11.2. Utilization attributes

To configure the capacity a node provides and the resource's requirements, use **`utilization`** attributes. You can name the **`utilization`** attributes according to your preferences and define as many **`name/value`** pairs as your configuration needs. However, the attribute's values must be **`integers`**.

First, specify the capacities the nodes provide:

```
<node id="node1" type="normal" uname="node1">
  <utilization id="node1-utilization">
    <nvpair id="node1-utilization-cpu" name="cpu" value="2"/>
    <nvpair id="node1-utilization-memory" name="memory" value="2048"/>
  </utilization>
</node>
<node id="node2" type="normal" uname="node2">
```

```
  <utilization id="node2-utilization">
    <nvpair id="node2-utilization-cpu" name="cpu" value="4"/>
    <nvpair id="node2-utilization-memory" name="memory" value="4096"/>
  </utilization>
</node>
```

Then, specify the capacities the resources require:

```
<primitive id="rsc-small" class="ocf" provider="pacemaker" type="Dummy">
  <utilization id="rsc-small-utilization">
    <nvpair id="rsc-small-utilization-cpu" name="cpu" value="1"/>
    <nvpair id="rsc-small-utilization-memory" name="memory" value="1024"/>
  </utilization>
</primitive>
<primitive id="rsc-medium" class="ocf" provider="pacemaker" type="Dummy">
  <utilization id="rsc-medium-utilization">
    <nvpair id="rsc-medium-utilization-cpu" name="cpu" value="2"/>
    <nvpair id="rsc-medium-utilization-memory" name="memory" value="2048"/>
  </utilization>
</primitive>
<primitive id="rsc-large" class="ocf" provider="pacemaker" type="Dummy">
  <utilization id="rsc-large-utilization">
    <nvpair id="rsc-large-utilization-cpu" name="cpu" value="3"/>
    <nvpair id="rsc-large-utilization-memory" name="memory" value="3072"/>
  </utilization>
</primitive>
```

A node is considered eligible for a resource if it has sufficient free capacity to satisfy the resource's requirements. The nature of the required or provided capacities is completely irrelevant for Pacemaker, it just makes sure that all capacity requirements of a resource are satisfied before placing a resource to a node.

11.3. Placement Strategy

After you have configured the capacities your nodes provide and the capacities your resources require, you need to set the **`placement-strategy`** in the global cluster options, otherwise the capacity configurations have **`no effect`**.

Four values are available for the **`placement-strategy`**:

`default`
: Utilization values are not taken into account at all, per default. Resources are allocated according to allocation scores. If scores are equal, resources are evenly distributed across nodes.

`utilization`
: Utilization values are taken into account when deciding whether a node is considered eligible if it has sufficient free capacity to satisfy the resource's requirements. However, load-balancing is still done based on the number of resources allocated to a node.

`balanced`
: Utilization values are taken into account when deciding whether a node is eligible to serve a resource; an attempt is made to spread the resources evenly, optimizing resource performance.

`minimal`
: Utilization values are taken into account when deciding whether a node is eligible to serve a resource; an attempt is made to concentrate the resources on as few nodes as possible, thereby enabling possible power savings on the remaining nodes.

Set **`placement-strategy`** with **`crm_attribute`**:

```
# crm_attribute --attr-name placement-strategy --attr-value balanced
```

Now Pacemaker will ensure the load from your resources will be distributed evenly throughout the cluster - without the need for convoluted sets of colocation constraints.

11.4. Allocation Details

11.4.1. Which node is preferred to be chosen to get consumed first on allocating resources?

- The node that is most healthy (which has the highest node weight) gets consumed first.
- If their weights are equal:
  - If **`placement-strategy="default|utilization"`**, the node that has the least number of allocated resources gets consumed first.
    - If their numbers of allocated resources are equal, the first eligible node listed in cib gets consumed first.
  - If **`placement-strategy="balanced"`**, the node that has more free capacity gets consumed first.
    - If the free capacities of the nodes are equal, the node that has the least number of allocated resources gets consumed first.
      - If their numbers of allocated resources are equal, the first eligible node listed in cib gets consumed first.
  - If **`placement-strategy="minimal"`**, the first eligible node listed in cib gets consumed first.

11.4.1.1. Which node has more free capacity?

This will be quite clear if we only define one type of **`capacity`**. While if we define multiple types of **`capacity`**, for example:

- If **`nodeA`** has more free **`cpus`**, **`nodeB`** has more free **`memory`**, their free capacities are equal.
- If **`nodeA`** has more free **`cpus`**, while **`nodeB`** has more free **`memory`** and **`storage`**, **`nodeB`** has more free capacity.

11.4.2. Which resource is preferred to be chosen to get assigned first?

- The resource that has the highest priority gets allocated first.
- If their priorities are equal, check if they are already running. The resource that has the highest score on the node where it's running gets allocated first (to prevent resource shuffling).
- If the scores above are equal or they are not running, the resource has the highest score on the preferred node gets allocated first.
- If the scores above are equal, the first runnable resource listed in cib gets allocated first.

11.5. Limitations

This type of problem Pacemaker is dealing with here is known as the *knapsack problem*[1] and falls into the *NP-complete*[2] category of computer science problems - which is fancy way of saying "it takes a really long time to solve".

Clearly in a HA cluster, it's not acceptable to spend minutes, let alone hours or days, finding an optional solution while services remain unavailable.

So instead of trying to solve the problem completely, Pacemaker uses a *best effort* algorithm for determining which node should host a particular service. This means it arrives at a solution much faster than traditional linear programming algorithms, but by doing so at the price of leaving some services stopped.

In the contrived example above:

- **`rsc-small`** would be allocated to **`node1`**
- **`rsc-medium`** would be allocated to **`node2`**
- **`rsc-large`** would remain inactive

Which is not ideal.

11.6. Strategies for Dealing with the Limitations

- Ensure you have sufficient physical capacity. It might sounds obvious, but if the physical capacity of your nodes is (close to) maxed out by the cluster under normal conditions, then failover isn't going to go well. Even without the Utilization feature, you'll start hitting timeouts and getting secondary failures'.
- Build some buffer into the capabilities advertised by the nodes. Advertise slightly more resources than we physically have on the (usually valid) assumption that a resource will not use 100% of the configured number of cpu/memory/etc **`all`** the time. This practice is also known as *over commit*.
- Specify resource priorities. If the cluster is going to sacrifice services, it should be the ones you care (comparatively) about the least. Ensure that resource priorities are properly set so that your most important resources are scheduled first.

[1] http://en.wikipedia.org/wiki/Knapsack_problem
[2] http://en.wikipedia.org/wiki/NP-complete

Resource Templates

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12.1. Abstract

If you want to create lots of resources with similar configurations, defining a resource template simplifies the task. Once defined, it can be referenced in primitives or in certain types of constraints.

12.2. Configuring Resources with Templates

The primitives referencing the template will inherit all meta attributes, instance attributes, utilization attributes and operations defined in the template. And you can define specific attributes and operations for any of the primitives. If any of these are defined in both the template and the primitive, the values defined in the primitive will take precedence over the ones defined in the template.

Hence, resource templates help to reduce the amount of configuration work. If any changes are needed, they can be done to the template definition and will take effect globally in all resource definitions referencing that template.

Resource templates have a similar syntax like primitives. For example:

```
<template id="vm-template" class="ocf" provider="heartbeat" type="Xen">
  <meta_attributes id="vm-template-meta_attributes">
    <nvpair id="vm-template-meta_attributes-allow-migrate" name="allow-migrate" value="true"/
>
  </meta_attributes>
  <utilization id="vm-template-utilization">
    <nvpair id="vm-template-utilization-memory" name="memory" value="512"/>
  </utilization>
  <operations>
    <op id="vm-template-monitor-15s" interval="15s" name="monitor" timeout="60s"/>
    <op id="vm-template-start-0" interval="0" name="start" timeout="60s"/>
  </operations>
</template>
```

Once you defined the new resource template, you can use it in primitives:

```
<primitive id="vm1" template="vm-template">
  <instance_attributes id="vm1-instance_attributes">
    <nvpair id="vm1-instance_attributes-name" name="name" value="vm1"/>
    <nvpair id="vm1-instance_attributes-xmfile" name="xmfile" value="/etc/xen/shared-vm/vm1"/
>
  </instance_attributes>
</primitive>
```

The new primitive **`vm1`** is going to inherit everything from the **`vm-template`**. For example, the equivalent of the above two would be:

```
<primitive id="vm1" class="ocf" provider="heartbeat" type="Xen">
  <meta_attributes id="vm-template-meta_attributes">
```

```
    <nvpair id="vm-template-meta_attributes-allow-migrate" name="allow-migrate" value="true"/
>
  </meta_attributes>
  <utilization id="vm-template-utilization">
    <nvpair id="vm-template-utilization-memory" name="memory" value="512"/>
  </utilization>
  <operations>
    <op id="vm-template-monitor-15s" interval="15s" name="monitor" timeout="60s"/>
    <op id="vm-template-start-0" interval="0" name="start" timeout="60s"/>
  </operations>
  <instance_attributes id="vm1-instance_attributes">
    <nvpair id="vm1-instance_attributes-name" name="name" value="vm1"/>
    <nvpair id="vm1-instance_attributes-xmfile" name="xmfile" value="/etc/xen/shared-vm/vm1"/
>
  </instance_attributes>
</primitive>
```

If you want to overwrite some attributes or operations, add them to the particular primitive's definition.

For instance, the following new primitive **vm2** has special attribute values. Its **monitor** operation has a longer **timeout** and **interval**, and the primitive has an additional **stop** operation.

```
<primitive id="vm2" template="vm-template">
  <meta_attributes id="vm2-meta_attributes">
    <nvpair id="vm2-meta_attributes-allow-migrate" name="allow-migrate" value="false"/>
  </meta_attributes>
  <utilization id="vm2-utilization">
    <nvpair id="vm2-utilization-memory" name="memory" value="1024"/>
  </utilization>
  <instance_attributes id="vm2-instance_attributes">
    <nvpair id="vm2-instance_attributes-name" name="name" value="vm2"/>
    <nvpair id="vm2-instance_attributes-xmfile" name="xmfile" value="/etc/xen/shared-vm/vm2"/
>
  </instance_attributes>
  <operations>
    <op id="vm2-monitor-30s" interval="30s" name="monitor" timeout="120s"/>
    <op id="vm2-stop-0" interval="0" name="stop" timeout="60s"/>
  </operations>
</primitive>
```

The following command shows the resulting definition of a resource:

```
# crm_resource --query-xml --resource vm2
```

The following command shows its raw definition in cib:

```
# crm_resource --query-xml-raw --resource vm2
```

12.3. Referencing Templates in Constraints

A resource template can be referenced in the following types of constraints:

- **order** constraints
- **colocation** constraints,
- **rsc_ticket** constraints (for multi-site clusters).

Resource templates referenced in constraints stand for all primitives which are derived from that template. This means, the constraint applies to all primitive resources referencing the resource

template. Referencing resource templates in constraints is an alternative to resource sets and can simplify the cluster configuration considerably.

For example:

```
<rsc_colocation id="vm-template-colo-base-rsc" rsc="vm-template" rsc-role="Started" with-
rsc="base-rsc" score="INFINITY"/>
```

is the equivalent of the following constraint configuration:

```
<rsc_colocation id="vm-colo-base-rsc" score="INFINITY">
  <resource_set id="vm-colo-base-rsc-0" sequential="false" role="Started">
    <resource_ref id="vm1"/>
    <resource_ref id="vm2"/>
  </resource_set>
  <resource_set id="vm-colo-base-rsc-1">
    <resource_ref id="base-rsc"/>
  </resource_set>
</rsc_colocation>
```

Note

In a colocation constraint, only one template may be referenced from either **rsc** or **with-rsc**, and the other reference must be a regular resource.

Resource templates can also be referenced in resource sets.

For example:

```
<rsc_order id="order1" score="INFINITY">
  <resource_set id="order1-0">
    <resource_ref id="base-rsc"/>
    <resource_ref id="vm-template"/>
    <resource_ref id="top-rsc"/>
  </resource_set>
</rsc_order>
```

is the equivalent of the following constraint configuration:

```
<rsc_order id="order1" score="INFINITY">
  <resource_set id="order1-0">
    <resource_ref id="base-rsc"/>
    <resource_ref id="vm1"/>
    <resource_ref id="vm2"/>
    <resource_ref id="top-rsc"/>
  </resource_set>
</rsc_order>
```

If the resources referencing the template can run in parallel:

```
<rsc_order id="order2" score="INFINITY">
  <resource_set id="order2-0">
    <resource_ref id="base-rsc"/>
  </resource_set>
  <resource_set id="order2-1" sequential="false">
```

```
    <resource_ref id="vm-template"/>
  </resource_set>
  <resource_set id="order2-2">
    <resource_ref id="top-rsc"/>
  </resource_set>
</rsc_order>
```

is the equivalent of the following constraint configuration:

```
<rsc_order id="order2" score="INFINITY">
  <resource_set id="order2-0">
    <resource_ref id="base-rsc"/>
  </resource_set>
  <resource_set id="order2-1" sequential="false">
    <resource_ref id="vm1"/>
    <resource_ref id="vm2"/>
  </resource_set>
  <resource_set id="order2-2">
    <resource_ref id="top-rsc"/>
  </resource_set>
</rsc_order>
```

Configure STONITH

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13.1. What Is STONITH

STONITH is an acronym for Shoot-The-Other-Node-In-The-Head and it protects your data from being corrupted by rogue nodes or concurrent access.

Just because a node is unresponsive, this doesn't mean it isn't accessing your data. The only way to be 100% sure that your data is safe, is to use STONITH so we can be certain that the node is truly offline, before allowing the data to be accessed from another node.

STONITH also has a role to play in the event that a clustered service cannot be stopped. In this case, the cluster uses STONITH to force the whole node offline, thereby making it safe to start the service elsewhere.

13.2. What STONITH Device Should You Use

It is crucial that the STONITH device can allow the cluster to differentiate between a node failure and a network one.

The biggest mistake people make in choosing a STONITH device is to use remote power switch (such as many on-board IMPI controllers) that shares power with the node it controls. In such cases, the cluster cannot be sure if the node is really offline, or active and suffering from a network fault.

Likewise, any device that relies on the machine being active (such as SSH-based "devices" used during testing) are inappropriate.

13.3. Configuring STONITH

1. Find the correct driver: **`stonith_admin --list-installed`**

2. Since every device is different, the parameters needed to configure it will vary. To find out the parameters associated with the device, run: **`stonith_admin --metadata --agent type`**

   ```
   The output should be XML formatted text containing additional
   parameter descriptions. We will endevor to make the output more
   friendly in a later version.
   ```

3. Enter the shell crm Create an editable copy of the existing configuration **`cib new stonith`** Create a fencing resource containing a primitive resource with a class of stonith, a type of type and a parameter for each of the values returned in step 2: **`configure primitive …`**

4. If the device does not know how to fence nodes based on their uname, you may also need to set the special **`pcmk_host_map`** parameter. See **`man stonithd`** for details.

5. If the device does not support the list command, you may also need to set the special **pcmk_host_list** and/or **pcmk_host_check** parameters. See **man stonithd** for details.

6. If the device does not expect the victim to be specified with the port parameter, you may also need to set the special **pcmk_host_argument** parameter. See **man stonithd** for details.

7. Upload it into the CIB from the shell: **cib commit stonith**

8. Once the stonith resource is running, you can test it by executing: **stonith_admin --reboot nodename**. Although you might want to stop the cluster on that machine first.

13.4. Example

Assuming we have an chassis containing four nodes and an IPMI device active on 10.0.0.1, then we would chose the fence_ipmilan driver in step 2 and obtain the following list of parameters

Obtaining a list of STONITH Parameters

```
# stonith_admin --metadata -a fence_ipmilan
```

```
<?xml version="1.0" ?>
<resource-agent name="fence_ipmilan" shortdesc="Fence agent for IPMI over LAN">
<longdesc>
fence_ipmilan is an I/O Fencing agent which can be used with machines controlled by IPMI.
 This agent calls support software using ipmitool (http://ipmitool.sf.net/).

To use fence_ipmilan with HP iLO 3 you have to enable lanplus option (lanplus / -P) and
 increase wait after operation to 4 seconds (power_wait=4 / -T 4)</longdesc>
<parameters>
        <parameter name="auth" unique="1">
                <getopt mixed="-A" />
                <content type="string" />
                <shortdesc>IPMI Lan Auth type (md5, password, or none)</shortdesc>
        </parameter>
        <parameter name="ipaddr" unique="1">
                <getopt mixed="-a" />
                <content type="string" />
                <shortdesc>IPMI Lan IP to talk to</shortdesc>
        </parameter>
        <parameter name="passwd" unique="1">
                <getopt mixed="-p" />
                <content type="string" />
                <shortdesc>Password (if required) to control power on IPMI device</shortdesc>
        </parameter>
        <parameter name="passwd_script" unique="1">
                <getopt mixed="-S" />
                <content type="string" />
                <shortdesc>Script to retrieve password (if required)</shortdesc>
        </parameter>
        <parameter name="lanplus" unique="1">
                <getopt mixed="-P" />
                <content type="boolean" />
                <shortdesc>Use Lanplus</shortdesc>
        </parameter>
        <parameter name="login" unique="1">
                <getopt mixed="-l" />
                <content type="string" />
                <shortdesc>Username/Login (if required) to control power on IPMI device</
shortdesc>
        </parameter>
        <parameter name="action" unique="1">
```

```
                <getopt mixed="-o" />
                <content type="string" default="reboot"/>
                <shortdesc>Operation to perform. Valid operations: on, off, reboot, status,
 list, diag, monitor or metadata</shortdesc>
        </parameter>
        <parameter name="timeout" unique="1">
                <getopt mixed="-t" />
                <content type="string" />
                <shortdesc>Timeout (sec) for IPMI operation</shortdesc>
        </parameter>
        <parameter name="cipher" unique="1">
                <getopt mixed="-C" />
                <content type="string" />
                <shortdesc>Ciphersuite to use (same as ipmitool -C parameter)</shortdesc>
        </parameter>
        <parameter name="method" unique="1">
                <getopt mixed="-M" />
                <content type="string" default="onoff"/>
                <shortdesc>Method to fence (onoff or cycle)</shortdesc>
        </parameter>
        <parameter name="power_wait" unique="1">
                <getopt mixed="-T" />
                <content type="string" default="2"/>
                <shortdesc>Wait X seconds after on/off operation</shortdesc>
        </parameter>
        <parameter name="delay" unique="1">
                <getopt mixed="-f" />
                <content type="string" />
                <shortdesc>Wait X seconds before fencing is started</shortdesc>
        </parameter>
        <parameter name="verbose" unique="1">
                <getopt mixed="-v" />
                <content type="boolean" />
                <shortdesc>Verbose mode</shortdesc>
        </parameter>
</parameters>
<actions>
        <action name="on" />
        <action name="off" />
        <action name="reboot" />
        <action name="status" />
        <action name="diag" />
        <action name="list" />
        <action name="monitor" />
        <action name="metadata" />
</actions>
</resource-agent>
```

from which we would create a STONITH resource fragment that might look like this

Sample STONITH Resource

```
# crm crm(live)# cib new stonith
INFO: stonith shadow CIB created
crm(stonith)# configure primitive impi-fencing stonith::fence_ipmilan \
 params pcmk_host_list="pcmk-1 pcmk-2" ipaddr=10.0.0.1 login=testuser passwd=abc123 \
 op monitor interval="60s"
```

And finally, since we disabled it earlier, we need to re-enable STONITH. At this point we should have the following configuration.

Now push the configuration into the cluster.

```
crm(stonith)# configure property stonith-enabled="true"
```

```
crm(stonith)# configure shownode pcmk-1
node pcmk-2
primitive WebData ocf:linbit:drbd \
    params drbd_resource="wwwdata" \
    op monitor interval="60s"
primitive WebFS ocf:heartbeat:Filesystem \
    params device="/dev/drbd/by-res/wwwdata" directory="/var/www/html" fstype="gfs2"
primitive WebSite ocf:heartbeat:apache \
    params configfile="/etc/httpd/conf/httpd.conf" \
    op monitor interval="1min"
primitive ClusterIP ocf:heartbeat:IPaddr2 \
    params ip="192.168.122.101" cidr_netmask="32" clusterip_hash="sourceip" \
    op monitor interval="30s"primitive ipmi-fencing
 stonith::fence_ipmilan \ params pcmk_host_list="pcmk-1
 pcmk-2" ipaddr=10.0.0.1 login=testuser passwd=abc123 \ op monitor interval="60s"ms
 WebDataClone WebData \
    meta master-max="2" master-node-max="1" clone-max="2" clone-node-max="1" notify="true"
clone WebFSClone WebFS
clone WebIP ClusterIP \
    meta globally-unique="true" clone-max="2" clone-node-max="2"
clone WebSiteClone WebSite
colocation WebSite-with-WebFS inf: WebSiteClone WebFSClone
colocation fs_on_drbd inf: WebFSClone WebDataClone:Master
colocation website-with-ip inf: WebSiteClone WebIP
order WebFS-after-WebData inf: WebDataClone:promote WebFSClone:start
order WebSite-after-WebFS inf: WebFSClone WebSiteClone
order apache-after-ip inf: WebIP WebSiteClone
property $id="cib-bootstrap-options" \
    dc-version="1.1.5-bdd89e69ba545404d02445be1f3d72e6a203ba2f" \
    cluster-infrastructure="openais" \
    expected-quorum-votes="2" \
    stonith-enabled="true" \
    no-quorum-policy="ignore"
rsc_defaults $id="rsc-options" \
    resource-stickiness="100"
crm(stonith)# cib commit stonithINFO: commited 'stonith' shadow CIB to the cluster
crm(stonith)# quit
bye
```

Status - Here be dragons

Table of Contents

Most users never need to understand the contents of the status section and can be happy with the output from **crm_mon**.

However for those with a curious inclination, this section attempts to provide an overview of its contents.

14.1. Node Status

In addition to the cluster's configuration, the CIB holds an up-to-date representation of each cluster node in the status section.

Example 14.1. A bare-bones status entry for a healthy node called **cl-virt-1**

```
 <node_state id="cl-virt-1" uname="cl-virt-2" ha="active" in_ccm="true" crmd="online"
join="member" expected="member" crm-debug-origin="do_update_resource">
  <transient_attributes id="cl-virt-1"/>
  <lrm id="cl-virt-1"/>
 </node_state>
```

Users are highly recommended *not to modify* any part of a node's state *directly*. The cluster will periodically regenerate the entire section from authoritative sources. So any changes should be done with the tools for those subsystems.

Table 14.1. Authoritative Sources for State Information

Dataset	Authoritative Source
node_state fields	crmd
transient_attributes tag	attrd
lrm tag	lrmd

The fields used in the **node_state** objects are named as they are largely for historical reasons and are rooted in Pacemaker's origins as the Heartbeat resource manager.

They have remained unchanged to preserve compatibility with older versions.

Table 14.2. Node Status Fields

Field	Description
id	Unique identifier for the node. Corosync based clusters use the uname of the machine, Heartbeat clusters use a human-readable (but annoying) UUID.

Field	Description
uname	The node's machine name (output from **uname -n**).
ha	Flag specifying whether the cluster software is active on the node. Allowed values: **active**, **dead**.
in_ccm	Flag for cluster membership; allowed values: **true**, **false**.
crmd	Flag: is the crmd process active on the node? One of **online**, **offline**.
join	Flag saying whether the node participates in hosting resources. Possible values: **down**, **pending**, **member**, **banned**.
expected	Expected value for **join**.
crm-debug-origin	Diagnostic indicator: the origin of the most recent change(s).

The cluster uses these fields to determine if, at the node level, the node is healthy or is in a failed state and needs to be fenced.

14.2. Transient Node Attributes

Like regular *node attributes*, the name/value pairs listed here also help to describe the node. However they are forgotten by the cluster when the node goes offline. This can be useful, for instance, when you want a node to be in standby mode (not able to run resources) until the next reboot.

In addition to any values the administrator sets, the cluster will also store information about failed resources here.

Example 14.2. Example set of transient node attributes for node "cl-virt-1"

```
 <transient_attributes id="cl-virt-1">
   <instance_attributes id="status-cl-virt-1">
      <nvpair id="status-cl-virt-1-pingd" name="pingd" value="3"/>
      <nvpair id="status-cl-virt-1-probe_complete" name="probe_complete" value="true"/>
      <nvpair id="status-cl-virt-1-fail-count-pingd:0" name="fail-count-pingd:0"
value="1"/>
      <nvpair id="status-cl-virt-1-last-failure-pingd:0" name="last-failure-pingd:0"
value="1239009742"/>
   </instance_attributes>
 </transient_attributes>
```

In the above example, we can see that the **pingd:0** resource has failed once, at **Mon Apr 6 11:22:22 2009**. [1] We also see that the node is connected to three "pingd" peers and that all known resources have been checked for on this machine (**probe_complete**).

14.3. Operation History

A node's resource history is held in the **lrm_resources** tag (a child of the **lrm** tag). The information stored here includes enough information for the cluster to stop the resource safely if it is removed from the **configuration** section. Specifically the resource's **id**, **class**, **type** and **provider** are stored.

[1] You can use the standard **date** command to print a human readable of any seconds-since-epoch value: # **date -d @<parameter>number</parameter>**

Example 14.3. A record of the apcstonith resource

```
<lrm_resource id="apcstonith" type="apcmastersnmp" class="stonith"/>
```

Additionally, we store the last job for every combination of **resource, action** and **interval**. The concatenation of the values in this tuple are used to create the id of the **lrm_rsc_op** object.

Table 14.3. Contents of an **lrm_rsc_op** job

Field	Description
id	Identifier for the job constructed from the resource's **id**, **operation** and **interval**.
call-id	The job's ticket number. Used as a sort key to determine the order in which the jobs were executed.
operation	The action the resource agent was invoked with.
interval	The frequency, in milliseconds, at which the operation will be repeated. A one-off job is indicated by 0.
op-status	The job's status. Generally this will be either 0 (done) or -1 (pending). Rarely used in favor of **rc-code**.
rc-code	The job's result. Refer to *Section B.4, "OCF Return Codes"* for details on what the values here mean and how they are interpreted.
last-run	Diagnostic indicator. Machine local date/time, in seconds since epoch, at which the job was executed.
last-rc-change	Diagnostic indicator. Machine local date/time, in seconds since epoch, at which the job first returned the current value of **rc-code**.
exec-time	Diagnostic indicator. Time, in milliseconds, that the job was running for.
queue-time	Diagnostic indicator. Time, in seconds, that the job was queued for in the LRMd.
crm_feature_set	

Field	Description
	The version which this job description conforms to. Used when processing **op-digest**.
transition-key	A concatenation of the job's graph action number, the graph number, the expected result and the UUID of the crmd instance that scheduled it. This is used to construct **transition-magic** (below).
transition-magic	A concatenation of the job's **op-status**, **rc-code** and **transition-key**. Guaranteed to be unique for the life of the cluster (which ensures it is part of CIB update notifications) and contains all the information needed for the crmd to correctly analyze and process the completed job. Most importantly, the decomposed elements tell the crmd if the job entry was expected and whether it failed.
op-digest	An MD5 sum representing the parameters passed to the job. Used to detect changes to the configuration, to restart resources if necessary.
crm-debug-origin	Diagnostic indicator. The origin of the current values.

14.3.1. Simple Example

Example 14.4. A monitor operation (determines current state of the apcstonith resource)

```
<lrm_resource id="apcstonith" type="apcmastersnmp" class="stonith">
  <lrm_rsc_op id="apcstonith_monitor_0" operation="monitor" call-id="2"
    rc-code="7" op-status="0" interval="0"
    crm-debug-origin="do_update_resource" crm_feature_set="3.0.1"
    op-digest="2e3da9274d3550dc6526fb24bfcbcba0"
    transition-key="22:2:7:2668bbeb-06d5-40f9-936d-24cb7f87006a"
    transition-magic="0:7;22:2:7:2668bbeb-06d5-40f9-936d-24cb7f87006a"
    last-run="1239008085" last-rc-change="1239008085" exec-time="10" queue-time="0"/>
</lrm_resource>
```

In the above example, the job is a non-recurring monitor operation often referred to as a "probe" for the **apcstonith** resource.

The cluster schedules probes for every configured resource on when a new node starts, in order to determine the resource's current state before it takes any further action.

From the **transition-key**, we can see that this was the 22nd action of the 2nd graph produced by this instance of the crmd (2668bbeb-06d5-40f9-936d-24cb7f87006a).

The third field of the **transition-key** contains a 7, this indicates that the job expects to find the resource inactive.

By looking at the **rc-code** property, we see that this was the case.

As that is the only job recorded for this node we can conclude that the cluster started the resource elsewhere.

14.3.2. Complex Resource History Example

Example 14.5. Resource history of a pingd clone with multiple jobs

```
<lrm_resource id="pingd:0" type="pingd" class="ocf" provider="pacemaker">
  <lrm_rsc_op id="pingd:0_monitor_30000" operation="monitor" call-id="34"
    rc-code="0" op-status="0" interval="30000"
    crm-debug-origin="do_update_resource" crm_feature_set="3.0.1"
    transition-key="10:11:0:2668bbeb-06d5-40f9-936d-24cb7f87006a"
    ...
    last-run="1239009741" last-rc-change="1239009741" exec-time="10" queue-time="0"/>
  <lrm_rsc_op id="pingd:0_stop_0" operation="stop"
    crm-debug-origin="do_update_resource" crm_feature_set="3.0.1" call-id="32"
    rc-code="0" op-status="0" interval="0"
    transition-key="11:11:0:2668bbeb-06d5-40f9-936d-24cb7f87006a"
    ...
    last-run="1239009741" last-rc-change="1239009741" exec-time="10" queue-time="0"/>
  <lrm_rsc_op id="pingd:0_start_0" operation="start" call-id="33"
    rc-code="0" op-status="0" interval="0"
    crm-debug-origin="do_update_resource" crm_feature_set="3.0.1"
    transition-key="31:11:0:2668bbeb-06d5-40f9-936d-24cb7f87006a"
    ...
    last-run="1239009741" last-rc-change="1239009741" exec-time="10" queue-time="0" />
  <lrm_rsc_op id="pingd:0_monitor_0" operation="monitor" call-id="3"
    rc-code="0" op-status="0" interval="0"
    crm-debug-origin="do_update_resource" crm_feature_set="3.0.1"
    transition-key="23:2:7:2668bbeb-06d5-40f9-936d-24cb7f87006a"
    ...
    last-run="1239008085" last-rc-change="1239008085" exec-time="20" queue-time="0"/>
  </lrm_resource>
```

When more than one job record exists, it is important to first sort them by **`call-id`** before interpreting them.

Once sorted, the above example can be summarized as:

1. A non-recurring monitor operation returning 7 (not running), with a **`call-id`** of 3
2. A stop operation returning 0 (success), with a **`call-id`** of 32
3. A start operation returning 0 (success), with a **`call-id`** of 33
4. A recurring monitor returning 0 (success), with a **`call-id`** of 34

The cluster processes each job record to build up a picture of the resource's state. After the first and second entries, it is considered stopped and after the third it considered active.

Based on the last operation, we can tell that the resource is currently active.

Additionally, from the presence of a **`stop`** operation with a lower **`call-id`** than that of the **`start`** operation, we can conclude that the resource has been restarted. Specifically this occurred as part of actions 11 and 31 of transition 11 from the crmd instance with the key **`2668bbeb…`**. This information can be helpful for locating the relevant section of the logs when looking for the source of a failure.

Multi-Site Clusters and Tickets

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15.1. Abstract

Apart from local clusters, Pacemaker also supports multi-site clusters. That means you can have multiple, geographically dispersed sites with a local cluster each. Failover between these clusters can be coordinated by a higher level entity, the so-called **`CTR (Cluster Ticket Registry)`**.

15.2. Challenges for Multi-Site Clusters

Typically, multi-site environments are too far apart to support synchronous communication between the sites and synchronous data replication. That leads to the following challenges:

- How to make sure that a cluster site is up and running?
- How to make sure that resources are only started once?
- How to make sure that quorum can be reached between the different sites and a split brain scenario can be avoided?
- How to manage failover between the sites?
- How to deal with high latency in case of resources that need to be stopped?

In the following sections, learn how to meet these challenges.

15.3. Conceptual Overview

Multi-site clusters can be considered as “overlay” clusters where each cluster site corresponds to a cluster node in a traditional cluster. The overlay cluster can be managed by a **`CTR (Cluster Ticket Registry)`** mechanism. It guarantees that the cluster resources will be highly available across different cluster sites. This is achieved by using so-called **`tickets`** that are treated as failover domain between cluster sites, in case a site should be down.

The following list explains the individual components and mechanisms that were introduced for multi-site clusters in more detail.

15.3.1. Components and Concepts

15.3.1.1. Ticket

"Tickets" are, essentially, cluster-wide attributes. A ticket grants the right to run certain resources on a specific cluster site. Resources can be bound to a certain ticket by **`rsc_ticket`** dependencies. Only if the ticket is available at a site, the respective resources are started. Vice versa, if the ticket is revoked, the resources depending on that ticket need to be stopped.

The ticket thus is similar to a *site quorum*; i.e., the permission to manage/own resources associated with that site.

(One can also think of the current **`have-quorum`** flag as a special, cluster-wide ticket that is granted in case of node majority.)

These tickets can be granted/revoked either manually by administrators (which could be the default for the classic enterprise clusters), or via an automated **`CTR`** mechanism described further below.

A ticket can only be owned by one site at a time. Initially, none of the sites has a ticket. Each ticket must be granted once by the cluster administrator.

The presence or absence of tickets for a site is stored in the CIB as a cluster status. With regards to a certain ticket, there are only two states for a site: **`true`** (the site has the ticket) or **`false`** (the site does not have the ticket). The absence of a certain ticket (during the initial state of the multi-site cluster) is also reflected by the value **`false`**.

15.3.1.2. Dead Man Dependency

A site can only activate the resources safely if it can be sure that the other site has deactivated them. However after a ticket is revoked, it can take a long time until all resources depending on that ticket are stopped "cleanly", especially in case of cascaded resources. To cut that process short, the concept of a **`Dead Man Dependency`** was introduced:

- If the ticket is revoked from a site, the nodes that are hosting dependent resources are fenced. This considerably speeds up the recovery process of the cluster and makes sure that resources can be migrated more quickly.

This can be configured by specifying a **`loss-policy="fence"`** in **`rsc_ticket`** constraints.

15.3.1.3. CTR (Cluster Ticket Registry)

This is for those scenarios where the tickets management is supposed to be automatic (instead of the administrator revoking the ticket somewhere, waiting for everything to stop, and then granting it on the desired site).

A **`CTR`** is a network daemon that handles granting, revoking, and timing out "tickets". The participating clusters would run the daemons that would connect to each other, exchange information on their connectivity details, and vote on which site gets which ticket(s).

A ticket would only be granted to a site once they can be sure that it has been relinquished by the previous owner, which would need to be implemented via a timer in most scenarios. If a site loses connection to its peers, its tickets time out and recovery occurs. After the connection timeout plus the recovery timeout has passed, the other sites are allowed to re-acquire the ticket and start the resources again.

This can also be thought of as a "quorum server", except that it is not a single quorum ticket, but several.

15.3.1.4. Configuration Replication

As usual, the CIB is synchronized within each cluster, but it is not synchronized across cluster sites of a multi-site cluster. You have to configure the resources that will be highly available across the multi-site cluster for every site accordingly.

15.4. Configuring Ticket Dependencies

The **rsc_ticket** constraint lets you specify the resources depending on a certain ticket. Together with the constraint, you can set a **loss-policy** that defines what should happen to the respective resources if the ticket is revoked.

The attribute **loss-policy** can have the following values:

fence
: Fence the nodes that are running the relevant resources.

stop
: Stop the relevant resources.

freeze
: Do nothing to the relevant resources.

demote
: Demote relevant resources that are running in master mode to slave mode.

An example to configure a **rsc_ticket** constraint:

```
<rsc_ticket id="rsc1-req-ticketA" rsc="rsc1" ticket="ticketA" loss-policy="fence"/>
```

This creates a constraint with the ID **rsc1-req-ticketA**. It defines that the resource **rsc1** depends on **ticketA** and that the node running the resource should be fenced in case **ticketA** is revoked.

If resource **rsc1** was a multi-state resource that can run in master or slave mode, you may want to configure that only **rsc1's** master mode depends on **ticketA**. With the following configuration, **rsc1** will be demoted to slave mode if **ticketA** is revoked:

```
<rsc_ticket id="rsc1-req-ticketA" rsc="rsc1" rsc-role="Master" ticket="ticketA" loss-
policy="demote"/>
```

You can create more **rsc_ticket** constraints to let multiple resources depend on the same ticket.

rsc_ticket also supports resource sets. So one can easily list all the resources in one **rsc_ticket** constraint. For example:

```
      <rsc_ticket id="resources-dep-ticketA" ticket="ticketA" loss-policy="fence">
        <resource_set id="resources-dep-ticketA-0" role="Started">
          <resource_ref id="rsc1"/>
          <resource_ref id="group1"/>
          <resource_ref id="clone1"/>
        </resource_set>
        <resource_set id="resources-dep-ticketA-1" role="Master">
          <resource_ref id="ms1"/>
        </resource_set>
      </rsc_ticket>
```

In the example, there are two resource sets for listing the resources with different **roles** in one **rsc_ticket** constraint. There's no dependency between the two resource sets. And there's no

dependency among the resources within a resource set. Each of the resources just depends on **ticketA**.

Referencing resource templates in **rsc_ticket** constraints, and even referencing them within resource sets, is also supported.

If you want other resources to depend on further tickets, create as many constraints as necessary with **rsc_ticket**.

15.5. Managing Multi-Site Clusters

15.5.1. Granting and Revoking Tickets Manually

You can grant tickets to sites or revoke them from sites manually. Though if you want to re-distribute a ticket, you should wait for the dependent resources to cleanly stop at the previous site before you grant the ticket to another desired site.

Use the **crm_ticket** command line tool to grant and revoke tickets.

To grant a ticket to this site:

```
# crm_ticket --ticket ticketA --grant
```

To revoke a ticket from this site:

```
# crm_ticket --ticket ticketA --revoke
```

Important

If you are managing tickets manually. Use the **crm_ticket** command with great care as they cannot help verify if the same ticket is already granted elsewhere.

15.5.2. Granting and Revoking Tickets via a Cluster Ticket Registry

15.5.2.1. Booth

Booth is an implementation of **Cluster Ticket Registry** or so-called **Cluster Ticket Manager**.

Booth is the instance managing the ticket distribution and thus, the failover process between the sites of a multi-site cluster. Each of the participating clusters and arbitrators runs a service, the boothd. It connects to the booth daemons running at the other sites and exchanges connectivity details. Once a ticket is granted to a site, the booth mechanism will manage the ticket automatically: If the site which holds the ticket is out of service, the booth daemons will vote which of the other sites will get the ticket. To protect against brief connection failures, sites that lose the vote (either explicitly or implicitly by being disconnected from the voting body) need to relinquish the ticket after a time-out. Thus, it is made sure that a ticket will only be re-distributed after it has been relinquished by the previous site. The resources that depend on that ticket will fail over to the new site holding the ticket. The nodes that have run the resources before will be treated according to the **loss-policy** you set within the **rsc_ticket** constraint.

Before the booth can manage a certain ticket within the multi-site cluster, you initially need to grant it to a site manually via **`booth client`** command. After you have initially granted a ticket to a site, the booth mechanism will take over and manage the ticket automatically.

Important

The **`booth client`** command line tool can be used to grant, list, or revoke tickets. The **`booth client`** commands work on any machine where the booth daemon is running.

If you are managing tickets via **`Booth`**, only use **`booth client`** for manual intervention instead of **`crm_ticket`**. That can make sure the same ticket will only be owned by one cluster site at a time.

Booth includes an implementation of *Paxos*[1] and *Paxos Lease* algorithm, which guarantees the distributed consensus among different cluster sites.

Note

`Arbitrator`

Each site runs one booth instance that is responsible for communicating with the other sites. If you have a setup with an even number of sites, you need an additional instance to reach consensus about decisions such as failover of resources across sites. In this case, add one or more arbitrators running at additional sites. Arbitrators are single machines that run a booth instance in a special mode. As all booth instances communicate with each other, arbitrators help to make more reliable decisions about granting or revoking tickets.

An arbitrator is especially important for a two-site scenario: For example, if site **A** can no longer communicate with site **B**, there are two possible causes for that:

- **A** network failure between **A** and **B**.
- Site **B** is down.

However, if site **C** (the arbitrator) can still communicate with site **B**, site **B** must still be up and running.

15.5.2.1.1. Requirements

- All clusters that will be part of the multi-site cluster must be based on Pacemaker.
- Booth must be installed on all cluster nodes and on all arbitrators that will be part of the multi-site cluster.

The most common scenario is probably a multi-site cluster with two sites and a single arbitrator on a third site. However, technically, there are no limitations with regards to the number of sites and the number of arbitrators involved.

[1] http://en.wikipedia.org/wiki/Paxos_algorithm

Nodes belonging to the same cluster site should be synchronized via NTP. However, time synchronization is not required between the individual cluster sites.

15.5.3. General Management of Tickets

Display the information of tickets:

```
# crm_ticket --info
```

Or you can monitor them with:

```
# crm_mon --tickets
```

Display the rsc_ticket constraints that apply to a ticket:

```
# crm_ticket --ticket ticketA --constraints
```

When you want to do maintenance or manual switch-over of a ticket, the ticket could be revoked from the site for any reason, which would trigger the loss-policies. If **`loss-policy="fence"`**, the dependent resources could not be gracefully stopped/demoted, and even, other unrelated resources could be impacted.

The proper way is making the ticket **`standby`** first with:

```
# crm_ticket --ticket ticketA --standby
```

Then the dependent resources will be stopped or demoted gracefully without triggering the loss-policies.

If you have finished the maintenance and want to activate the ticket again, you can run:

```
# crm_ticket --ticket ticketA --activate
```

15.6. For more information

`Multi-site Clusters`*http://doc.opensuse.org/products/draft/SLE-HA/SLE-ha-guide_sd_draft/cha.ha.geo.html*

`Booth`*https://github.com/ClusterLabs/booth*

Appendix A. FAQ

A.1. History

Q: Why is the Project Called Pacemaker?

A: First of all, the reason its not called the CRM is because of the abundance of terms[1] that are commonly abbreviated to those three letters.

The Pacemaker name came from Kham[2], a good friend of mine, and was originally used by a Java GUI that I was prototyping in early 2007. Alas other commitments have prevented the GUI from progressing much and, when it came time to choose a name for this project, Lars suggested it was an even better fit for an independent CRM.

The idea stems from the analogy between the role of this software and that of the little device that keeps the human heart pumping. Pacemaker monitors the cluster and intervenes when necessary to ensure the smooth operation of the services it provides.

There were a number of other names (and acronyms) tossed around, but suffice to say "Pacemaker" was the best

Q: Why was the Pacemaker Project Created?

A: The decision was made to spin-off the CRM into its own project after the 2.1.3 Heartbeat release in order to

- support both the Corosync and Heartbeat cluster stacks equally
- decouple the release cycles of two projects at very different stages of their life-cycles
- foster the clearer package boundaries, thus leading to
- better and more stable interfaces

A.2. Setup

Q: What Messaging Layers are Supported?

A:
- Corosync (*http://www.corosync.org/*)
- Heartbeat (*http://linux-ha.org/*)

Q: Can I Choose which Messaging Layer to use at Run Time?

A: Yes. The CRM will automatically detect which started it and behave accordingly.

Q: Can I Have a Mixed Heartbeat-Corosync Cluster?

A: No.

Q: Which Messaging Layer Should I Choose?

A: This is discussed in *Appendix D, Installation*.

[1] *http://en.wikipedia.org/wiki/CRM*
[2] *http://khamsouk.souvanlasy.com/*

Q: Where Can I Get Pre-built Packages?

A: Official packages for most major .rpm and based distributions are available from the ClusterLabs Website[3].

For Debian packages, building from source and details on using the above repositories, see our installation page[4].

Q: What Versions of Pacemaker Are Supported?

A: Please refer to the Releases page[5] for an up-to-date list of versions supported directly by the project.

When seeking assistance, please try to ensure you have one of these versions.

[3] *http://www.clusterlabs.org/rpm*
[4] *http://clusterlabs.org/wiki/Install*
[5] *http://clusterlabs.org/wiki/Releases*

Appendix B. More About OCF Resource Agents

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B.1. Location of Custom Scripts

OCF Resource Agents are found in */usr/lib/ocf/resource.d/**provider***.

When creating your own agents, you are encouraged to create a new directory under */usr/lib/ocf/resource.d/* so that they are not confused with (or overwritten by) the agents shipped with Heartbeat.

So, for example, if you chose the provider name of bigCorp and wanted a new resource named bigApp, you would create a script called */usr/lib/ocf/resource.d/bigCorp/bigApp* and define a resource:

```
<primitive id="custom-app" class="ocf" provider="bigCorp" type="bigApp"/>
```

B.2. Actions

All OCF Resource Agents are required to implement the following actions

Table B.1. Required Actions for OCF Agents

Action	Description	Instructions
start	Start the resource	Return 0 on success and an appropriate error code otherwise. Must not report success until the resource is fully active.
stop	Stop the resource	Return 0 on success and an appropriate error code otherwise. Must not report success until the resource is fully stopped.
monitor	Check the resource's state	Exit 0 if the resource is running, 7 if it is stopped, and anything else if it is failed. NOTE: The monitor script should test the state of the resource on the local machine only.
meta-data	Describe the resource	Provide information about this resource as an XML snippet. Exit with 0. NOTE: This is **not** performed as root.
validate-all	Verify the supplied parameters	Exit with 0 if parameters are valid, 2 if not valid, 6 if resource is not configured.

Additional requirements (not part of the OCF specs) are placed on agents that will be used for advanced concepts like *clones* and *multi-state* resources.

Table B.2. Optional Actions for OCF Agents

Action	Description	Instructions
promote	Promote the local instance of a multi-state resource to the master/primary state.	Return 0 on success
demote	Demote the local instance of a multi-state resource to the slave/secondary state.	Return 0 on success
notify	Used by the cluster to send the agent pre and post notification events telling the resource what has happened and will happen.	Must not fail. Must exit with 0

One action specified in the OCF specs is not currently used by the cluster:

- **recover** - a variant of the **start** action, this should try to recover a resource locally.

Remember to use **ocf-tester** to verify that your new agent complies with the OCF standard properly.

B.3. How are OCF Return Codes Interpreted?

The first thing the cluster does is to check the return code against the expected result. If the result does not match the expected value, then the operation is considered to have failed and recovery action is initiated.

There are three types of failure recovery:

Table B.3. Types of recovery performed by the cluster

Type	Description	Action Taken by the Cluster
soft	A transient error occurred	Restart the resource or move it to a new location
hard	A non-transient error that may be specific to the current node occurred	Move the resource elsewhere and prevent it from being retried on the current node
fatal	A non-transient error that will be common to all cluster nodes (eg. a bad configuration was specified)	Stop the resource and prevent it from being started on any cluster node

Assuming an action is considered to have failed, the following table outlines the different OCF return codes and the type of recovery the cluster will initiate when it is received.

B.4. OCF Return Codes

Table B.4. OCF Return Codes and their Recovery Types

RC	OCF Alias	Description	RT
0	**OCF_SUCCESS**	Success. The command completed successfully. This is the expected result for all start, stop, promote and demote commands.	**soft**
1	**OCF_ERR_GENERIC**	Generic "there was a problem" error code.	**soft**

RC	OCF Alias	Description	RT
2	**OCF_ERR_ARGS**	The resource's configuration is not valid on this machine. Eg. refers to a location/tool not found on the node.	**hard**
3	**OCF_ERR_UNIMPLEMENTED**	The requested action is not implemented.	**hard**
4	**OCF_ERR_PERM**	The resource agent does not have sufficient privileges to complete the task.	**hard**
5	**OCF_ERR_INSTALLED**	The tools required by the resource are not installed on this machine.	**hard**
6	**OCF_ERR_CONFIGURED**	The resource's configuration is invalid. Eg. required parameters are missing.	**fatal**
7	**OCF_NOT_RUNNING**	The resource is safely stopped. The cluster will not attempt to stop a resource that returns this for any action.	**N/A**
8	**OCF_RUNNING_MASTER**	The resource is running in **Master** mode.	**soft**
9	**OCF_FAILED_MASTER**	The resource is in **Master** mode but has failed. The resource will be demoted, stopped and then started (and possibly promoted) again.	**soft**
other	**NA**	Custom error code.	**soft**

Although counterintuitive, even actions that return 0 (aka. **OCF_SUCCESS**) can be considered to have failed.

B.5. Exceptions

- Non-recurring monitor actions (probes) that find a resource active (or in Master mode) will not result in recovery action unless it is also found active elsewhere
- The recovery action taken when a resource is found active more than once is determined by the *multiple-active* property of the resource
- Recurring actions that return **OCF_ERR_UNIMPLEMENTED** do not cause any type of recovery

Appendix C. What Changed in 1.0

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C.1. New

- Failure timeouts. See *Section 9.3.2, "Moving Resources Due to Failure"*
- New section for resource and operation defaults. See *Section 5.5, "Setting Global Defaults for Resource Options"* and *Section 5.7.2, "Setting Global Defaults for Operations"*
- Tool for making offline configuration changes. See *Section 2.6, "Making Configuration Changes in a Sandbox"*
- **`Rules, instance_attributes, meta_attributes`** and sets of operations can be defined once and referenced in multiple places. See *Section 9.4, "Reusing Rules, Options and Sets of Operations"*
- The CIB now accepts XPath-based create/modify/delete operations. See the **`cibadmin`** help text.
- Multi-dimensional colocation and ordering constraints. See *Section 6.5, "Ordering Sets of Resources"* and *Section 6.9, "Collocating Sets of Resources"*
- The ability to connect to the CIB from non-cluster machines. See *Section 9.1, "Connecting from a Remote Machine"*
- Allow recurring actions to be triggered at known times. See *Section 9.2, "Specifying When Recurring Actions are Performed"*

C.2. Changed

- Syntax
  - All resource and cluster options now use dashes (-) instead of underscores (_)
  - **`master_slave`** was renamed to **`master`**
  - The **`attributes`** container tag was removed
  - The operation field **`pre-req`** has been renamed **`requires`**
  - All operations must have an **`interval`**, **`start`**/**`stop`** must have it set to zero
- The **`stonith-enabled`** option now defaults to true.
- The cluster will refuse to start resources if **`stonith-enabled`** is true (or unset) and no STONITH resources have been defined
- The attributes of colocation and ordering constraints were renamed for clarity. See *Section 6.3, "Specifying in which Order Resources Should Start/Stop"* and *Section 6.4, "Placing Resources Relative to other Resources"*

- **`resource-failure-stickiness`** has been replaced by **`migration-threshold`**. See *Section 9.3.2, “Moving Resources Due to Failure”*
- The parameters for command-line tools have been made consistent
- Switched to *RelaxNG* schema validation and *libxml2* parser
  - id fields are now XML IDs which have the following limitations:
    - id’s cannot contain colons (:)
    - id’s cannot begin with a number
    - id’s must be globally unique (not just unique for that tag)
  - Some fields (such as those in constraints that refer to resources) are IDREFs.

    This means that they must reference existing resources or objects in order for the configuration to be valid. Removing an object which is referenced elsewhere will therefore fail.
  - The CIB representation, from which a MD5 digest is calculated to verify CIBs on the nodes, has changed.

    This means that every CIB update will require a full refresh on any upgraded nodes until the cluster is fully upgraded to 1.0. This will result in significant performance degradation and it is therefore highly inadvisable to run a mixed 1.0/0.6 cluster for any longer than absolutely necessary.
- Ping node information no longer needs to be added to *ha.cf*.

  Simply include the lists of hosts in your ping resource(s).

C.3. Removed

- Syntax
  - It is no longer possible to set resource meta options as top-level attributes. Use meta attributes instead.
  - Resource and operation defaults are no longer read from **`crm_config`**. See *Section 5.5, “Setting Global Defaults for Resource Options”* and *Section 5.7.2, “Setting Global Defaults for Operations”* instead.

Appendix D. Installation

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Warning

The following text may no longer be accurate in some places.

D.1. Choosing a Cluster Stack

Ultimately the choice of cluster stack is a personal decision that must be made in the context of you or your company's needs and strategic direction. Pacemaker currently functions equally well with both stacks.

Here are some factors that may influence the decision:

- SUSE/Novell, Red Hat and Oracle are all putting their collective weight behind the Corosync cluster stack.
- Using Corosync gives your applications access to the following additional cluster services
  - distributed locking service
  - extended virtual synchronization service
  - cluster closed process group service
- It is likely that Pacemaker, at some point in the future, will make use of some of these additional services not provided by Heartbeat

D.2. Enabling Pacemaker

D.2.1. For Corosync

The Corosync configuration is normally located in */etc/corosync/corosync.conf* and an example for a machine with an address of **1.2.3.4** in a cluster communicating on port 1234 (without peer authentication and message encryption) is shown below.

An example Corosync configuration file

```
totem {
    version: 2
```

```
      secauth: off
      threads: 0
      interface {
          ringnumber: 0
          bindnetaddr: 1.2.3.4
          mcastaddr: 239.255.1.1
          mcastport: 1234
      }
  }
  logging {
      fileline: off
      to_syslog: yes
      syslog_facility: daemon
  }
  amf {
      mode: disabled
  }
```

The logging should be mostly obvious and the amf section refers to the Availability Management Framework and is not covered in this document.

The interesting part of the configuration is the totem section. This is where we define how the node can communicate with the rest of the cluster and what protocol version and options (including encryption [1]) it should use. Beginners are encouraged to use the values shown and modify the interface section based on their network.

It is also possible to configure Corosync for an IPv6 based environment. Simply configure **`bindnetaddr`** and **`mcastaddr`** with their IPv6 equivalents, eg.

Example options for an IPv6 environment

```
  bindnetaddr: fec0::1:a800:4ff:fe00:20
  mcastaddr: ff05::1
```

To tell Corosync to use the Pacemaker cluster manager, add the following fragment to a functional Corosync configuration and restart the cluster.

Configuration fragment for enabling Pacemaker under Corosync

```
aisexec {
    user:  root
    group: root
}
service {
    name: pacemaker
    ver: 0
}
```

The cluster needs to be run as root so that its child processes (the **`lrmd`** in particular) have sufficient privileges to perform the actions requested of it. After all, a cluster manager that can't add an IP address or start apache is of little use.

The second directive is the one that actually instructs the cluster to run Pacemaker.

[1] Please consult the Corosync website (*http://www.corosync.org/*) and documentation for details on enabling encryption and peer authentication for the cluster.

D.2.2. For Heartbeat

Add the following to a functional *ha.cf* configuration file and restart Heartbeat:

Configuration fragment for enabling Pacemaker under Heartbeat

```
crm respawn
```

Appendix E. Upgrading Cluster Software

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E.1. Version Compatibility

When releasing newer versions we take care to make sure we are backwards compatible with older versions. While you will always be able to upgrade from version x to x+1, in order to continue to produce high quality software it may occasionally be necessary to drop compatibility with older versions.

There will always be an upgrade path from any series-2 release to any other series-2 release.

There are three approaches to upgrading your cluster software:

- Complete Cluster Shutdown
- Rolling (node by node)
- Disconnect and Reattach

Each method has advantages and disadvantages, some of which are listed in the table below, and you should chose the one most appropriate to your needs.

Table E.1. Summary of Upgrade Methodologies

Type	Available between all software versions	Service Outage During Upgrade	Service Recovery During Upgrade	Exercises Failover Logic/ Configuration	Allows change of cluster stack type [1]
Shutdown	yes	always	N/A	no	yes
Rolling	no	always	yes	yes	no
Reattach	yes	only due to failure	no	no	yes

[1] For example, switching from Heartbeat to Corosync. Consult the Heartbeat or Corosync documentation to see if upgrading them to a newer version is also supported.

E.2. Complete Cluster Shutdown

In this scenario one shuts down all cluster nodes and resources and upgrades all the nodes before restarting the cluster.

E.2.1. Procedure

1. On each node:
   a. Shutdown the cluster stack (Heartbeat or Corosync)
   b. Upgrade the Pacemaker software. This may also include upgrading the cluster stack and/or the underlying operating system.
   c. Check the configuration manually or with the **`crm_verify`** tool if available.
2. On each node:
   a. Start the cluster stack. This can be either Corosync or Heartbeat and does not need to be the same as the previous cluster stack.

E.3. Rolling (node by node)

In this scenario each node is removed from the cluster, upgraded and then brought back online until all nodes are running the newest version.

Important

This method is currently broken between Pacemaker 0.6.x and 1.0.x.

Measures have been put into place to ensure rolling upgrades always work for versions after 1.0.0. Please try one of the other upgrade strategies. Detach/Reattach is a particularly good option for most people.

E.3.1. Procedure

On each node: . Shutdown the cluster stack (Heartbeat or Corosync) . Upgrade the Pacemaker software. This may also include upgrading the cluster stack and/or the underlying operating system. .. On the first node, check the configuration manually or with the **`crm_verify`** tool if available. .. Start the cluster stack.

+ This must be the same type of cluster stack (Corosync or Heartbeat) that the rest of the cluster is using. Upgrading Corosync/Heartbeat may also be possible, please consult the documentation for those projects to see if the two versions will be compatible.

+ .. Repeat for each node in the cluster.

E.3.2. Version Compatibility

Table E.2. Version Compatibility Table

Version being Installed	Oldest Compatible Version
Pacemaker 1.0.x	Pacemaker 1.0.0

Version being Installed	Oldest Compatible Version
Pacemaker 0.7.x	Pacemaker 0.6 or Heartbeat 2.1.3
Pacemaker 0.6.x	Heartbeat 2.0.8
Heartbeat 2.1.3 (or less)	Heartbeat 2.0.4
Heartbeat 2.0.4 (or less)	Heartbeat 2.0.0
Heartbeat 2.0.0	None. Use an alternate upgrade strategy.

E.3.3. Crossing Compatibility Boundaries

Rolling upgrades that cross compatibility boundaries must be preformed in multiple steps. For example, to perform a rolling update from Heartbeat 2.0.1 to Pacemaker 0.6.6 one must:

1. Perform a rolling upgrade from Heartbeat 2.0.1 to Heartbeat 2.0.4
2. Perform a rolling upgrade from Heartbeat 2.0.4 to Heartbeat 2.1.3
3. Perform a rolling upgrade from Heartbeat 2.1.3 to Pacemaker 0.6.6

E.4. Disconnect and Reattach

A variant of a complete cluster shutdown, but the resources are left active and get re-detected when the cluster is restarted.

E.4.1. Procedure

1. Tell the cluster to stop managing services.

   This is required to allow the services to remain active after the cluster shuts down.

   ```
   # crm_attribute -t crm_config -n is-managed-default -v false
   ```

2. For any resource that has a value for **`is-managed`**, make sure it is set to **`false`** (so that the cluster will not stop it)

   ```
   # crm_resource -t primitive -r $rsc_id -p is-managed -v false
   ```

3. On each node:

   a. Shutdown the cluster stack (Heartbeat or Corosync)

   b. Upgrade the cluster stack program - This may also include upgrading the underlying operating system.

4. Check the configuration manually or with the **`crm_verify`** tool if available.

5. On each node:

   a. Start the cluster stack.

      This can be either Corosync or Heartbeat and does not need to be the same as the previous cluster stack.

6. Verify that the cluster re-detected all resources correctly.

7. Allow the cluster to resume managing resources again:

```
# crm_attribute -t crm_config -n is-managed-default -v true
```

8. For any resource that has a value for **is-managed** reset it to **true** (so the cluster can recover the service if it fails) if desired:

```
# crm_resource -t primitive -r $rsc_id -p is-managed -v true
```

E.4.2. Notes

Important

Always check your existing configuration is still compatible with the version you are installing before starting the cluster.

Note

The oldest version of the CRM to support this upgrade type was in Heartbeat 2.0.4

Appendix F. Upgrading the Configuration from 0.6

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F.1. Preparation

Download the latest *DTD*[1] and ensure your configuration validates.

F.2. Perform the upgrade

F.2.1. Upgrade the software

Refer to the appendix: *Appendix E, Upgrading Cluster Software*

F.2.2. Upgrade the Configuration

As XML is not the friendliest of languages, it is common for cluster administrators to have scripted some of their activities. In such cases, it is likely that those scripts will not work with the new 1.0 syntax.

In order to support such environments, it is actually possible to continue using the old 0.6 syntax.

The downside is, however, that not all the new features will be available and there is a performance impact since the cluster must do a non-persistent configuration upgrade before each transition. So while using the old syntax is possible, it is not advisable to continue using it indefinitely.

Even if you wish to continue using the old syntax, it is advisable to follow the upgrade procedure to ensure that the cluster is able to use your existing configuration (since it will perform much the same task internally).

1. Create a shadow copy to work with

```
# crm_shadow --create upgrade06
```

2. Verify the configuration is valid

[1] http://hg.clusterlabs.org/pacemaker/stable-1.0/file-raw/tip/xml/crm.dtd

```
# crm_verify --live-check
```

3. Fix any errors or warnings
4. Perform the upgrade:

```
# cibadmin --upgrade
```

5. If this step fails, there are three main possibilities:
   a. The configuration was not valid to start with - go back to step 2
   b. The transformation failed - report a bug or *email the project*[2]
   c. The transformation was successful but produced an invalid result [3]

      If the result of the transformation is invalid, you may see a number of errors from the validation library. If these are not helpful, visit *http://clusterlabs.org/wiki/Validation_FAQ* and/or try the procedure described below under *Section F.2.3, "Manually Upgrading the Configuration"*
6. Check the changes

```
# crm_shadow --diff
```

If at this point there is anything about the upgrade that you wish to fine-tune (for example, to change some of the automatic IDs) now is the time to do so. Since the shadow configuration is not in use by the cluster, it is safe to edit the file manually:

```
# crm_shadow --edit
```

This will open the configuration in your favorite editor (whichever is specified by the standard **$EDITOR** environment variable)

7. Preview how the cluster will react

   Test what the cluster will do when you upload the new configuration

```
# crm_simulate --live-check --save-dotfile upgrade06.dot -S
# graphviz upgrade06.dot
```

Verify that either no resource actions will occur or that you are happy with any that are scheduled. If the output contains actions you do not expect (possibly due to changes to the score calculations), you may need to make further manual changes. See *Section 2.7, "Testing Your Configuration Changes"* for further details on how to interpret the output of **crm_simulate**

8. Upload the changes

```
# crm_shadow --commit upgrade06 --force
```

[2] mailto:pacemaker@oss.clusterlabs.org?subject=Transformation%20failed%20during%20upgrade
[3] The most common reason is ID values being repeated or invalid. Pacemaker 1.0 is much stricter regarding this type of validation.

If this step fails, something really strange has occurred. You should report a bug.

F.2.3. Manually Upgrading the Configuration

It is also possible to perform the configuration upgrade steps manually. To do this

Locate the *upgrade06.xsl* conversion script or download the latest version from *Git*[4]

1. Convert the XML blob:

```
# xsltproc /path/to/upgrade06.xsl config06.xml > config10.xml
```

2. Locate the *pacemaker.rng* script.

3. Check the XML validity:

```
# xmllint --relaxng /path/to/pacemaker.rng config10.xml
```

The advantage of this method is that it can be performed without the cluster running and any validation errors should be more informative (despite being generated by the same library!) since they include line numbers.

[4] https://github.com/ClusterLabs/pacemaker/tree/master/xml/upgrade06.xsl

Appendix G. init-Script LSB Compliance

The relevant part of *LSB spec*[1] includes a description of all the return codes listed here.

Assuming **`some_service`** is configured correctly and currently not active, the following sequence will help you determine if it is LSB compatible:

1. Start (stopped):

```
# /etc/init.d/some_service start ; echo "result: $?"
```

   a. Did the service start?

   b. Did the command print result: 0 (in addition to the regular output)?

2. Status (running):

```
# /etc/init.d/some_service status ; echo "result: $?"
```

   a. Did the script accept the command?

   b. Did the script indicate the service was running?

   c. Did the command print result: 0 (in addition to the regular output)?

3. Start (running):

```
# /etc/init.d/some_service start ; echo "result: $?"
```

   a. Is the service still running?

   b. Did the command print result: 0 (in addition to the regular output)?

4. Stop (running):

```
# /etc/init.d/some_service stop ; echo "result: $?"
```

   a. Was the service stopped?

   b. Did the command print result: 0 (in addition to the regular output)?

5. Status (stopped):

```
# /etc/init.d/some_service status ; echo "result: $?"
```

   a. Did the script accept the command?

   b. Did the script indicate the service was not running?

[1] http://refspecs.freestandards.org/LSB_3.1.0/LSB-Core-generic/LSB-Core-generic/iniscrptact.html

c. Did the command print result: 3 (in addition to the regular output)?

6. Stop (stopped):

```
# /etc/init.d/some_service stop ; echo "result: $?"
```

a. Is the service still stopped?

b. Did the command print result: 0 (in addition to the regular output)?

7. Status (failed):

This step is not readily testable and relies on manual inspection of the script.

The script can use one of the error codes (other than 3) listed in the LSB spec to indicate that it is active but failed. This tells the cluster that before moving the resource to another node, it needs to stop it on the existing one first.

If the answer to any of the above questions is no, then the script is not LSB compliant. Your options are then to either fix the script or write an OCF agent based on the existing script.

Appendix H. Sample Configurations

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H.1. Empty

Example H.1. An Empty Configuration

```
<cib admin_epoch="0" epoch="0" num_updates="0" have-quorum="false">
  <configuration>
    <crm_config/>
    <nodes/>
    <resources/>
    <constraints/>
  </configuration>
  <status/>
</cib>
```

H.2. Simple

Example H.2. Simple Configuration - 2 nodes, some cluster options and a resource

```
<cib admin_epoch="0" epoch="1" num_updates="0" have-quorum="false"
    validate-with="pacemaker-1.0">
  <configuration>
    <crm_config>
      <nvpair id="option-1" name="symmetric-cluster" value="true"/>
      <nvpair id="option-2" name="no-quorum-policy" value="stop"/>
    </crm_config>
    <op_defaults>
      <nvpair id="op-default-1" name="timeout" value="30s"/>
    </op_defaults>
    <rsc_defaults>
      <nvpair id="rsc-default-1" name="resource-stickiness" value="100"/>
      <nvpair id="rsc-default-2" name="migration-threshold" value="10"/>
    </rsc_defaults>
    <nodes>
      <node id="xxx" uname="c001n01" type="normal"/>
      <node id="yyy" uname="c001n02" type="normal"/>
    </nodes>
    <resources>
      <primitive id="myAddr" class="ocf" provider="heartbeat" type="IPaddr">
        <operations>
          <op id="myAddr-monitor" name="monitor" interval="300s"/>
        </operations>
        <instance_attributes>
          <nvpair name="ip" value="10.0.200.30"/>
        </instance_attributes>
      </primitive>
    </resources>
    <constraints>
      <rsc_location id="myAddr-prefer" rsc="myAddr" node="c001n01" score="INFINITY"/>
```

```
    </constraints>
  </configuration>
  <status/>
</cib>
```

In this example, we have one resource (an IP address) that we check every five minutes and will run on host **`c001n01`** until either the resource fails 10 times or the host shuts down.

H.3. Advanced Configuration

Example H.3. Advanced configuration - groups and clones with stonith

```
<cib admin_epoch="0" epoch="1" num_updates="0" have-quorum="false"
    validate-with="pacemaker-1.0">
  <configuration>
    <crm_config>
      <nvpair id="option-1" name="symmetric-cluster" value="true"/>
      <nvpair id="option-2" name="no-quorum-policy" value="stop"/>
      <nvpair id="option-3" name="stonith-enabled" value="true"/>
    </crm_config>
    <op_defaults>
      <nvpair id="op-default-1" name="timeout" value="30s"/>
    </op_defaults>
    <rsc_defaults>
      <nvpair id="rsc-default-1" name="resource-stickiness" value="100"/>
      <nvpair id="rsc-default-2" name="migration-threshold" value="10"/>
    </rsc_defaults>
    <nodes>
      <node id="xxx" uname="c001n01" type="normal"/>
      <node id="yyy" uname="c001n02" type="normal"/>
      <node id="zzz" uname="c001n03" type="normal"/>
    </nodes>
    <resources>
      <primitive id="myAddr" class="ocf" provider="heartbeat" type="IPaddr">
        <operations>
          <op id="myAddr-monitor" name="monitor" interval="300s"/>
        </operations>
        <instance_attributes>
          <nvpair name="ip" value="10.0.200.30"/>
        </instance_attributes>
      </primitive>
      <group id="myGroup">
        <primitive id="database" class="lsb" type="oracle">
          <operations>
            <op id="database-monitor" name="monitor" interval="300s"/>
          </operations>
        </primitive>
        <primitive id="webserver" class="lsb" type="apache">
          <operations>
            <op id="webserver-monitor" name="monitor" interval="300s"/>
          </operations>
        </primitive>
      </group>
      <clone id="STONITH">
        <meta_attributes id="stonith-options">
          <nvpair id="stonith-option-1" name="globally-unique" value="false"/>
        </meta_attributes>
        <primitive id="stonithclone" class="stonith" type="external/ssh">
          <operations>
            <op id="stonith-op-mon" name="monitor" interval="5s"/>
          </operations>
          <instance_attributes id="stonith-attrs">
```

```
            <nvpair id="stonith-attr-1" name="hostlist" value="c001n01,c001n02"/>
          </instance_attributes>
        </primitive>
      </clone>
    </resources>
    <constraints>
      <rsc_location id="myAddr-prefer" rsc="myAddr" node="c001n01"
        score="INFINITY"/>
      <rsc_colocation id="group-with-ip" rsc="myGroup" with-rsc="myAddr"
        score="INFINITY"/>
    </constraints>
  </configuration>
  <status/>
</cib>
```

Appendix I. Further Reading

- Project Website *http://www.clusterlabs.org/*
- Project Documentation *http://www.clusterlabs.org/wiki/Documentation*
- A comprehensive guide to cluster commands has been written by Novell[1]
- Heartbeat configuration: *http://www.linux-ha.org/*
- Corosync Configuration: *http://www.corosync.org/*

[1] *http://www.suse.com/documentation/sle_ha/book_sleha/data/book_sleha.html*

Appendix J. Revision History

Revision 1-1 **19 Oct 2009** **Andrew Beekhof** ***andrew@beekhof.net***

Import from Pages.app

Revision 2-1 **26 Oct 2009** **Andrew Beekhof** ***andrew@beekhof.net***

Cleanup and reformatting of docbook xml complete

Revision 3-1 **Tue Nov 12 2009** **Andrew Beekhof** ***andrew@beekhof.net***

Split book into chapters and pass validation
Re-organize book for use with *Publican*[1]

Revision 4-1 **Mon Oct 8 2012** **Andrew Beekhof** ***andrew@beekhof.net***

Converted to *asciidoc*[2] (which is converted to docbook for use with *Publican*[3])

[1] https://fedorahosted.org/publican/
[2] http://www.methods.co.nz/asciidoc
[3] https://fedorahosted.org/publican/

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