Pacemaker 1.1

Clusters from Scratch

Creating Active/Passive and Active/Active Clusters on Fedora

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Creating Active/Passive and Active/Active Clusters on Fedora
Edition 5

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The purpose of this document is to provide a start-to-finish guide to building an example active/passive cluster with Pacemaker and show how it can be converted to an active/active one.

The example cluster will use:

1. Fedora 17 as the host operating system

2. Corosync to provide messaging and membership services,

3. Pacemaker to perform resource management,

4. DRBD as a cost-effective alternative to shared storage,

5. GFS2 as the cluster filesystem (in active/active mode)

Given the graphical nature of the Fedora install process, a number of screenshots are included. However the guide is primarily composed of commands, the reasons for executing them and their expected outputs.

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

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1.1. The Scope of this Document

Computer clusters can be used to provide highly available services or resources. The redundancy of multiple machines is used to guard against failures of many types.

This document will walk through the installation and setup of simple clusters using the Fedora distribution, version 17.

The clusters described here will use Pacemaker and Corosync to provide resource management and messaging. Required packages and modifications to their configuration files are described along with the use of the Pacemaker command line tool for generating the XML used for cluster control.

Pacemaker is a central component and provides the resource management required in these systems. This management includes detecting and recovering from the failure of various nodes, resources and services under its control.

When more in depth information is required and for real world usage, please refer to the *Pacemaker Explained*[1] manual.

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 or Heartbeat).

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 for ensuring data integrity
- Supports large and small clusters
- Supports both quorate and resource driven clusters

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

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

1.3. Pacemaker Architecture

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

- Non-cluster aware components (illustrated in green). These pieces include the resources themselves, scripts that start, stop and monitor them, and also a local daemon that masks the differences between the different standards these scripts implement.
- Resource management Pacemaker provides the brain (illustrated in blue) that processes and reacts to events regarding the cluster. These events include nodes joining or leaving the cluster; resource events caused by failures, maintenance, scheduled activities; and other administrative actions. Pacemaker will compute the ideal state of the cluster and plot a path to achieve it after any of these events. This may include moving resources, stopping nodes and even forcing them offline with remote power switches.
- Low level infrastructure Corosync provides reliable messaging, membership and quorum information about the cluster (illustrated in red).

Figure 1.1. Conceptual Stack Overview

When combined with Corosync, Pacemaker also supports popular open source cluster filesystems. [2]

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.

[2] 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.

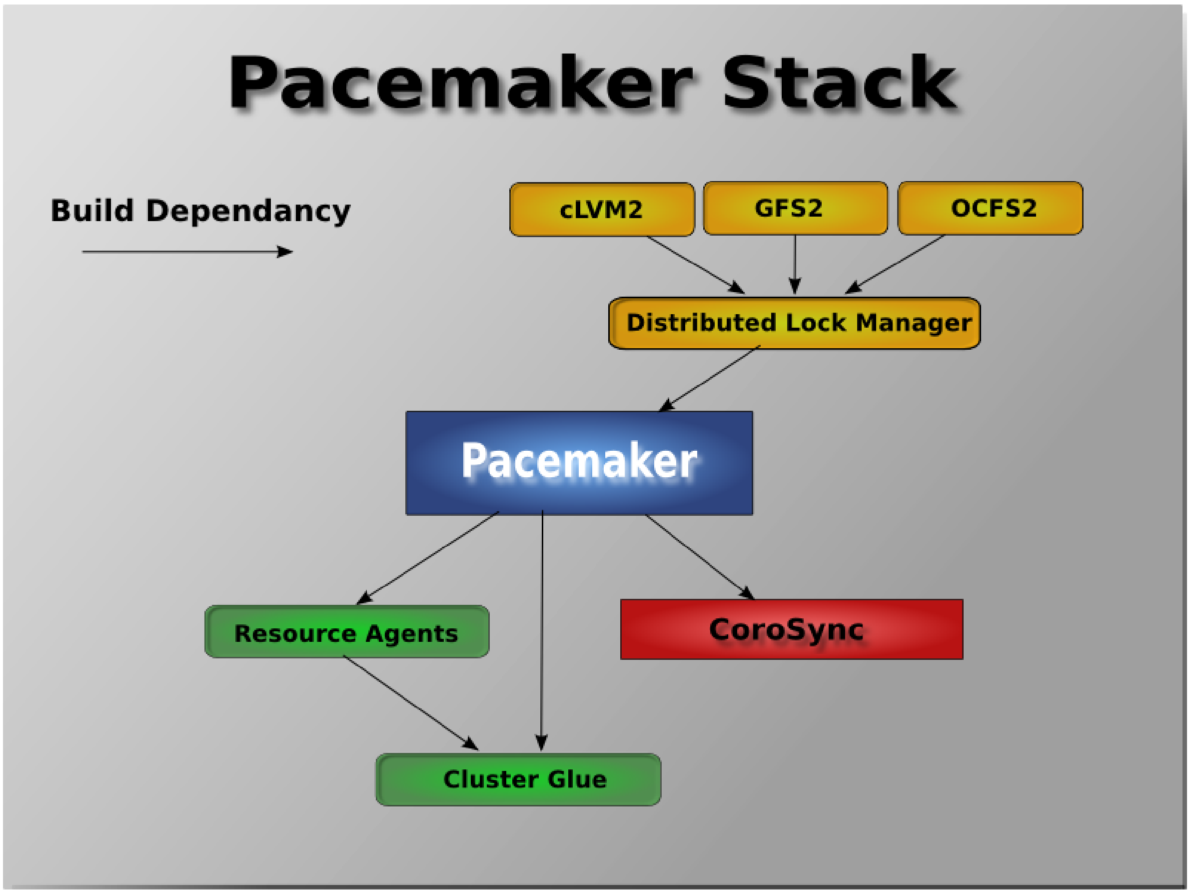

Figure 1.2. The Pacemaker Stack

1.3.1. 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

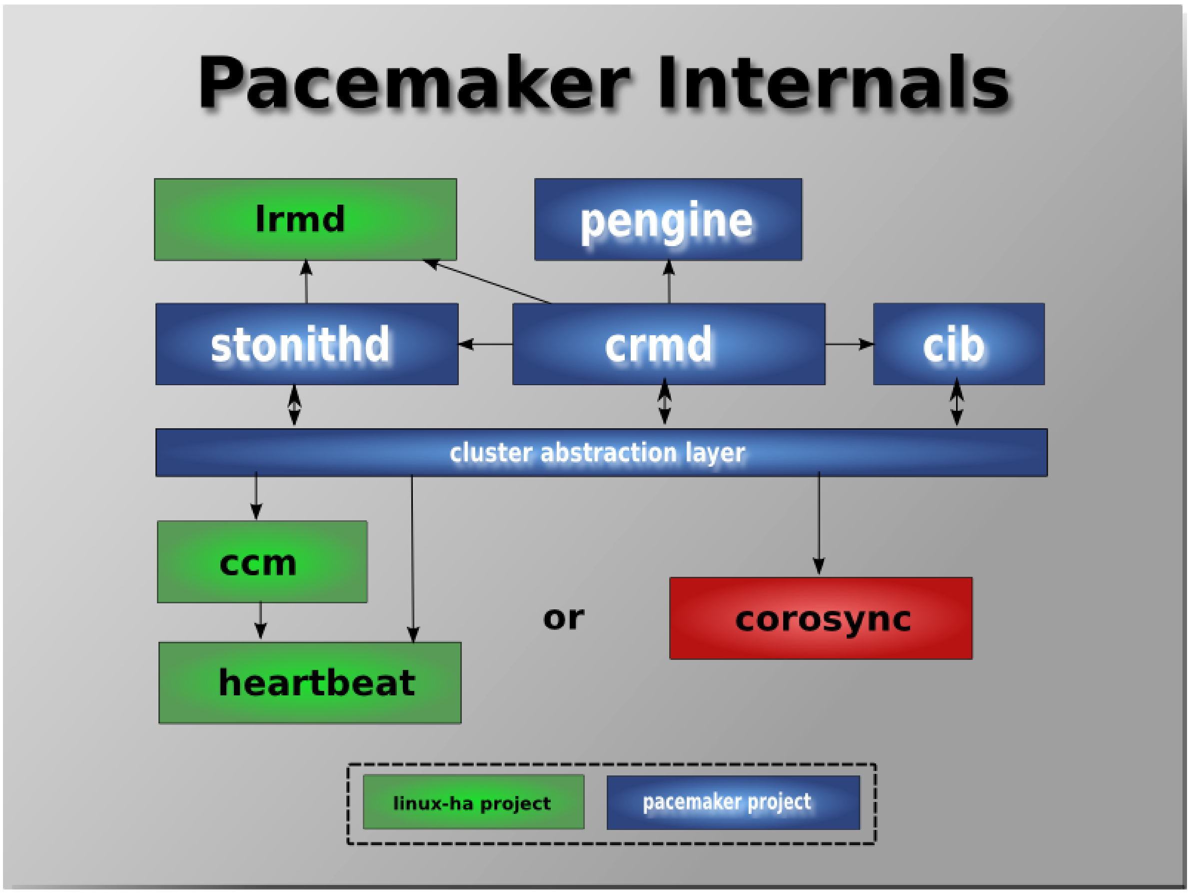

Figure 1.3. Internal Components

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 Co-ordinator). 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 the 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.

1.4. Types of Pacemaker Clusters

Pacemaker makes no assumptions about your environment, this allows it to support practically any *redundancy configuration*[3] including Active/Active, Active/Passive, N+1, N+M, N-to-1 and N-to-N.

In this document we will focus on the setup of a highly available Apache web server with an Active/Passive cluster using DRBD and Ext4 to store data. Then, we will upgrade this cluster to Active/Active using GFS2.

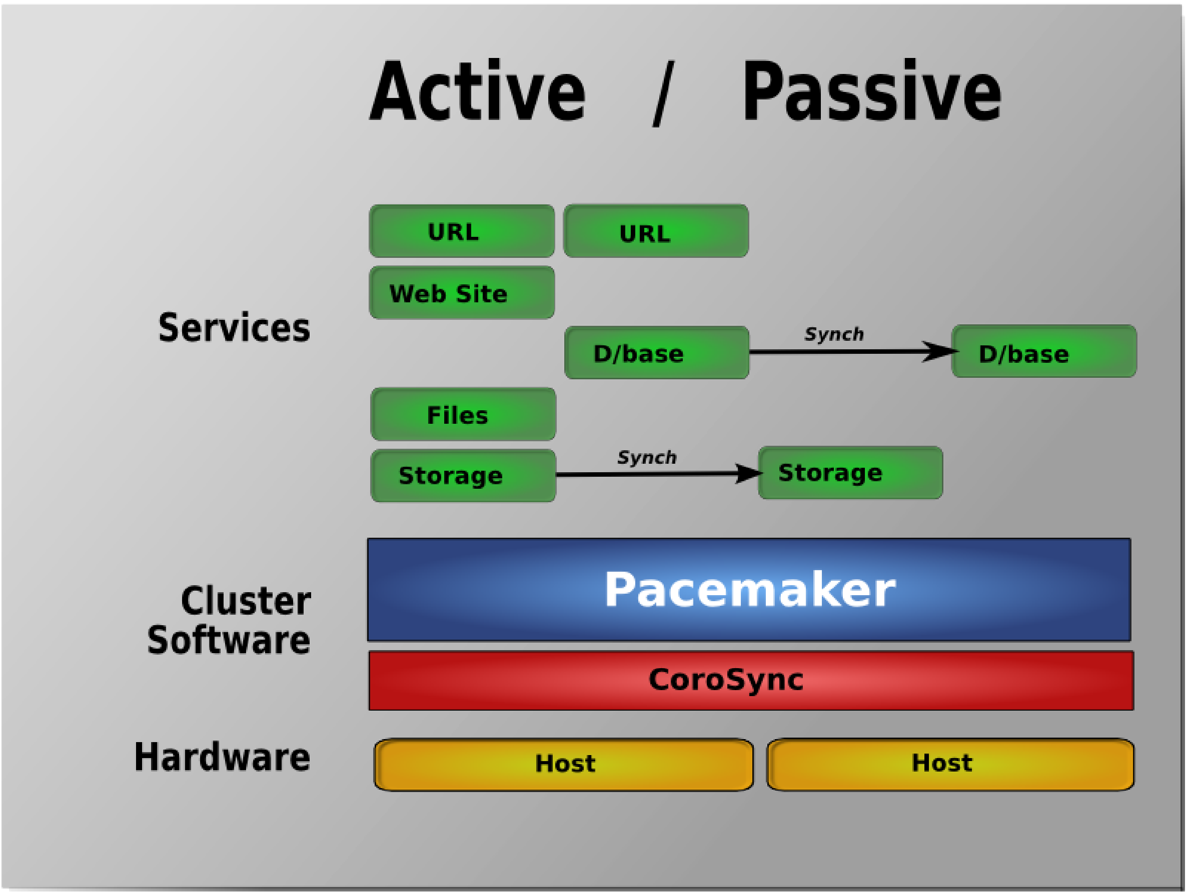

Figure 1.4. Active/Passive Redundancy

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

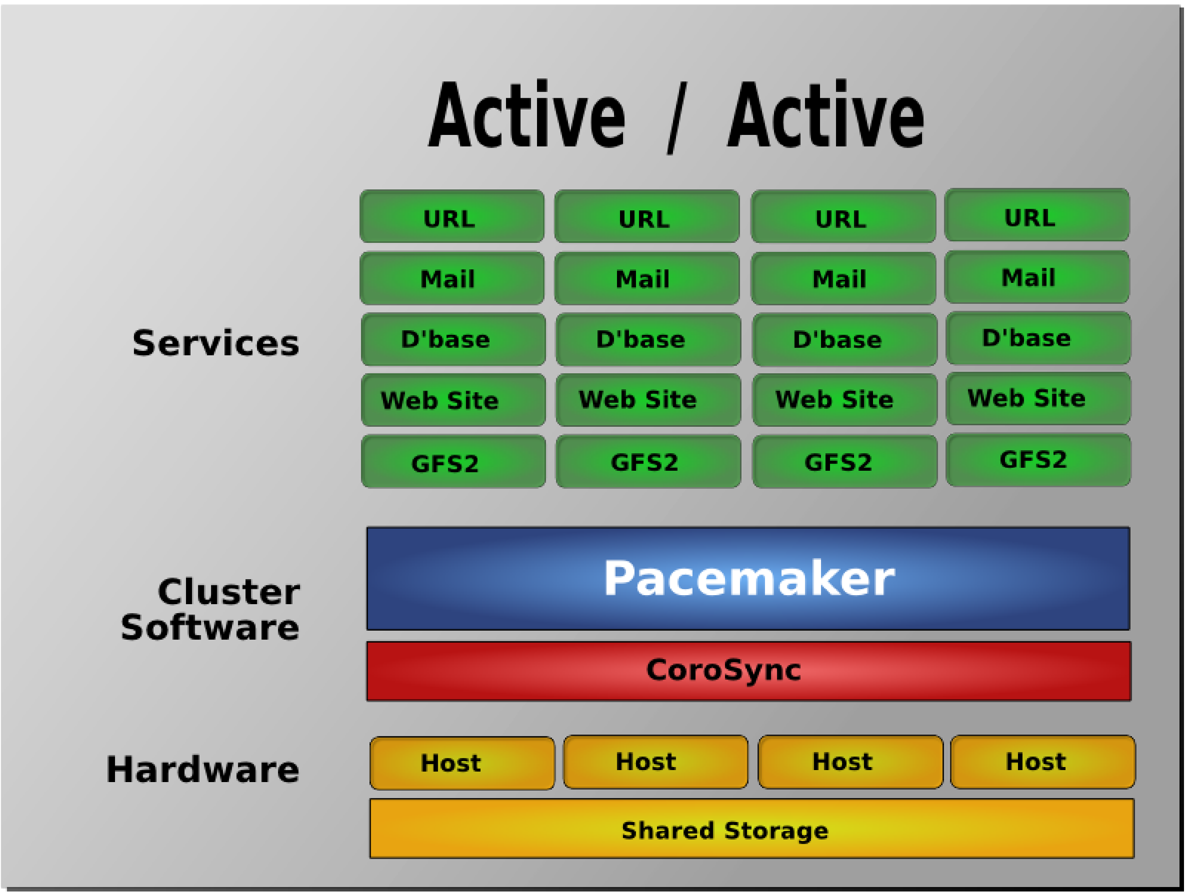

Figure 1.5. N to N Redundancy

Installation

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2.1. OS Installation

Detailed instructions for installing Fedora are available at *http://docs.fedoraproject.org/en-US/Fedora/17/html/Installation_Guide/* in a number of languages. The abbreviated version is as follows…

Point your browser to *http://fedoraproject.org/en/get-fedora-all*, locate the **`Install Media`** section and download the install DVD that matches your hardware.

Burn the disk image to a DVD [1] and boot from it, or use the image to boot a virtual machine.

After clicking through the welcome screen, select your language, keyboard layout [2] and storage type [3]

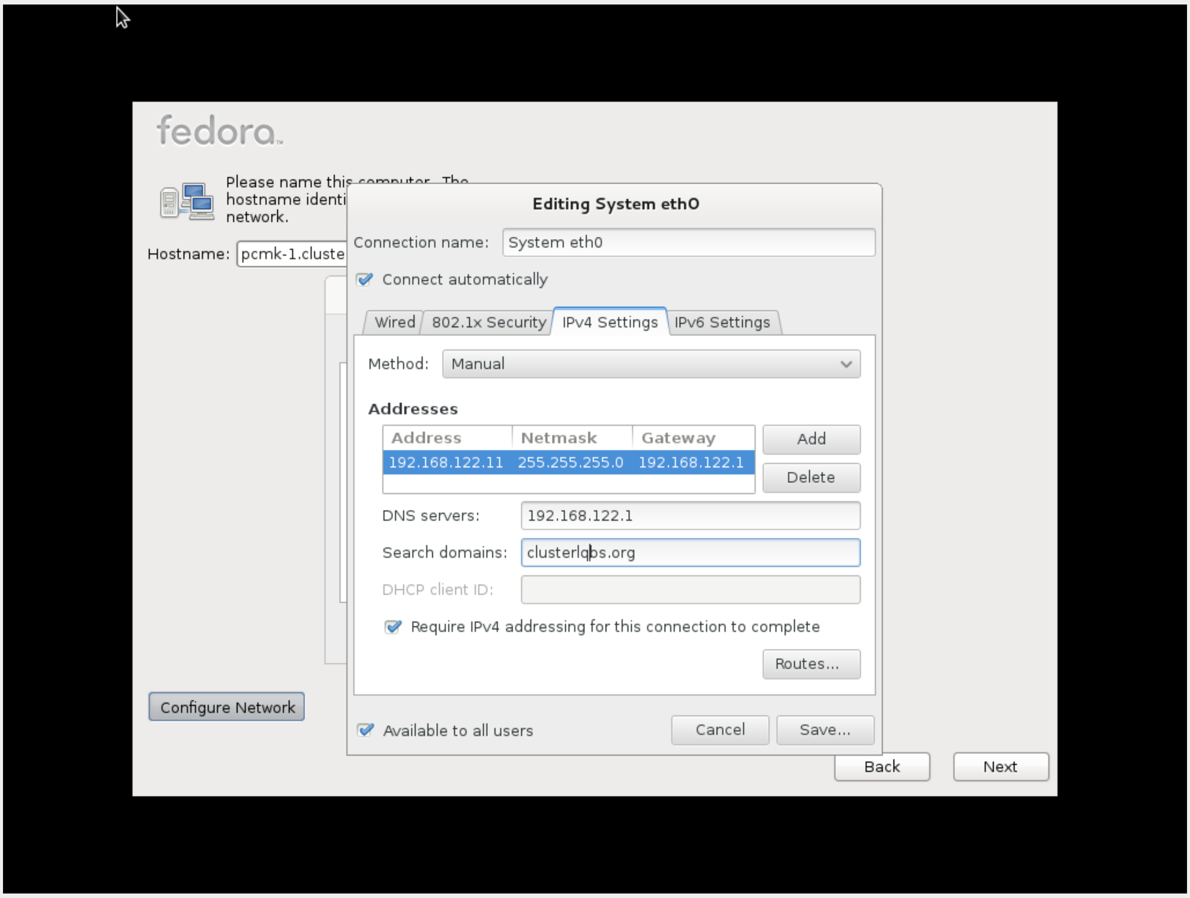
Assign your machine a host name. [4] I happen to control the clusterlabs.org domain name, so I will use that here.

[1] *http://docs.fedoraproject.org/en-US/Fedora/16/html/Burning_ISO_images_to_disc/index.html*
[2] *http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/sn-keyboard-x86.html*
[3] *http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/Storage_Devices-x86.html*
[4] *http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/sn-Netconfig-x86.html*

Important

Do not accept the default network settings. Cluster machines should never obtain an IP address via DHCP.

When you are presented with the **`Configure Network`** advanced option, select that option before continuing with the installation process to specify a fixed IPv4 address for **`System eth0`**. Be sure to also enter the **`Routes`** section and add an entry for your default gateway.



If you miss this step, this can easily be configured after installation. You will have to navigate to **`system settings`** and select **`network`**. From there you can select what device to configure.

You will then be prompted to indicate the machine's physical location [5] and to supply a root password. [6]

Now select where you want Fedora installed. [7] As I don't care about any existing data, I will accept the default and allow Fedora to use the complete drive.

5 http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/s1-timezone-x86.html
6 http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/sn-account_configuration-x86.html
7 http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/s1-diskpartsetup-x86.html

Important

By default Fedora uses LVM for partitioning which allows us to dynamically change the amount of space allocated to a given partition.

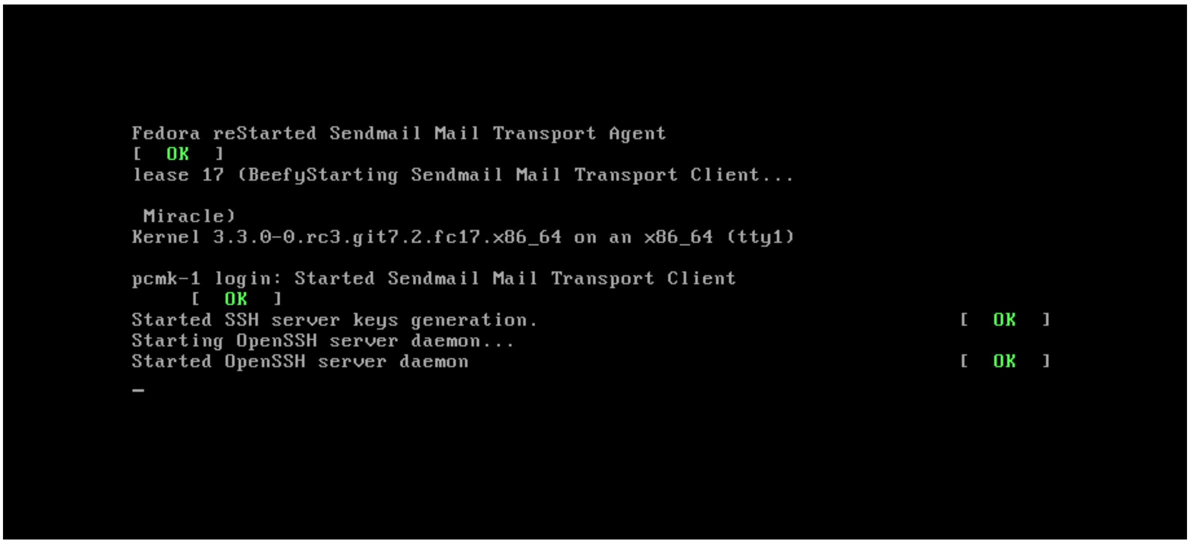
However, by default it also allocates all free space to the `/` (aka. **`root`**) partition which cannot be dynamically *reduced* in size (dynamic increases are fine by-the-way).

So if you plan on following the DRBD or GFS2 portions of this guide, you should reserve at least 1Gb of space on each machine from which to create a shared volume. To do so select the **`Review and modify partitioning layout`** checkbox before clicking **`Next`**. You will then be given an opportunity to reduce the size of the **`root`** partition.

Next choose which software should be installed. [8] Change the selection to Minimal so that we see everything that gets installed. Don't enable updates yet, we'll do that (and install any extra software we need) later. After you click next, Fedora will begin installing.

Go grab something to drink, this may take a while.

Once the node reboots, you'll see a (possibly mangled) login prompt on the console. Login using **`root`** and the password you created earlier.



Note

From here on in we're going to be working exclusively from the terminal.

[8] http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/s1-pkgselection-x86.html

2.2. Post Installation Tasks

2.2.1. Networking

Bring up the network and ensure it starts at boot

```
# service network start
# chkconfig network on
```

Check the machine has the static IP address you configured earlier

```
# ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 16436 qdisc noqueue state UNKNOWN
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP qlen 1000
    link/ether 52:54:00:d7:d6:08 brd ff:ff:ff:ff:ff:ff
    inet 192.168.122.101/24 brd 192.168.122.255 scope global eth0
    inet6 fe80::5054:ff:fed7:d608/64 scope link
       valid_lft forever preferred_lft forever
```

Now check the default route setting:

```
[root@pcmk-1 ~]# ip route
default via 192.168.122.1 dev eth0
192.168.122.0/24 dev eth0  proto kernel  scope link  src 192.168.122.101
```

If there is no line beginning with **`default via`**, then you may need to add a line such as

```
GATEWAY=192.168.122.1
```

to */etc/sysconfig/network* and restart the network.

Now check for connectivity to the outside world. Start small by testing if we can read the gateway we configured.

```
# ping -c 1 192.168.122.1
PING 192.168.122.1 (192.168.122.1) 56(84) bytes of data.
64 bytes from 192.168.122.1: icmp_req=1 ttl=64 time=0.249 ms

--- 192.168.122.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.249/0.249/0.249/0.000 ms
```

Now try something external, choose a location you know will be available.

```
# ping -c 1 www.google.com
PING www.l.google.com (173.194.72.106) 56(84) bytes of data.
64 bytes from tf-in-f106.1e100.net (173.194.72.106): icmp_req=1 ttl=41 time=167 ms

--- www.l.google.com ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 167.618/167.618/167.618/0.000 ms
```

2.2.2. Leaving the Console

The console isn't a very friendly place to work from, we will now switch to accessing the machine remotely via SSH where we can use copy&paste etc.

First we check we can see the newly installed at all:

```
beekhof@f16 ~ # ping -c 1 192.168.122.101
PING 192.168.122.101 (192.168.122.101) 56(84) bytes of data.
64 bytes from 192.168.122.101: icmp_req=1 ttl=64 time=1.01 ms

--- 192.168.122.101 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 1.012/1.012/1.012/0.000 ms
```

Next we login via SSH

```
beekhof@f16 ~ # ssh -l root 192.168.122.11
root@192.168.122.11's password:
Last login: Fri Mar 30 19:41:19 2012 from 192.168.122.1
[root@pcmk-1 ~]#
```

2.2.3. Security Shortcuts

To simplify this guide and focus on the aspects directly connected to clustering, we will now disable the machine's firewall and SELinux installation.

Warning

Both of these actions create significant security issues and should not be performed on machines that will be exposed to the outside world.

Important

```
TODO: Create an Appendix that deals with (at least) re-enabling the firewall.
```

```
# setenforce 0
# sed -i.bak "s/SELINUX=enforcing/SELINUX=permissive/g" /etc/selinux/config
# systemctl disable iptables.service
# rm '/etc/systemd/system/basic.target.wants/iptables.service'
# systemctl stop iptables.service
```

2.2.4. Short Node Names

During installation, we filled in the machine's fully qualifier domain name (FQDN) which can be rather long when it appears in cluster logs and status output. See for yourself how the machine identifies itself:

```
# uname -n
```

```
pcmk-1.clusterlabs.org
# dnsdomainname
clusterlabs.org
```

The output from the second command is fine, but we really don't need the domain name included in the basic host details. To address this, we need to update /etc/sysconfig/network. This is what it should look like before we start.

```
# cat /etc/sysconfig/network
NETWORKING=yes
HOSTNAME=pcmk-1.clusterlabs.org
GATEWAY=192.168.122.1
```

All we need to do now is strip off the domain name portion, which is stored elsewhere anyway.

```
 # sed -i.sed 's/\.[a-z].*//g' /etc/sysconfig/network
```

Now confirm the change was successful. The revised file contents should look something like this.

```
# cat /etc/sysconfig/network
NETWORKING=yes
HOSTNAME=pcmk-1
GATEWAY=192.168.122.1
```

However we're not finished. The machine wont normally see the shortened host name until about it reboots, but we can force it to update.

```
# source /etc/sysconfig/network
# hostname $HOSTNAME
```

Now check the machine is using the correct names

```
# uname -n
pcmk-1
# dnsdomainname
clusterlabs.org
```

2.2.5. NTP

It is highly recommended to enable NTP on your cluster nodes. Doing so ensures all nodes agree on the current time and makes reading log files significantly easier. [9]

2.3. Before You Continue

Repeat the Installation steps so far, so that you have two Fedora nodes ready to have the cluster software installed.

For the purposes of this document, the additional node is called pcmk-2 with address 192.168.122.102.

[9] *http://docs.fedoraproject.org/en-US/Fedora/17/html-single/System_Administrators_Guide/index.html#ch-Configuring_the_Date_and_Time*

2.3.1. Finalize Networking

Confirm that you can communicate between the two new nodes:

```
# ping -c 3 192.168.122.102
PING 192.168.122.102 (192.168.122.102) 56(84) bytes of data.
64 bytes from 192.168.122.102: icmp_seq=1 ttl=64 time=0.343 ms
64 bytes from 192.168.122.102: icmp_seq=2 ttl=64 time=0.402 ms
64 bytes from 192.168.122.102: icmp_seq=3 ttl=64 time=0.558 ms

--- 192.168.122.102 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 0.343/0.434/0.558/0.092 ms
```

Now we need to make sure we can communicate with the machines by their name. If you have a DNS server, add additional entries for the two machines. Otherwise, you'll need to add the machines to */etc/hosts* . Below are the entries for my cluster nodes:

```
# grep pcmk /etc/hosts
192.168.122.101 pcmk-1.clusterlabs.org pcmk-1
192.168.122.102 pcmk-2.clusterlabs.org pcmk-2
```

We can now verify the setup by again using ping:

```
# ping -c 3 pcmk-2
PING pcmk-2.clusterlabs.org (192.168.122.101) 56(84) bytes of data.
64 bytes from pcmk-1.clusterlabs.org (192.168.122.101): icmp_seq=1 ttl=64 time=0.164 ms
64 bytes from pcmk-1.clusterlabs.org (192.168.122.101): icmp_seq=2 ttl=64 time=0.475 ms
64 bytes from pcmk-1.clusterlabs.org (192.168.122.101): icmp_seq=3 ttl=64 time=0.186 ms

--- pcmk-2.clusterlabs.org ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2001ms
rtt min/avg/max/mdev = 0.164/0.275/0.475/0.141 ms
```

2.3.2. Configure SSH

SSH is a convenient and secure way to copy files and perform commands remotely. For the purposes of this guide, we will create a key without a password (using the -N option) so that we can perform remote actions without being prompted.

Warning

Unprotected SSH keys, those without a password, are not recommended for servers exposed to the outside world. We use them here only to simplify the demo.

Create a new key and allow anyone with that key to log in:

Creating and Activating a new SSH Key

```
# ssh-keygen -t dsa -f ~/.ssh/id_dsa -N ""
```

```
Generating public/private dsa key pair.
Your identification has been saved in /root/.ssh/id_dsa.
Your public key has been saved in /root/.ssh/id_dsa.pub.
The key fingerprint is:
91:09:5c:82:5a:6a:50:08:4e:b2:0c:62:de:cc:74:44 root@pcmk-1.clusterlabs.org

The key's randomart image is:
+--[ DSA 1024]----+
|==.ooEo..        |
|X O + .o o       |
| * A    +        |
|  +      .       |
| .      S        |
|                 |
|                 |
|                 |
|                 |
+-----------------+

# cp .ssh/id_dsa.pub .ssh/authorized_keys
```

Install the key on the other nodes and test that you can now run commands remotely, without being prompted

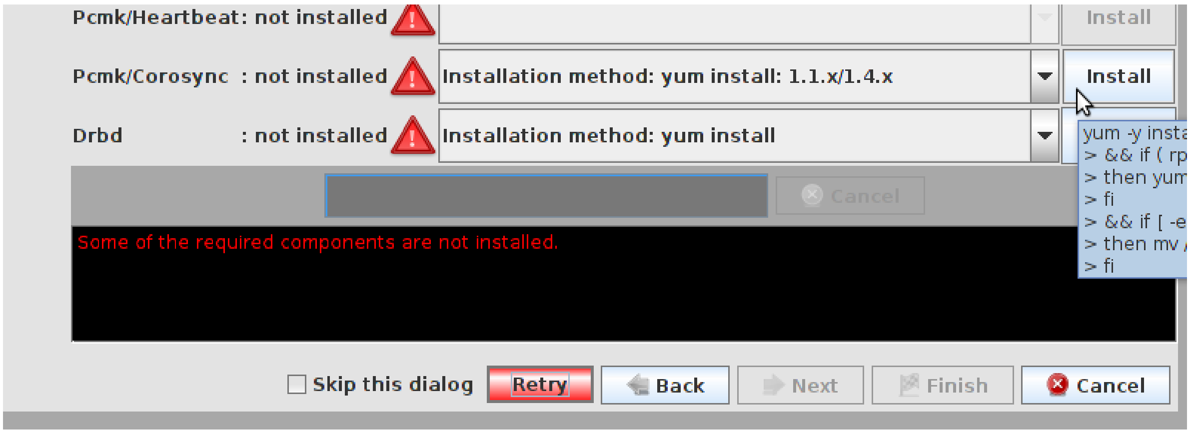
Installing the SSH Key on Another Host

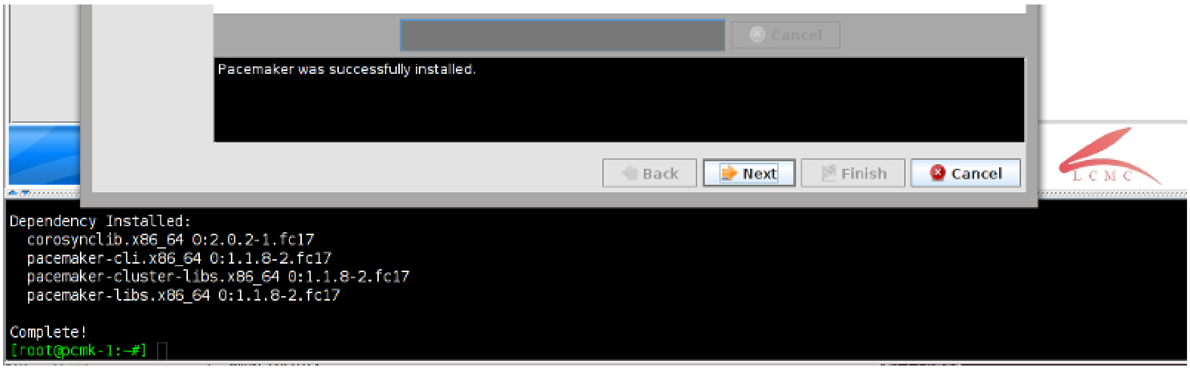
```
# scp -r .ssh pcmk-2:
The authenticity of host 'pcmk-2 (192.168.122.102)' can't be established.
RSA key fingerprint is b1:2b:55:93:f1:d9:52:2b:0f:f2:8a:4e:ae:c6:7c:9a.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'pcmk-2,192.168.122.102' (RSA) to the list of known
 hosts.root@pcmk-2's password:
id_dsa.pub                                  100%  616     0.6KB/s   00:00
id_dsa                                      100%  672     0.7KB/s   00:00
known_hosts                                 100%  400     0.4KB/s   00:00
authorized_keys                             100%  616     0.6KB/s   00:00
# ssh pcmk-2 -- uname -n
pcmk-2
#
```

2.4. Cluster Software Installation

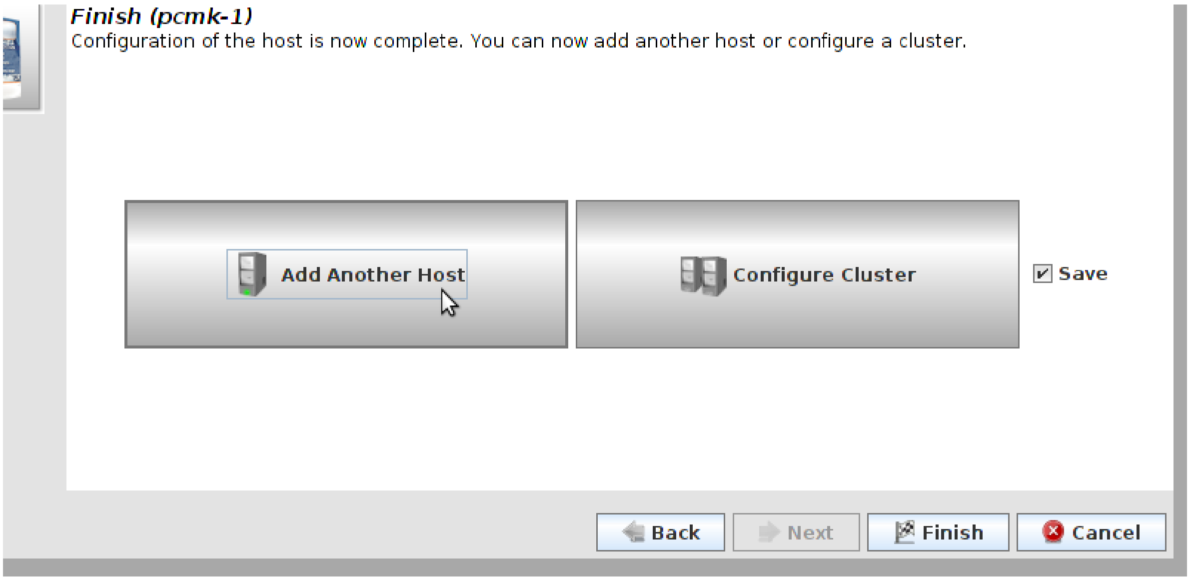
2.4.1. Install the Cluster Software

Since version 12, Fedora comes with recent versions of everything you need, so simply fire up the GUI and run:





Now install the cluster software on the second node.



2.5. Setup

2.5.1. Preparation - Multicast

Choose a port number and *multi-cast*[10] address. *http://en.wikipedia.org/wiki/Multicast_address*

[10] http://en.wikipedia.org/wiki/Multicast

Be sure that the values you chose do not conflict with any existing clusters you might have. For this document, I have chosen port *4000* and used *239.255.1.1* as the multi-cast address.

2.5.2. Notes on Multicast Address Assignment

There are several subtle points that often deserve consideration when choosing/assigning multicast addresses. [11]

1. Avoid *224.0.0.x*

   Traffic to addresses of the form *224.0.0.x* is often flooded to all switch ports. This address range is reserved for link-local uses. Many routing protocols assume that all traffic within this range will be received by all routers on the network. Hence (at least all Cisco) switches flood traffic within this range. The flooding behavior overrides the normal selective forwarding behavior of a multicast-aware switch (e.g. IGMP snooping, CGMP, etc.).

2. Watch for *32:1* overlap

   32 non-contiguous IP multicast addresses are mapped onto each Ethernet multicast address. A receiver that joins a single IP multicast group implicitly joins 31 others due to this overlap. Of course, filtering in the operating system discards undesired multicast traffic from applications, but NIC bandwidth and CPU resources are nonetheless consumed discarding it. The overlap occurs in the 5 high-order bits, so it's best to use the 23 low-order bits to make distinct multicast streams unique. For example, IP multicast addresses in the range *239.0.0.0* to *239.127.255.255* all map to unique Ethernet multicast addresses. However, IP multicast address *239.128.0.0* maps to the same Ethernet multicast address as *239.0.0.0*, *239.128.0.1* maps to the same Ethernet multicast address as *239.0.0.1*, etc.

3. Avoid *x.0.0.y* and *x.128.0.y*

   Combining the above two considerations, it's best to avoid using IP multicast addresses of the form *x.0.0.y* and *x.128.0.y* since they all map onto the range of Ethernet multicast addresses that are flooded to all switch ports.

4. Watch for address assignment conflicts

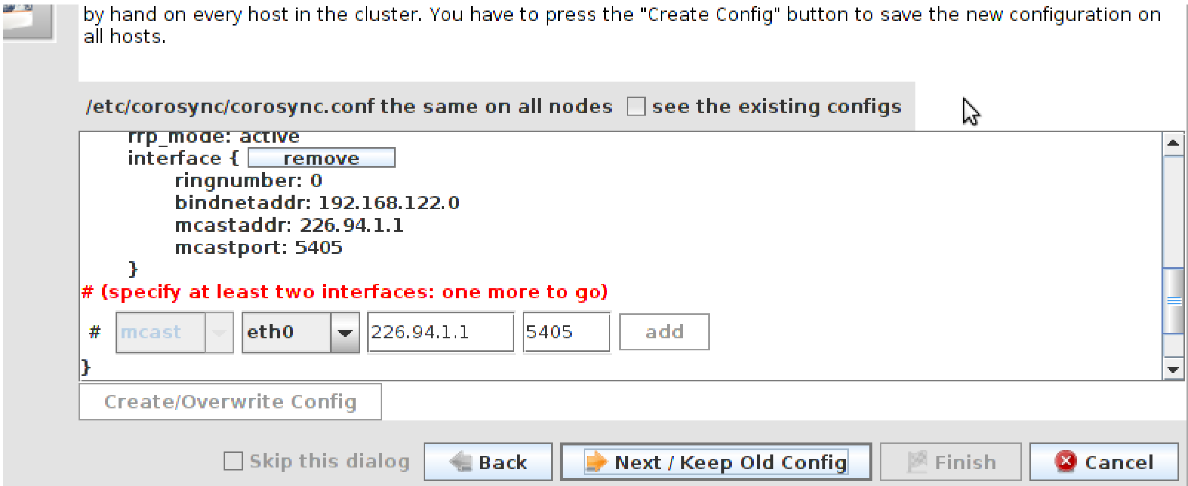
   IANA[12] administers *Internet multicast addresses*[13]. Potential conflicts with Internet multicast address assignments can be avoided by using *GLOP addressing*[14] (*AS*[15] required) or *administratively scoped*[16] addresses. Such addresses can be safely used on a network connected to the Internet without fear of conflict with multicast sources originating on the Internet. Administratively scoped addresses are roughly analogous to the unicast address space for *private internets*[17]. Site-local multicast addresses are of the form *239.255.x.y*, but can grow down to *239.252.x.y* if needed. Organization-local multicast addresses are of the form *239.192-251.x.y*, but can grow down to *239.x.y.z* if needed.

[11] This information is borrowed from, the now defunct, *http://web.archive.org/web/20101211210054/http://29west.com/docs/THPM/multicast-address-assignment.html*
[12] http://www.iana.org/
[13] http://www.iana.org/assignments/multicast-addresses
[14] http://www.ietf.org/rfc/rfc3180.txt
[15] http://en.wikipedia.org/wiki/Autonomous_system_%28Internet%29
[16] http://www.ietf.org/rfc/rfc2365.txt
[17] http://www.ietf.org/rfc/rfc1918.txt

For a more detailed treatment (57 pages!), see *Cisco's Guidelines for Enterprise IP Multicast Address Allocation*[18] paper.

2.5.3. Configuring Corosync

In the past, at this point in the tutorial an explanation of how to configure and propagate corosync's /etc/corosync.conf file would be necessary. Using LCMC greatly simplifies this process by generating *corosync.conf* across all the nodes in the cluster with a single click.



The final /etc/corosync.conf configuration on each node should look something like the sample in Appendix B, Sample Corosync Configuration.

Important

Pacemaker used to obtain membership and quorum from a custom Corosync plugin. This plugin also had the capability to start Pacemaker automatically when Corosync was started.

Neither behavior is possible with Corosync 2.0 and beyond as support for plugins was removed.

Instead, Pacemaker must be started as a separate job/initscript. Also, since Pacemaker made use of the plugin for message routing, a node using the plugin (Corosync prior to 2.0) cannot talk to one that isn't (Corosync 2.0+).

Rolling upgrades between these versions are therefor not possible and an alternate strategy [19] must be used.

[18] http://www.cisco.com/en/US/tech/tk828/technologies_white_paper09186a00802d4643.shtml
[19] *http://www.clusterlabs.org/doc/en-US/Pacemaker/1.1/html/Pacemaker_Explained/ap-upgrade.html*

Pacemaker Tools

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3.1. Using Pacemaker Tools

In the dark past, configuring Pacemaker required the administrator to read and write XML. In true UNIX style, there were also a number of different commands that specialized in different aspects of querying and updating the cluster.

All of that has been greatly simplified with the creation of unified command-line shells (and GUIs) that hide all the messy XML scaffolding.

These shells take all the individual aspects required for managing and configuring a cluster, and packs them into one simple to use command line tool.

They even allow you to queue up several changes at once and commit them atomically.

There are currently two command-line shells that people use, **`pcs`** and **`crmsh`**. This edition of Clusters from Scratch is based on **`lcmc`**. Start by taking some time to familiarize yourself with what it can do.

Note

Although **`lcmc`** has the ability to manage all aspects of the cluster (both corosync and pacemaker), it does not require any specific cluster stack to be in use.

```
# lcmc
```

Verify Cluster Installation

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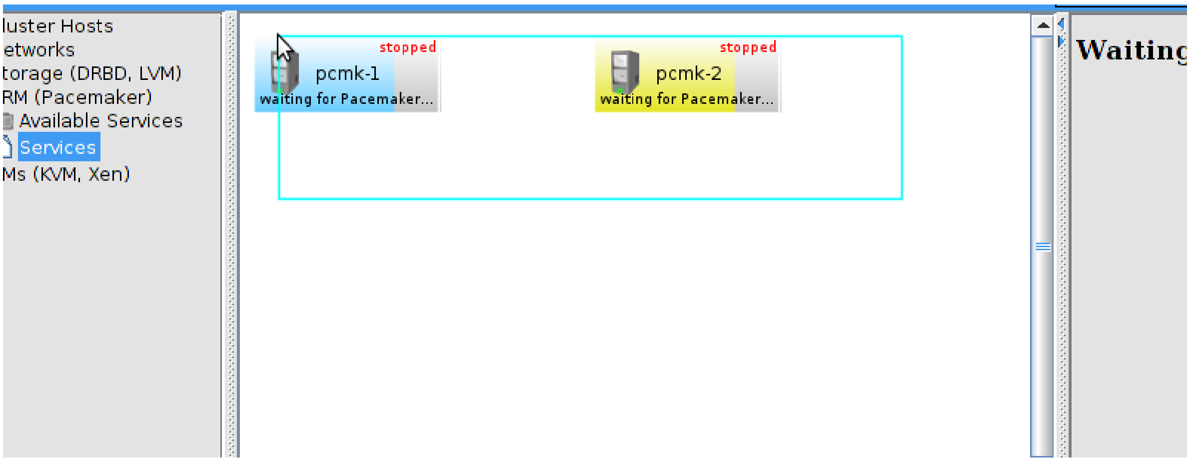
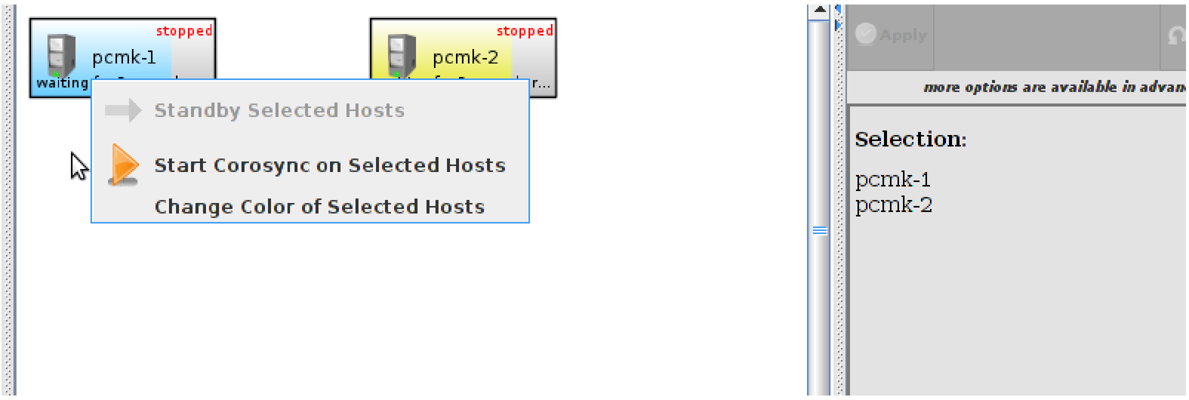
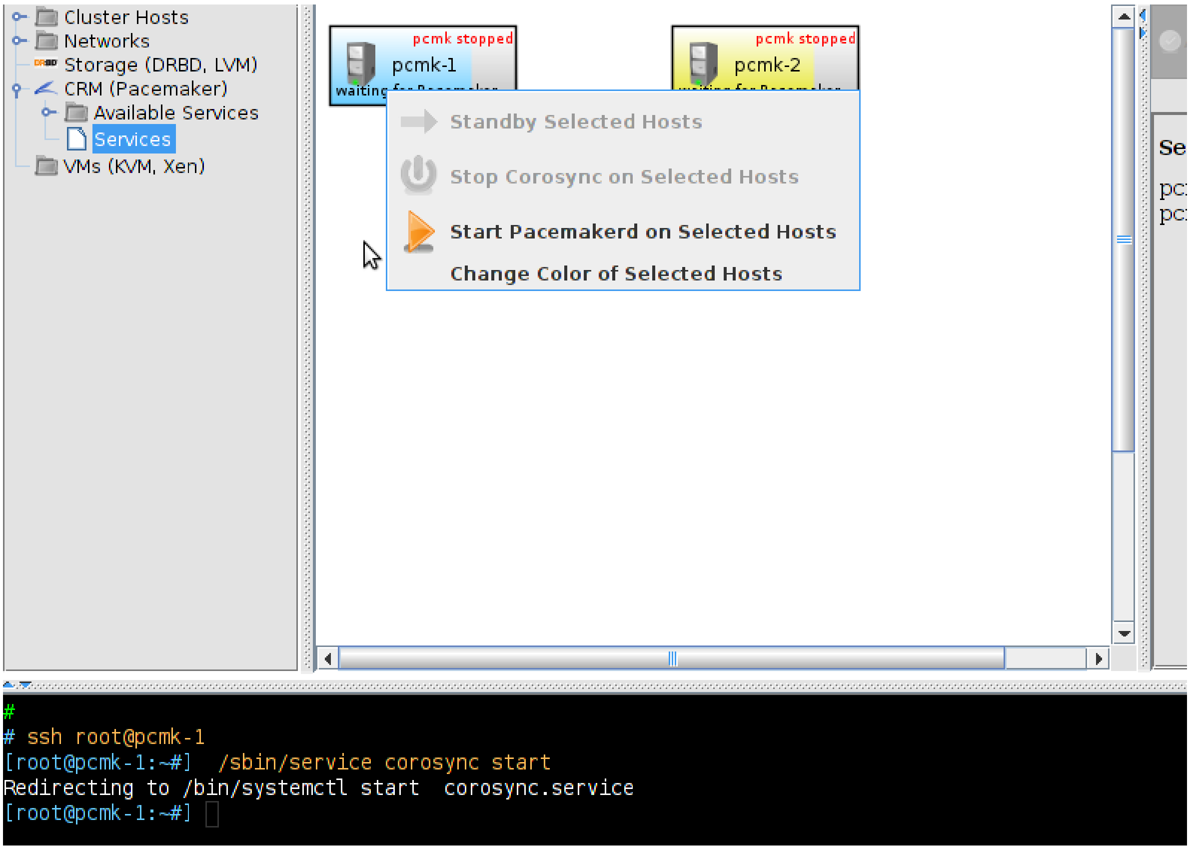
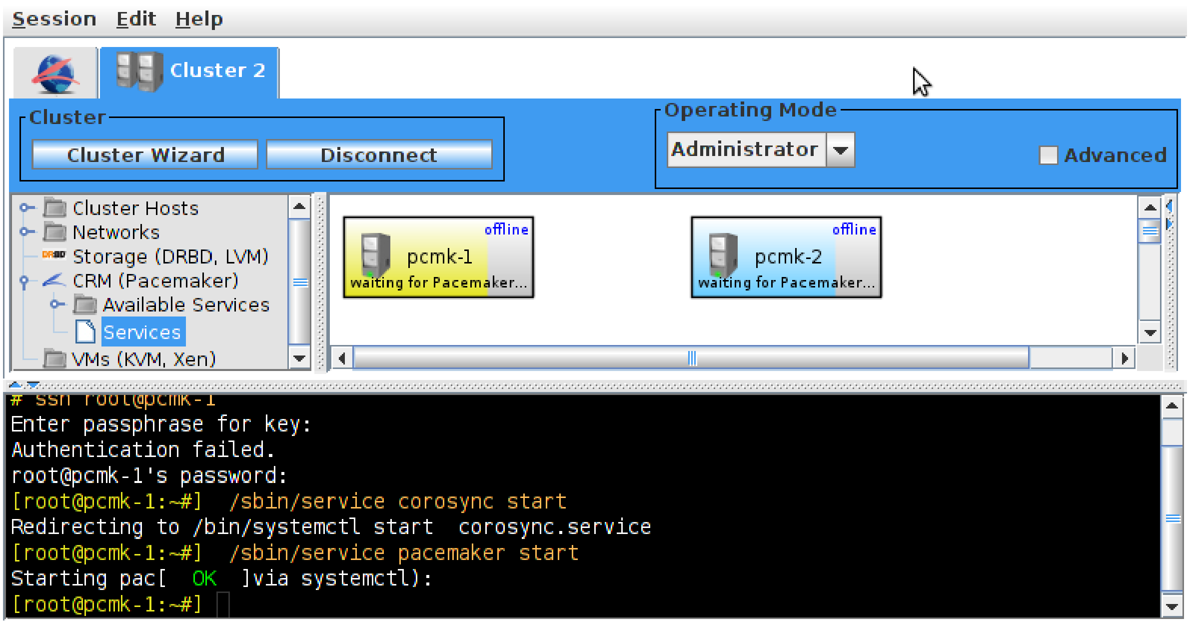
4.1. Start the Cluster

Now that corosync is configured, it is time to start the cluster. The menu items below will start corosync and pacemaker on both nodes in the cluster.



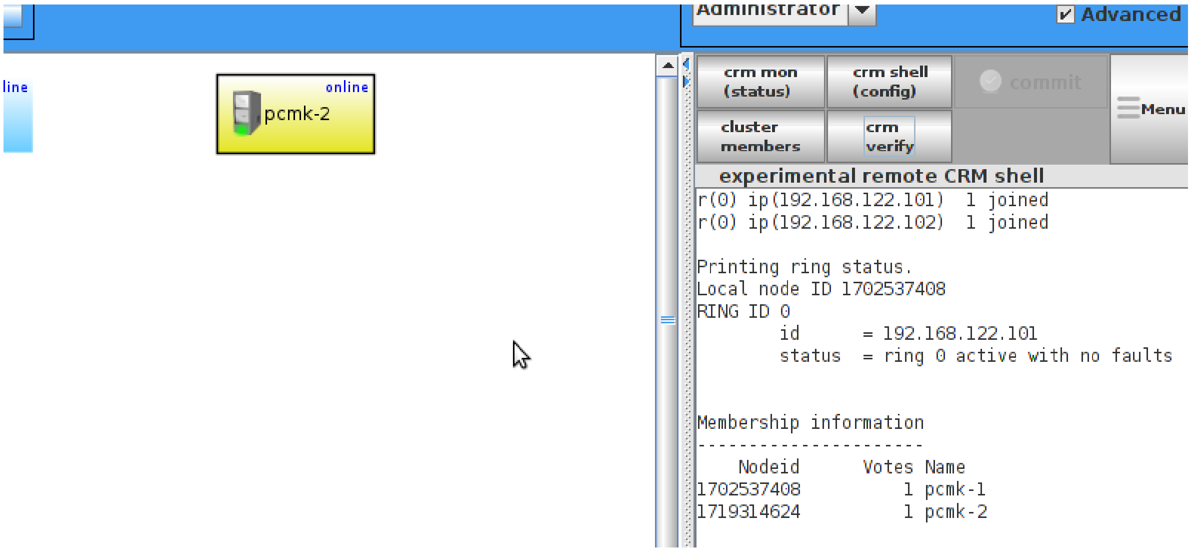






4.2. Verify Corosync Installation

The first thing to check is if cluster communication is happy, for that we use **`corosync-cfgtool`**.



We can see here that everything appears normal with our fixed IP address, not a 127.0.0.x loopback address, listed as the **`id`** and **`no faults`** for the status.

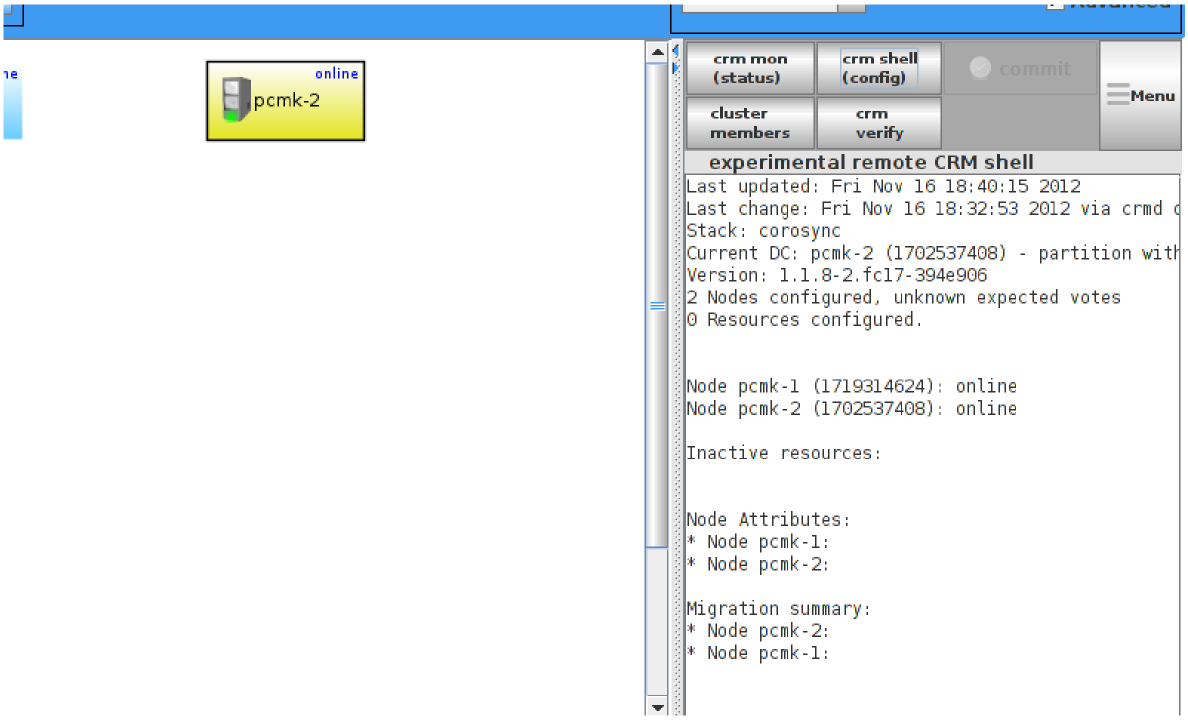
If you see something different, you might want to start by checking the node's network, firewall and selinux configurations.

Next we check the membership and quorum APIs:

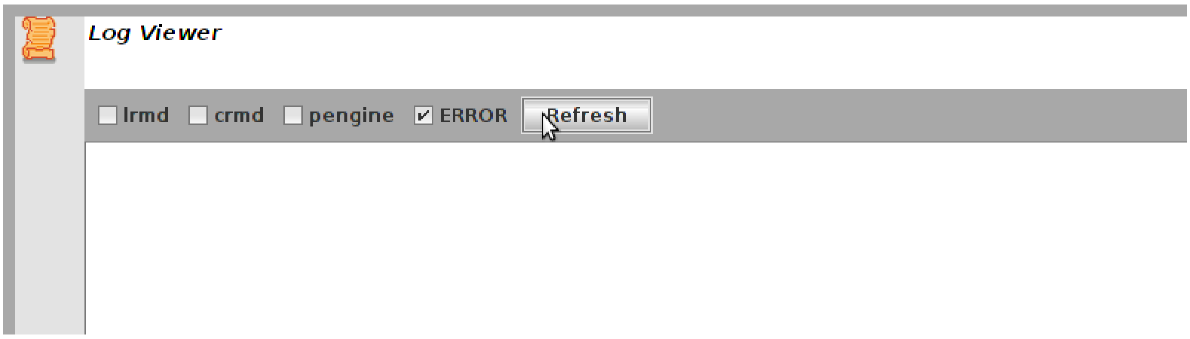
All good!

4.3. Verify Pacemaker Installation

Check the logs and crm_mon.



Next, check for any ERRORs during startup - there shouldn't be any.


Log Viewer
lrmd
crmd
pengine
ERROR
Refresh

Creating an Active/Passive Cluster

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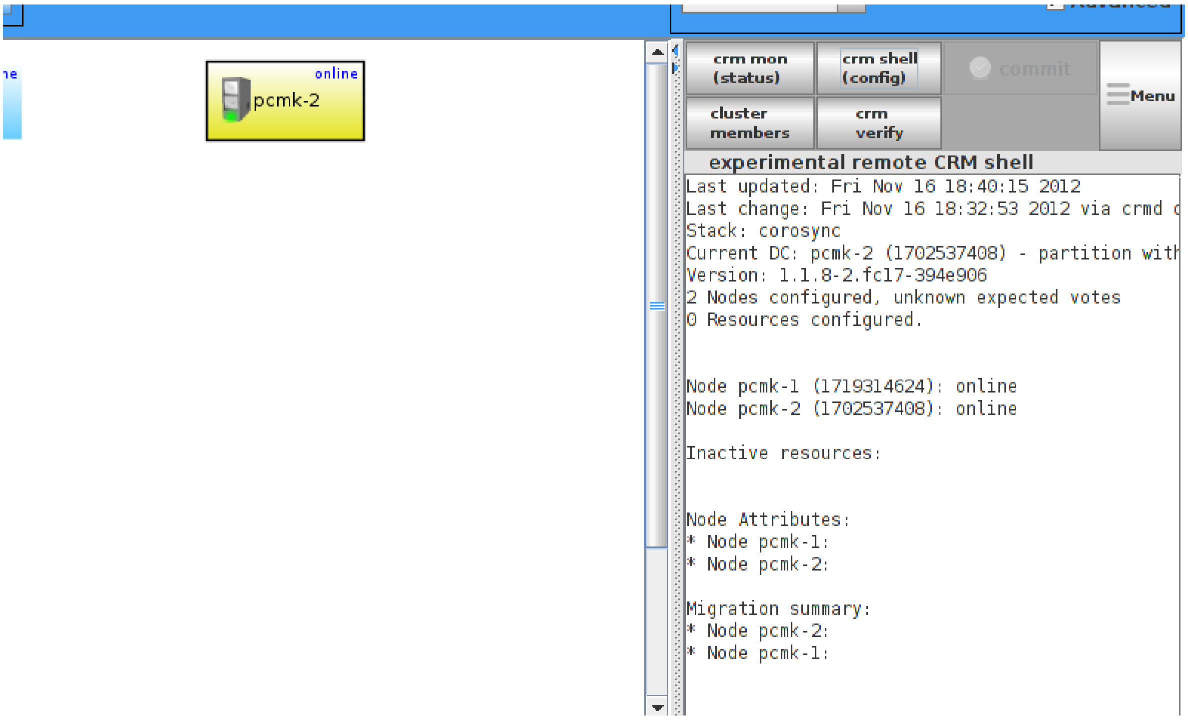
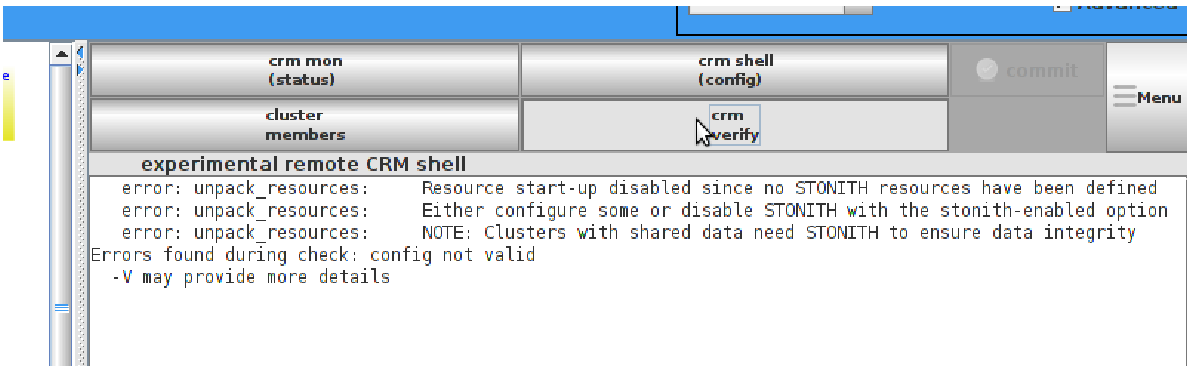
5.1. Exploring the Existing Configuration

When Pacemaker starts up, it automatically records the number and details of the nodes in the cluster as well as which stack is being used and the version of Pacemaker being used.

This is what the base configuration should look like.



Before we make any changes, its a good idea to check the validity of the configuration.

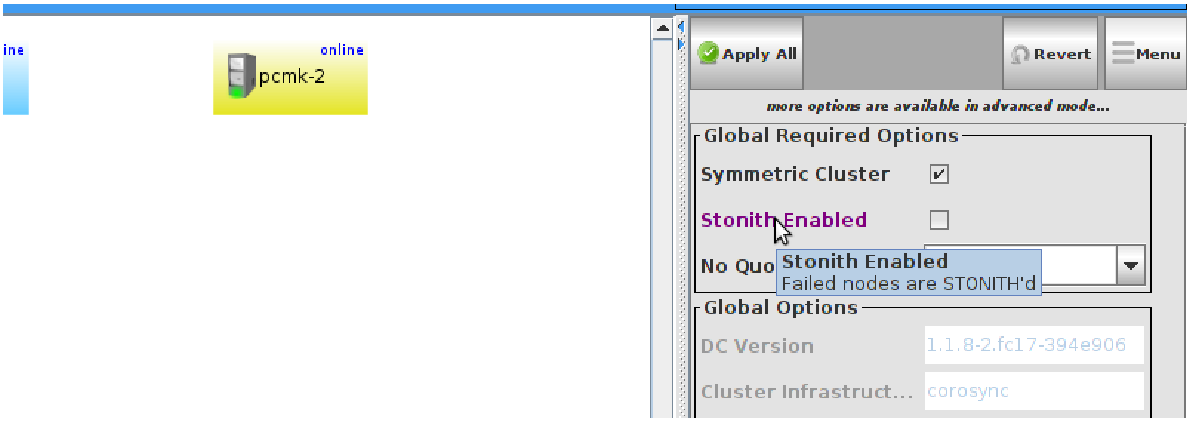


As you can see, the tool has found some errors.

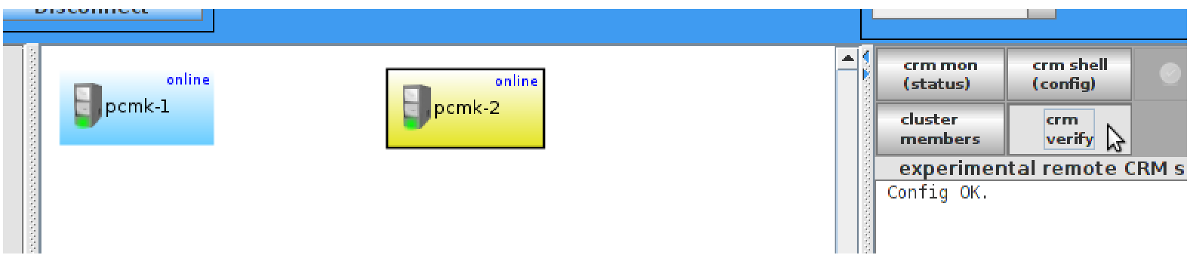
In order to guarantee the safety of your data [1] , the default for STONITH [2] in Pacemaker is **`enabled`**. However it also knows when no STONITH configuration has been supplied and reports this as a problem (since the cluster would not be able to make progress if a situation requiring node fencing arose).

For now, we will disable this feature and configure it later in the Configuring STONITH section. It is important to note that the use of STONITH is highly encouraged, turning it off tells the cluster to simply pretend that failed nodes are safely powered off. Some vendors will even refuse to support clusters that have it disabled.

To disable STONITH, we set the *stonith-enabled* cluster option to false.



With the new cluster option set, the configuration is now valid.



Warning

The use of stonith-enabled=false is completely inappropriate for a production cluster. We use it here to defer the discussion of its configuration which can differ widely from one installation to the next. See *Section 9.1, “What Is STONITH”* for information on why STONITH is important and details on how to configure it.

5.2. Adding a Resource

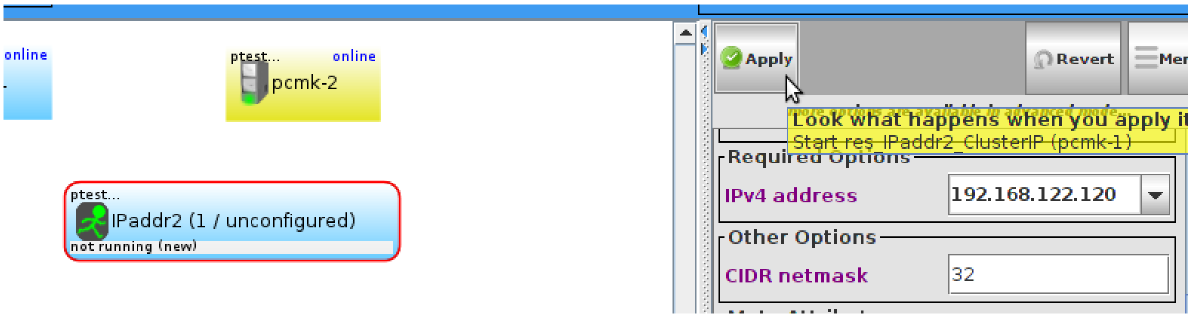
The first thing we should do is configure an IP address. Regardless of where the cluster service(s) are running, we need a consistent address to contact them on. Here I will choose and add 192.168.122.120 as the floating address, give it the imaginative name ClusterIP and tell the cluster to check that its running every 30 seconds.

[1] If the data is corrupt, there is little point in continuing to make it available

[2] A common node fencing mechanism. Used to ensure data integrity by powering off "bad" nodes

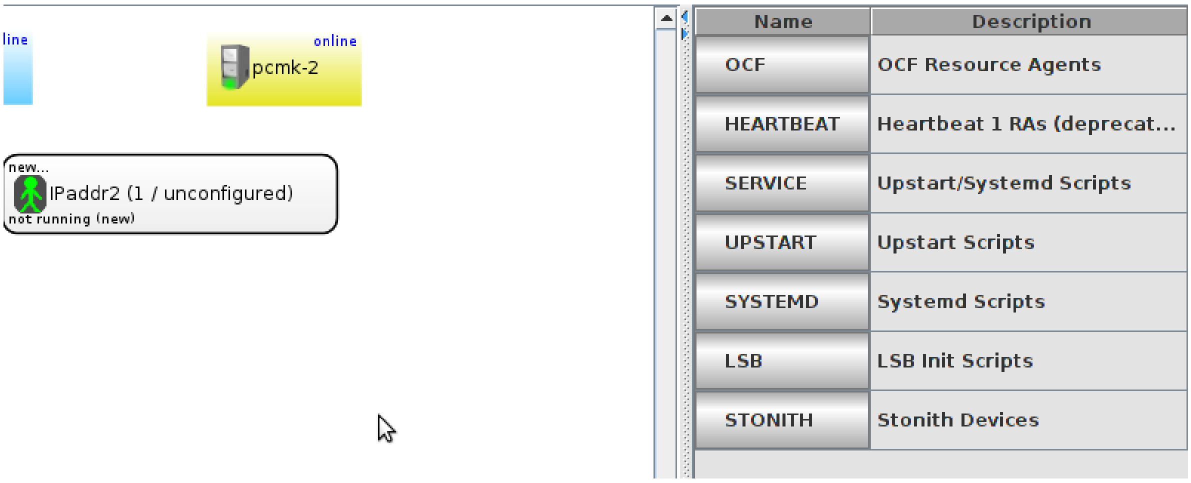
Important

The chosen address must not be one already associated with a physical node

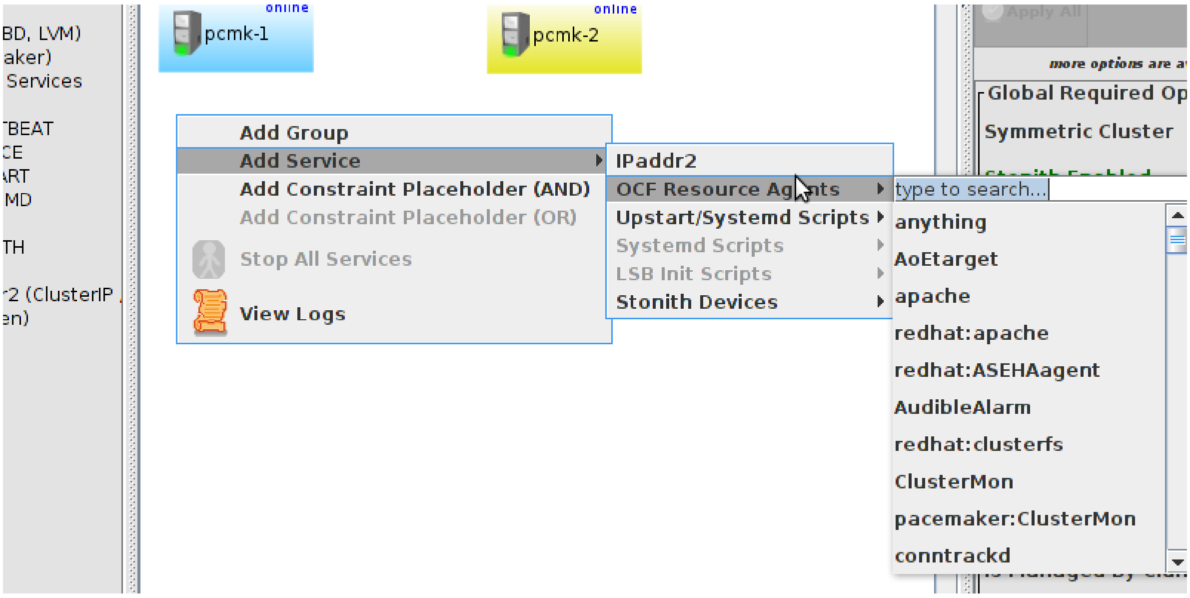


The other important piece of information here is ocf:heartbeat:IPaddr2.

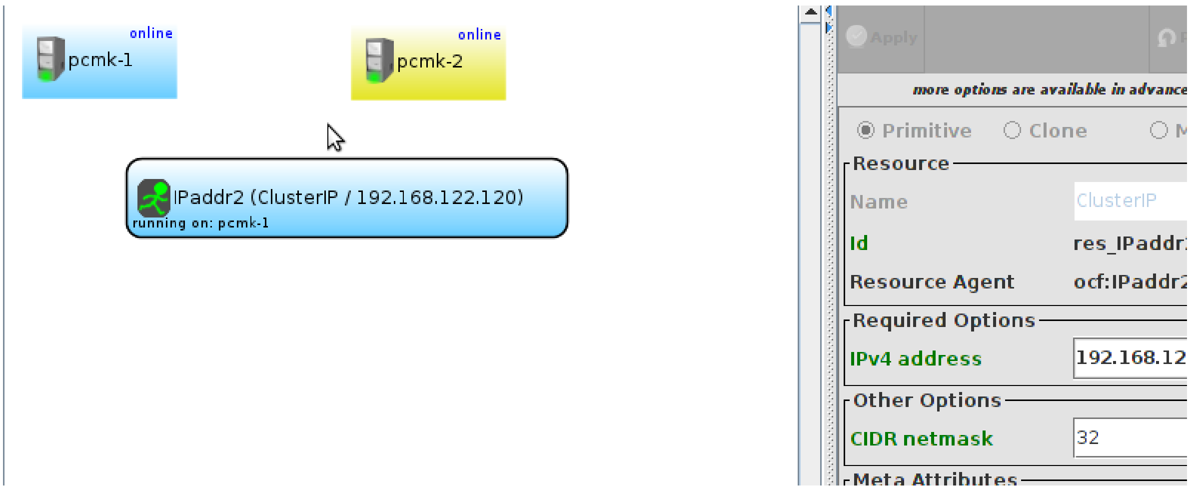
This tells Pacemaker three things about the resource you want to add. The first field, ocf, is the standard to which the resource script conforms to and where to find it. The second field is specific to OCF resources and tells the cluster which namespace to find the resource script in, in this case heartbeat. The last field indicates the name of the resource script.



Finally, if you want to see all the resource agents available for a specific ocf provider (the IPaddr2 part of ocf:heartbeat:IPaddr2), run



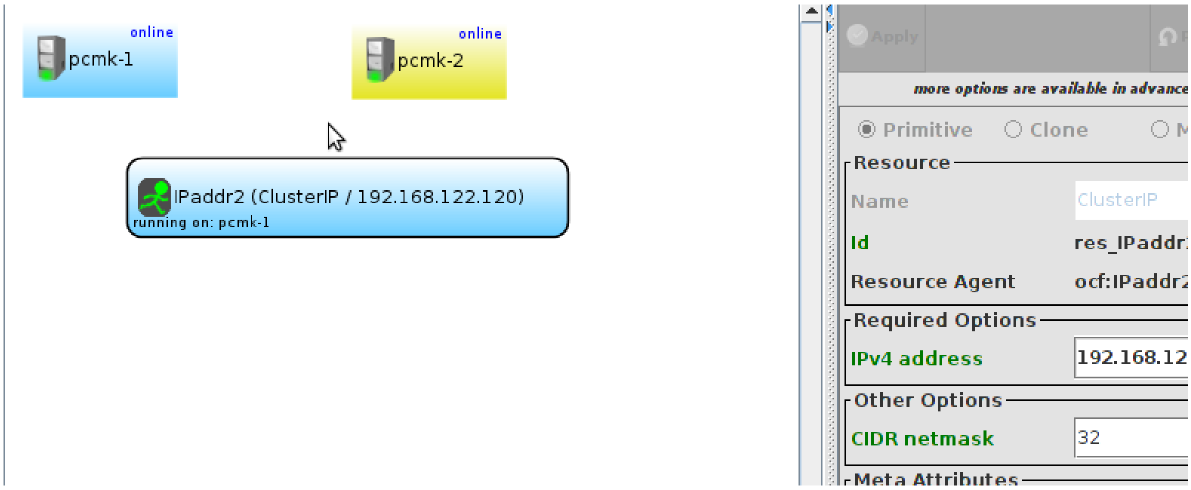
Now verify that the IP resource has been added and display the cluster's status to see that it is now active.



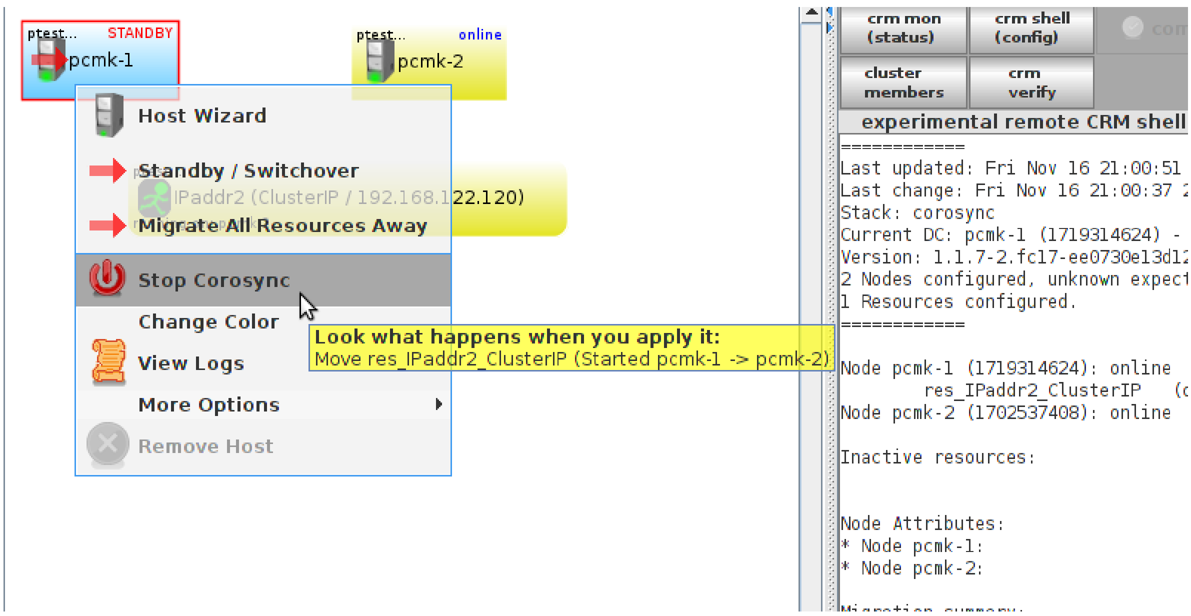
5.3. Perform a Failover

Being a high-availability cluster, we should test failover of our new resource before moving on.

First, find the node on which the IP address is running.



Shut down Pacemaker and Corosync on that machine.



There are three things to notice about the cluster's current state. The first is that, as expected, **`pcmk-1`** is now offline. However we can also see that **`ClusterIP`** isn't running anywhere!

5.3.1. Quorum and Two-Node Clusters

This is because the cluster no longer has quorum, as can be seen by the text "partition WITHOUT quorum" in the status output. In order to reduce the possibility of data corruption, Pacemaker's default behavior is to stop all resources if the cluster does not have quorum.

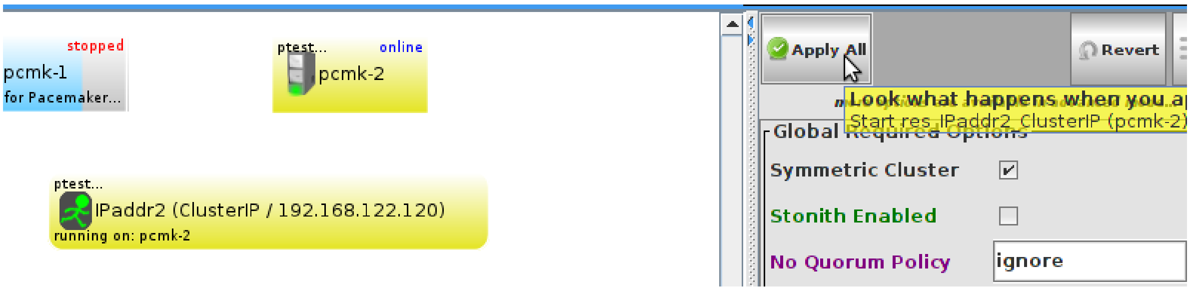
A cluster is said to have quorum when more than half the known or expected nodes are online, or for the mathematically inclined, whenever the following equation is true:

```
total_nodes < 2 * active_nodes
```

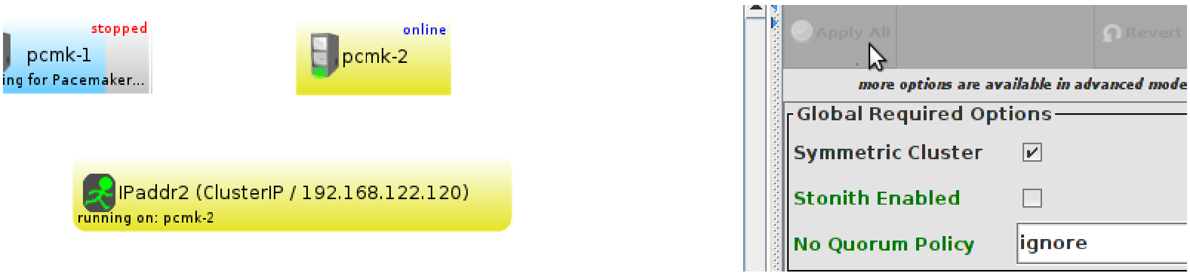
Therefore a two-node cluster only has quorum when both nodes are running, which is no longer the case for our cluster. This would normally make the creation of a two-node cluster pointless [3] , howev-

[3] Actually some would argue that two-node clusters are always pointless, but that is an argument for another time

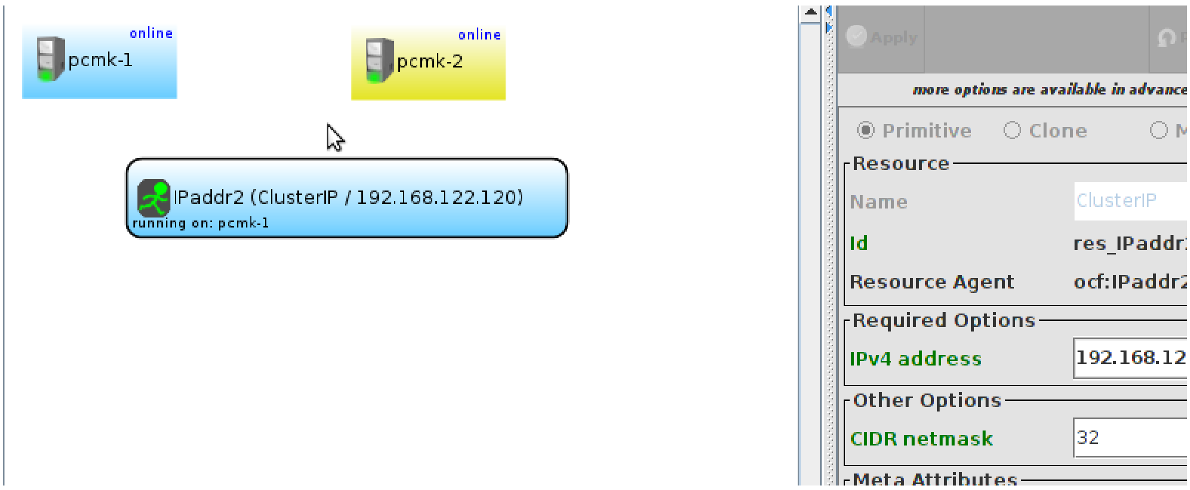
er it is possible to control how Pacemaker behaves when quorum is lost. In particular, we can tell the cluster to simply ignore quorum altogether.



After a few moments, the cluster will start the IP address on the remaining node. Note that the cluster still does not have quorum.



Now simulate node recovery by restarting the cluster stack on **pcmk-1** and check the cluster's status.



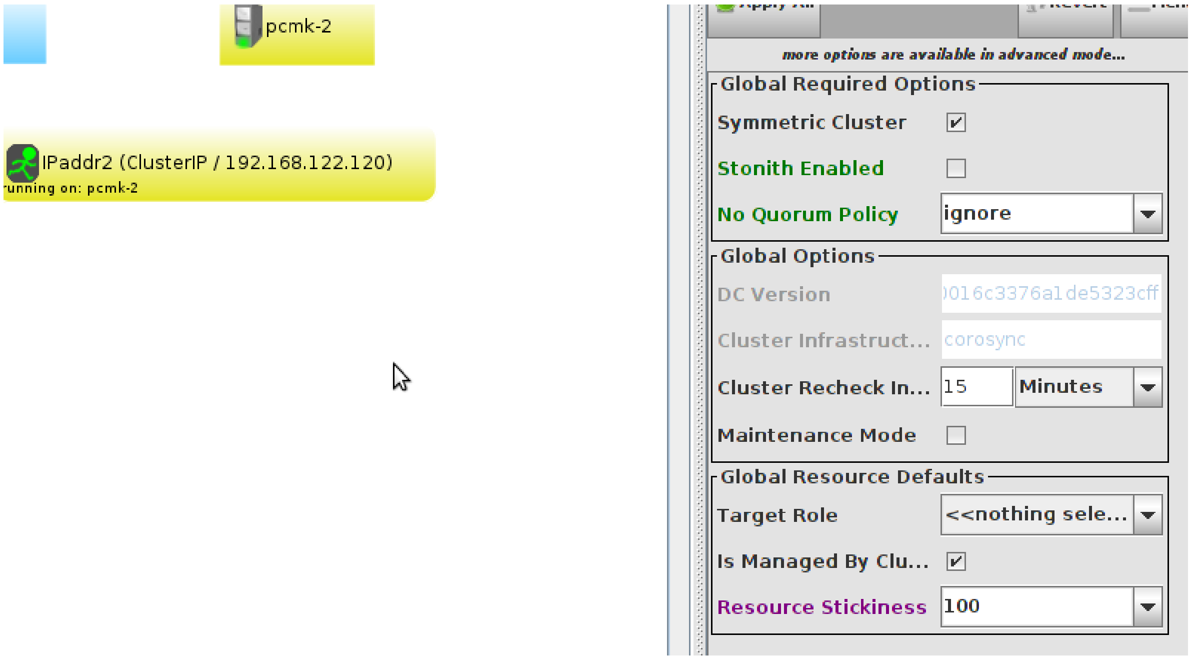
Note

In the dark days, the cluster may have moved the IP back to its original location (**pcmk-1**). Usually this is no longer the case.

5.3.2. Prevent Resources from Moving after Recovery

In most circumstances, it is highly desirable to prevent healthy resources from being moved around the cluster. Moving resources almost always requires a period of downtime. For complex services like Oracle databases, this period can be quite long.

To address this, Pacemaker has the concept of resource stickiness which controls how much a service prefers to stay running where it is. You may like to think of it as the "cost" of any downtime. By default, Pacemaker assumes there is zero cost associated with moving resources and will do so to achieve "optimal" [4] resource placement. We can specify a different stickiness for every resource, but it is often sufficient to change the default.



[4] It should be noted that Pacemaker's definition of optimal may not always agree with that of a human's. The order in which Pacemaker processes lists of resources and nodes creates implicit preferences in situations where the administrator has not explicitly specified them

Apache - Adding More Services

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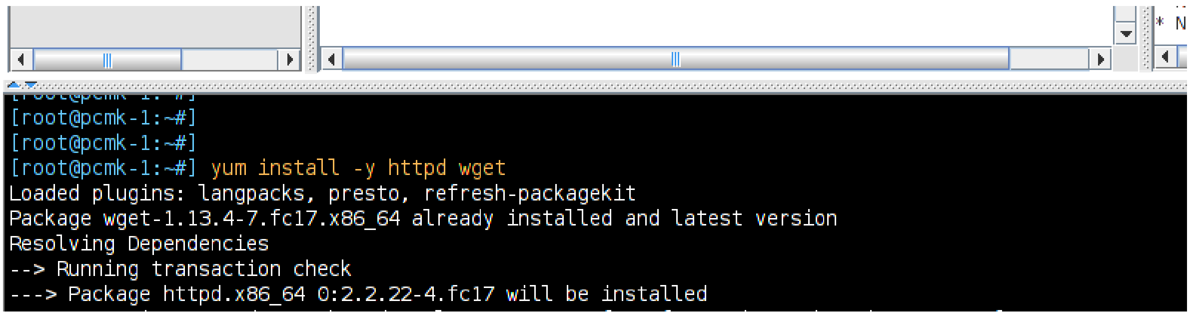
6.1. Forward

Now that we have a basic but functional active/passive two-node cluster, we're ready to add some real services. We're going to start with Apache because its a feature of many clusters and relatively simple to configure.

6.2. Installation

Before continuing, we need to make sure Apache is installed on both hosts. We also need the wget tool in order for the cluster to be able to check the status of the Apache server.



6.3. Preparation

First we need to create a page for Apache to serve up. On Fedora the default Apache docroot is /var/www/html, so we'll create an index file there.

```
# cat <<-END >/var/www/html/index.html
 <html>
 <body>My Test Site - pcmk-1</body>
 </html>
END
```

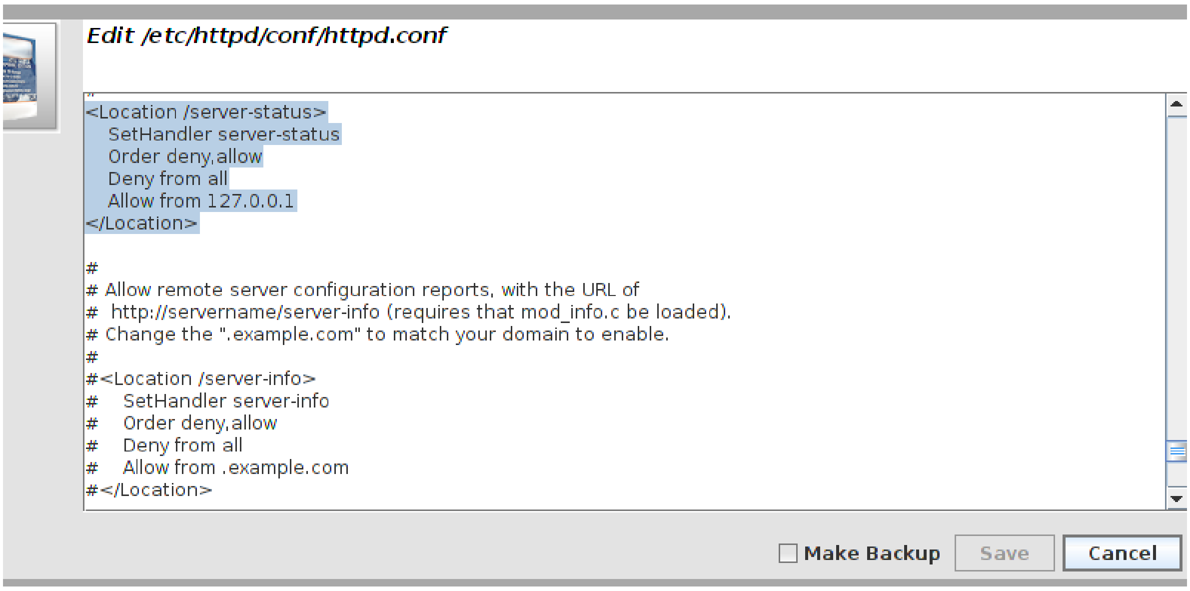
For the moment, we will simplify things by serving up only a static site and manually sync the data between the two nodes. So run the command again on pcmk-2.

```
[root@pcmk-2 ~]# cat <<-END >/var/www/html/index.html <html>
```

```
<body>My Test Site - pcmk-2</body>
</html>
END
```

6.4. Enable the Apache status URL

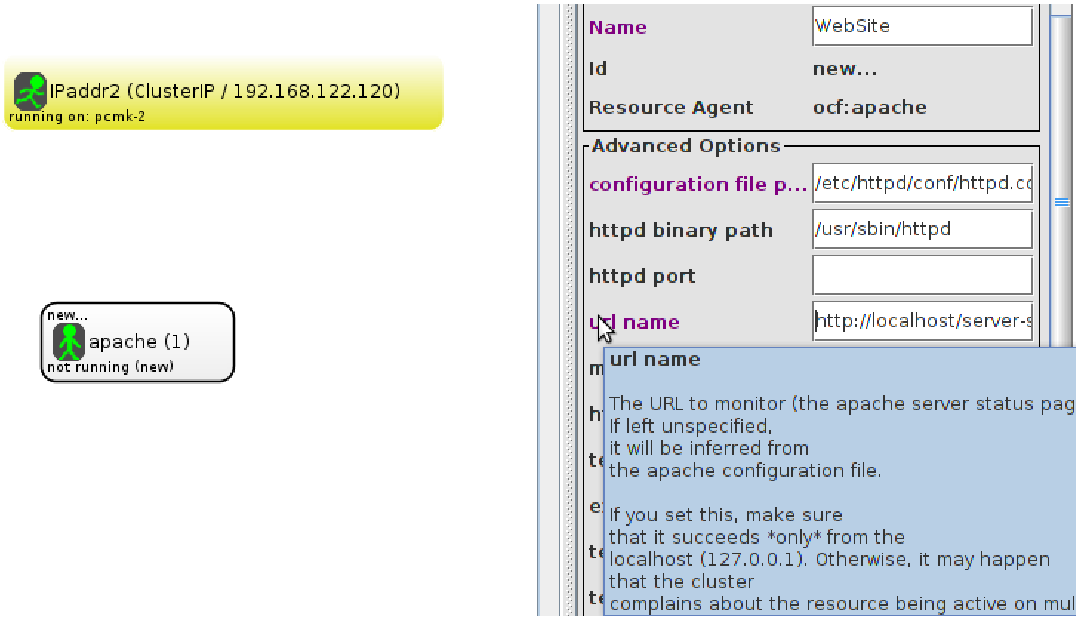
In order to monitor the health of your Apache instance, and recover it if it fails, the resource agent used by Pacemaker assumes the server-status URL is available. Look for the following in */etc/httpd/conf/httpd.conf* and make sure it is not disabled or commented out:



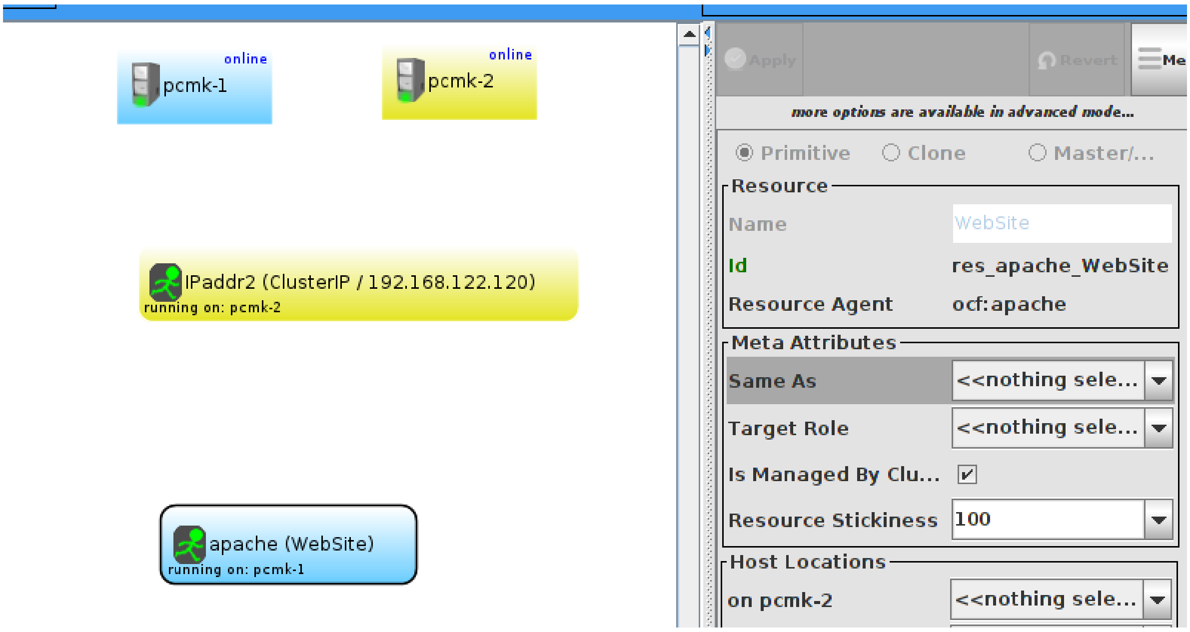
6.5. Update the Configuration

At this point, Apache is ready to go, all that needs to be done is to add it to the cluster. Lets call the resource WebSite. We need to use an OCF script called apache in the heartbeat namespace [1] , the only required parameter is the path to the main Apache configuration file and we'll tell the cluster to check once a minute that apache is still running.

[1] Compare the key used here ocf:heartbeat:apache with the one we used earlier for the IP address: ocf:heartbeat:IPaddr2



After a short delay, we should see the cluster start apache



Wait a moment, the WebSite resource isn't running on the same host as our IP address!

> **Note**
>
> If you see the WebSite resource has failed to start, then you've likely not enabled the status URL correctly.
>
> 
>
>
> You can check if this is the problem by running:
>
> ```
> wget http://127.0.0.1/server-status
> ```
>
> If you see **Connection refused** in the output, then this is indeed the problem. Check to ensure that **Allow from 127.0.0.1** is present for the **<Location /server-status>** block.

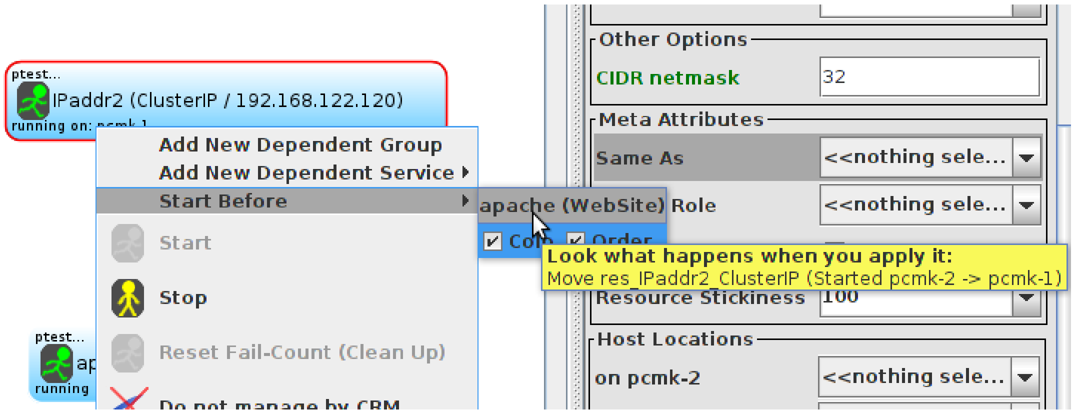
6.6. Ensuring Resources Run on the Same Host

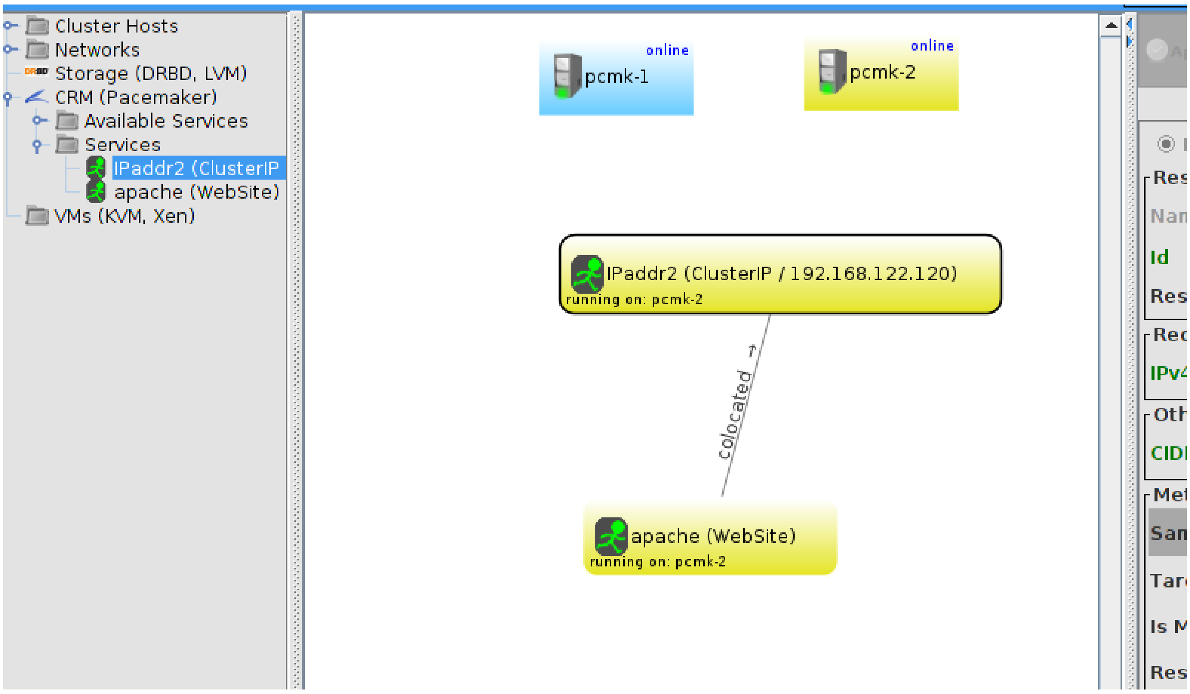
To reduce the load on any one machine, Pacemaker will generally try to spread the configured resources across the cluster nodes. However we can tell the cluster that two resources are related and need to run on the same host (or not at all). Here we instruct the cluster that WebSite can only run on the host that ClusterIP is active on.

To achieve this we use a colocation constraint that indicates it is mandatory for WebSite to run on the same node as ClusterIP. The "mandatory" part of the colocation constraint is indicated by using a score of INFINITY. The INFINITY score also means that if ClusterIP is not active anywhere, WebSite will not be permitted to run.

> **Note**
>
> If ClusterIP is not active anywhere, WebSite will not be permitted to run anywhere.

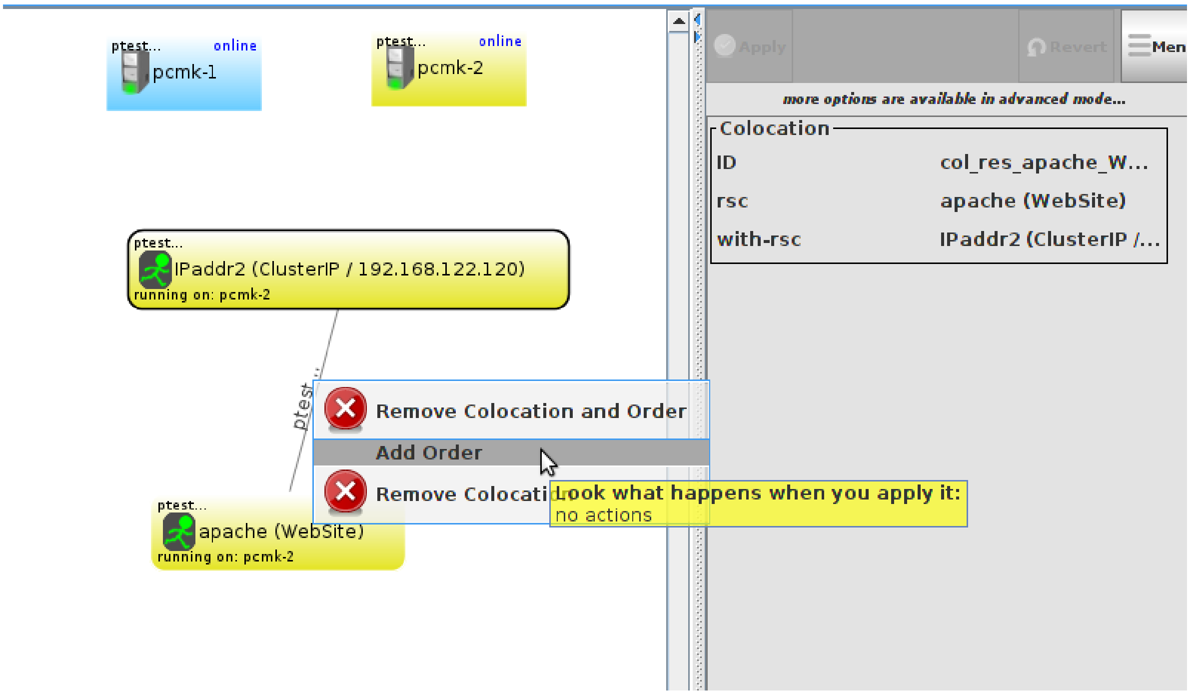
> **Important**
>
> Colocation constraints are "directional", in that they imply certain things about the order in which the two resources will have a location chosen. In this case we're saying **WebSite** needs to be placed on the same machine as **ClusterIP**, this implies that we must know the location of **ClusterIP** before choosing a location for **WebSite**.





6.7. Controlling Resource Start/Stop Ordering

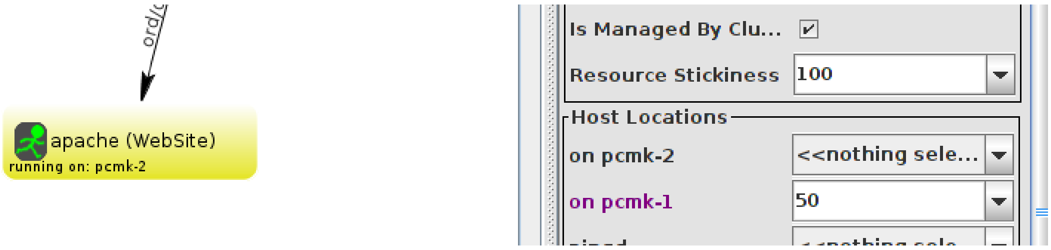
When Apache starts, it binds to the available IP addresses. It doesn't know about any addresses we add afterwards, so not only do they need to run on the same node, but we need to make sure ClusterIP is already active before we start WebSite. We do this by adding an ordering constraint.

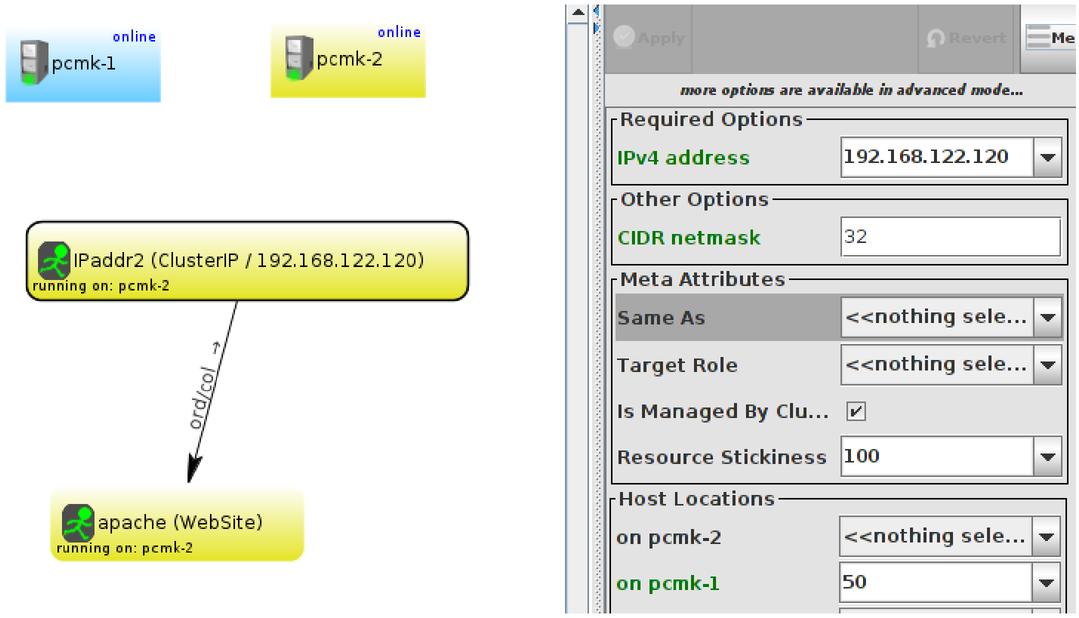


6.8. Specifying a Preferred Location

Pacemaker does not rely on any sort of hardware symmetry between nodes, so it may well be that one machine is more powerful than the other. In such cases it makes sense to host the resources there if it is available. To do this we create a location constraint.

In the location constraint below, we are saying the WebSite resource prefers the node pcmk-1 with a score of 50. The score here indicates how badly we'd like the resource to run somewhere.

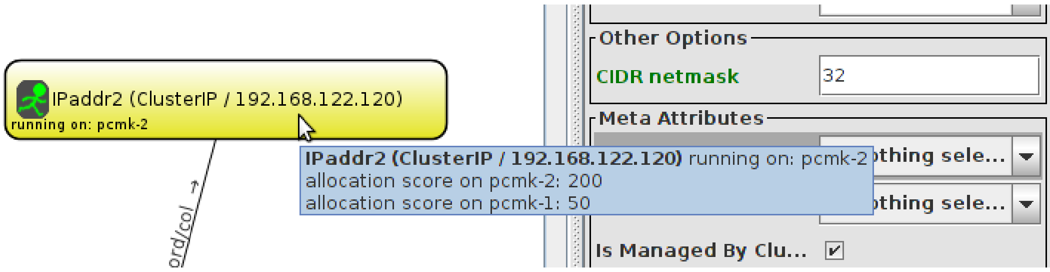


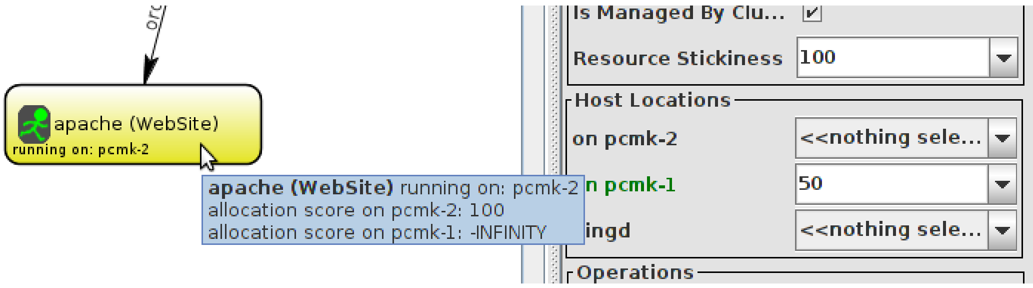


Wait a minute, the resources are still on pcmk-2!

Even though we now prefer pcmk-1 over pcmk-2, that preference is (intentionally) less than the resource stickiness (how much we preferred not to have unnecessary downtime).

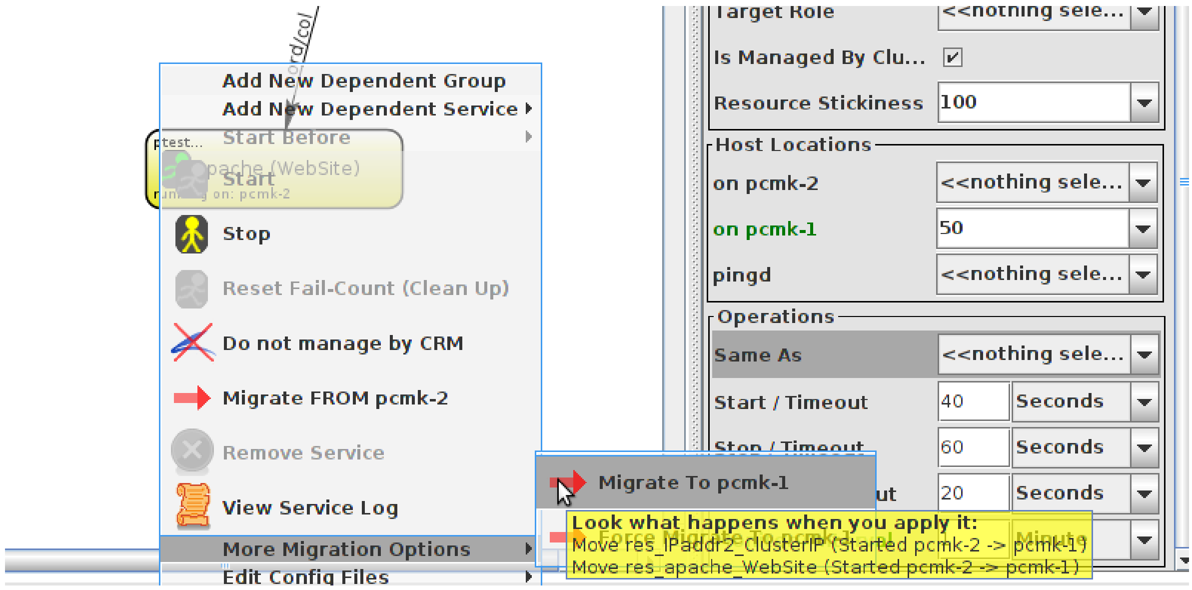
To see the current placement scores, you can use resource tool-tips





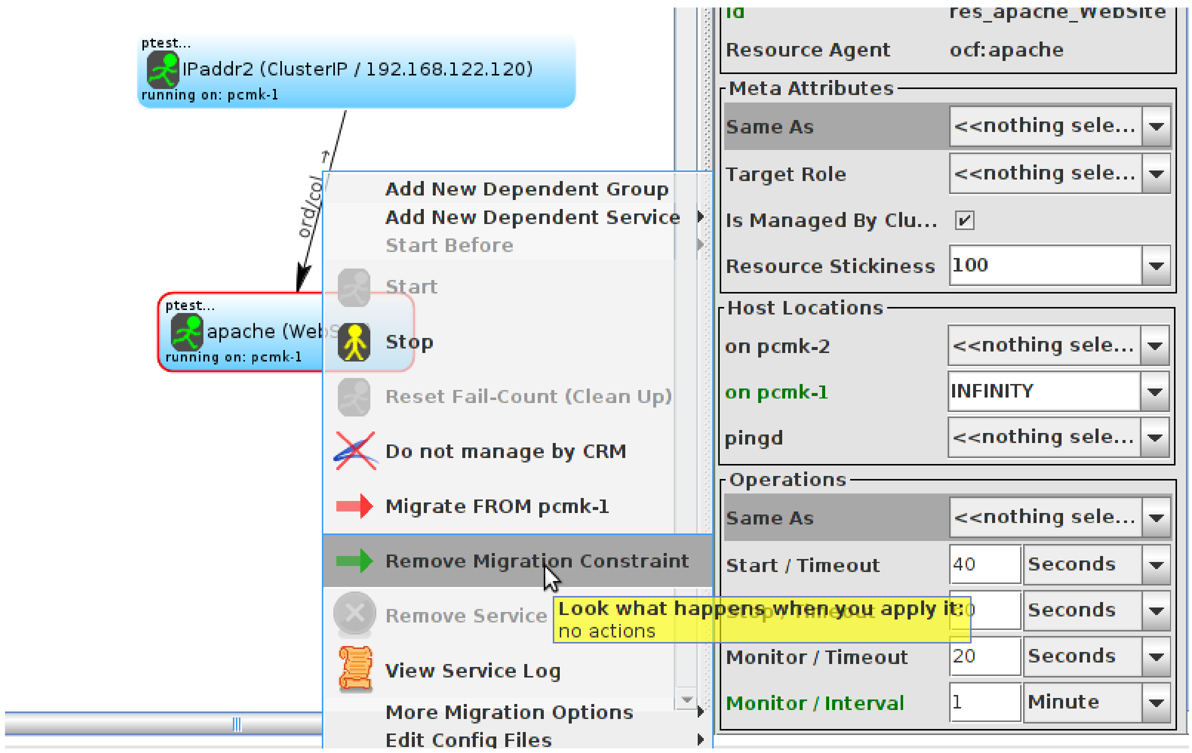
6.9. Manually Moving Resources Around the Cluster

There are always times when an administrator needs to override the cluster and force resources to move to a specific location. Underneath we use location constraints like the one we created above, happily you don't need to care.

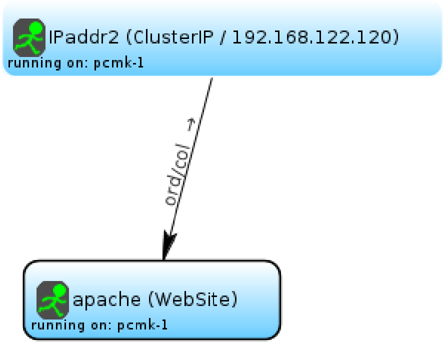


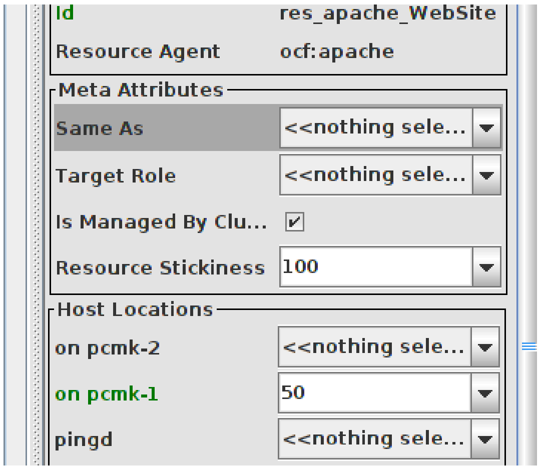
6.9.1. Giving Control Back to the Cluster

Once we've finished whatever activity that required us to move the resources to pcmk-1, in our case nothing, we can then allow the cluster to resume normal operation with the unmove command. Since we previously configured a default stickiness, the resources will remain on pcmk-1.



Note that the constraint is now gone. If we check the cluster status, we can also see that as expected the resources are still active on pcmk-1.


IPaddr2 (ClusterIP / 192.168.122.120)
running on: pcmk-1
ord/col →
apache (WebSite)
running on: pcmk-1


Id
res_apache_WebSite
Resource Agent
ocf:apache
Meta Attributes
Same As
<<nothing sele...
Target Role
<<nothing sele...
Is Managed By Clu...
Resource Stickiness
100
Host Locations
on pcmk-2
<<nothing sele...
on pcmk-1
50
pingd
<<nothing sele...

Replicated Storage with DRBD

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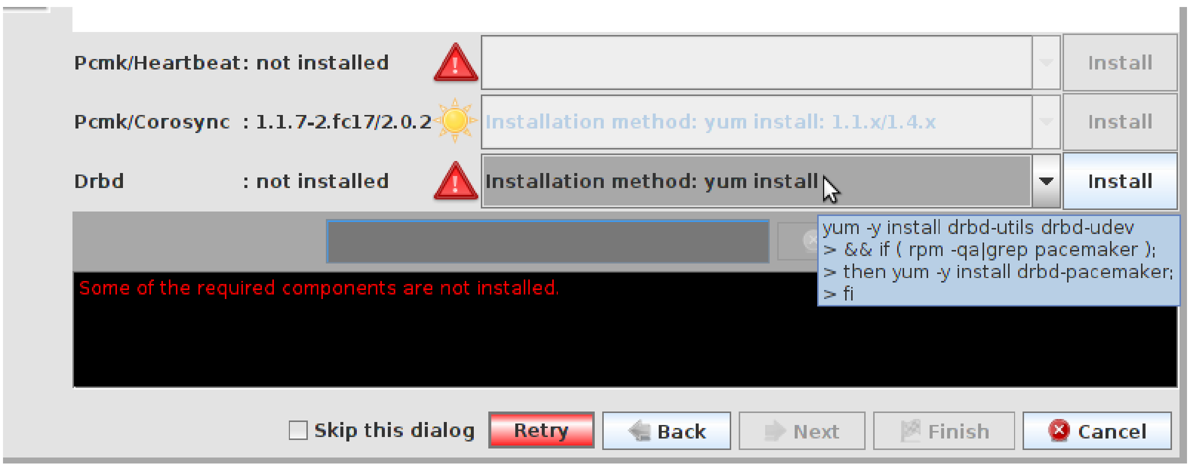
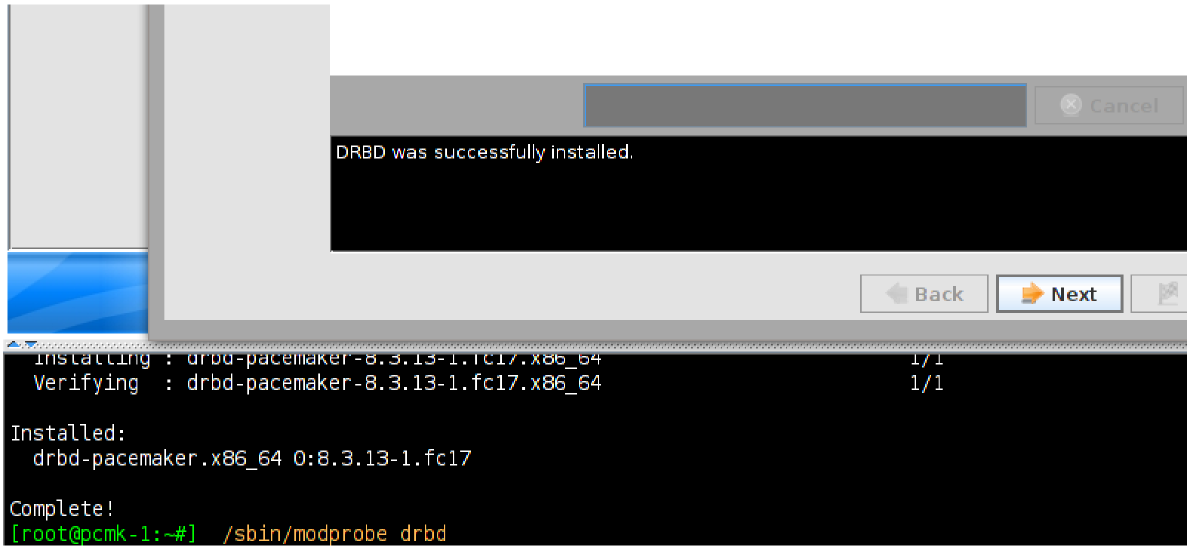
7.1. Background

Even if you're serving up static websites, having to manually synchronize the contents of that website to all the machines in the cluster is not ideal. For dynamic websites, such as a wiki, it's not even an option. Not everyone care afford network-attached storage but somehow the data needs to be kept in sync. Enter DRBD which can be thought of as network based RAID-1. See *http://www.drbd.org/* for more details.

7.2. Install the DRBD Packages

Since its inclusion in the upstream 2.6.33 kernel, everything needed to use DRBD has shiped with Fedora since version 13. All you need to do is install it:



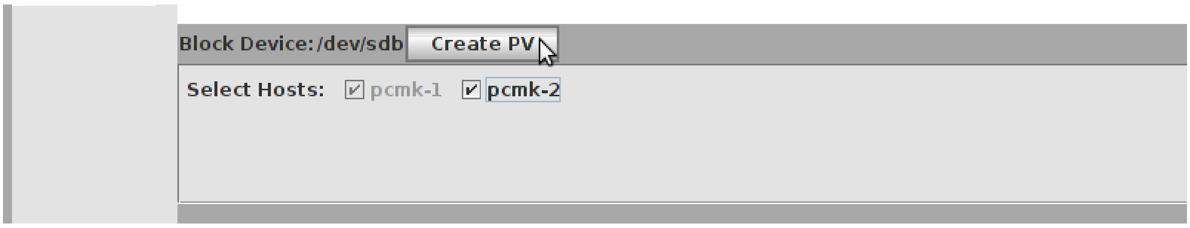


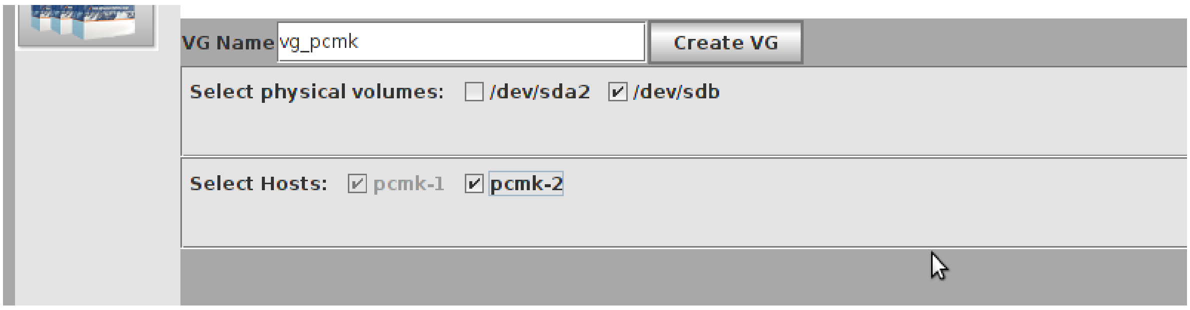
7.3. Configure DRBD

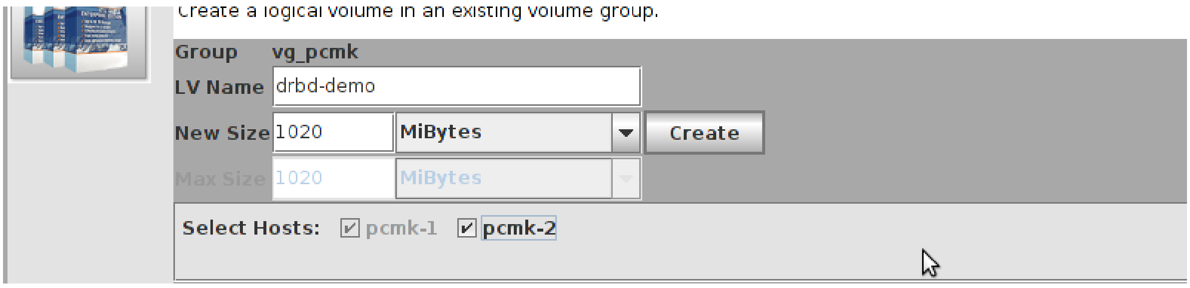
Before we configure DRBD, we need to set aside some disk for it to use.

7.3.1. Create A Partition for DRBD

If you have more than 1Gb free, feel free to use it. For this guide however, 1Gb is plenty of space for a single html file and sufficient for later holding the GFS2 metadata.





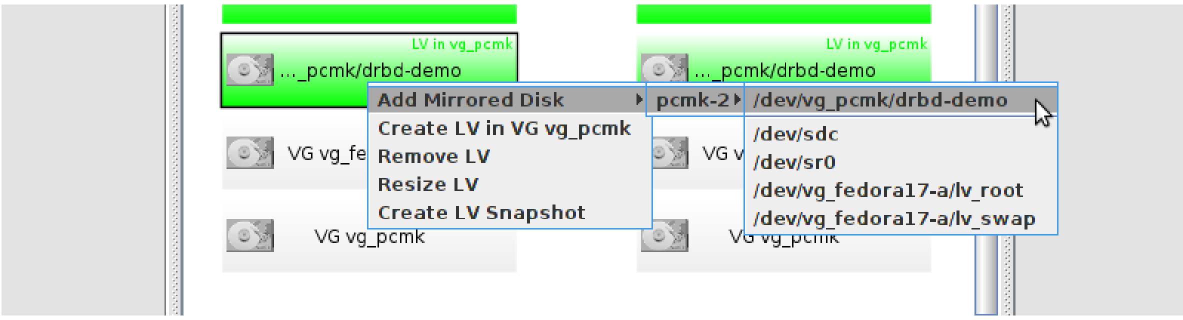


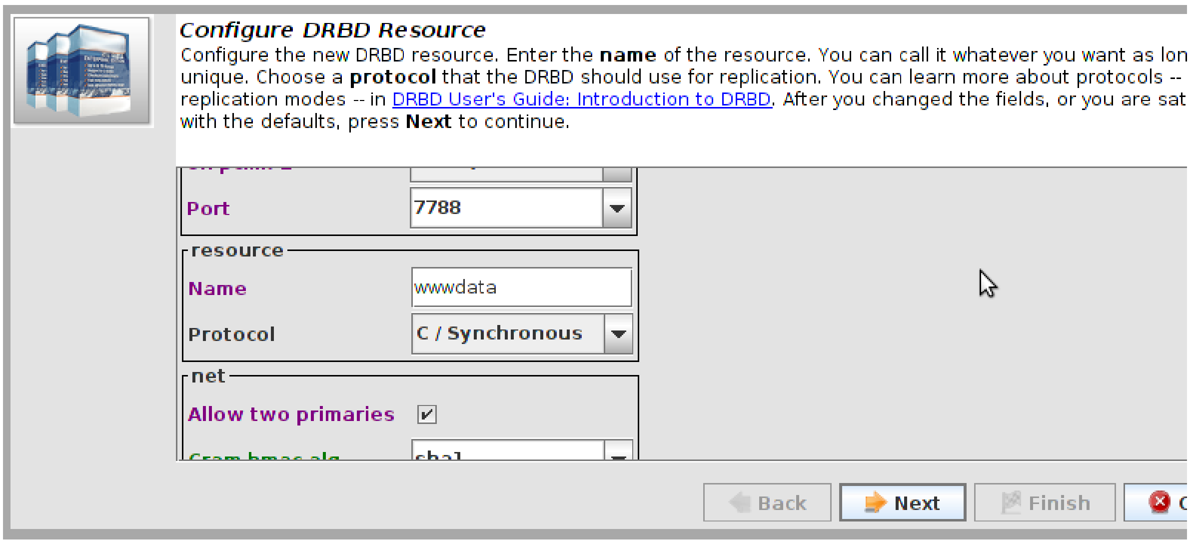
7.3.2. Write the DRBD Config

Detailed information on the directives used in this configuration (and other alternatives) is available from *http://www.drbd.org/users-guide/ch-configure.html*

Warning

Be sure to use the names and addresses of your nodes if they differ from the ones used in this guide.

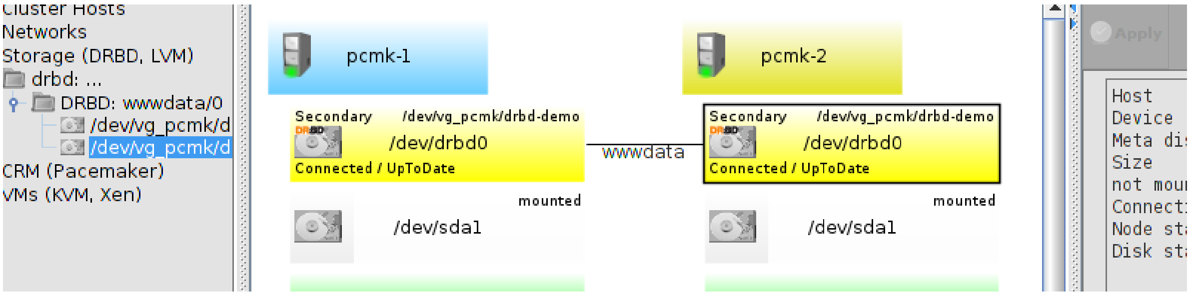




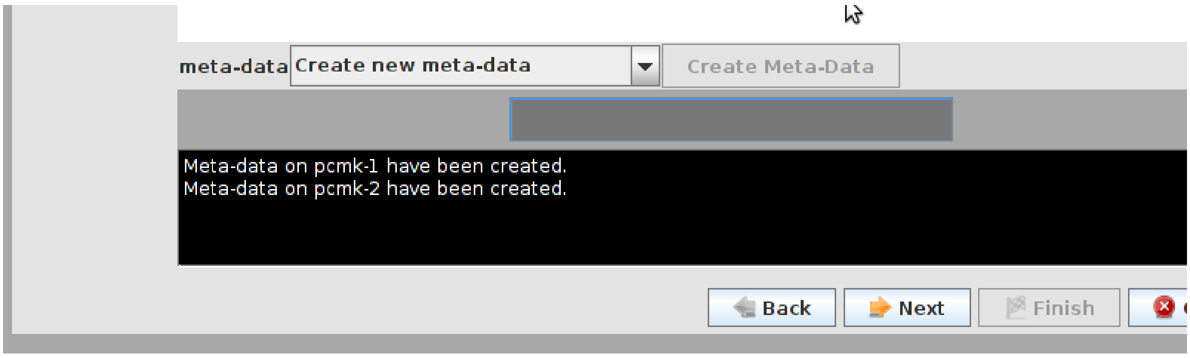
Note

TODO: Explain the reason for the allow-two-primaries option

7.3.3. Initialize and Load DRBD

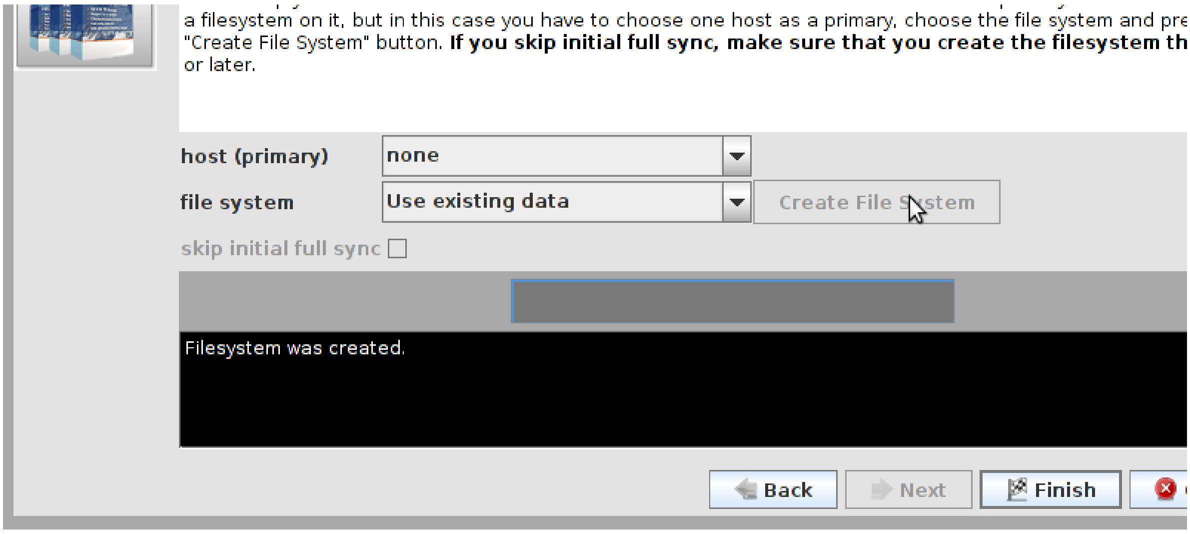


With the configuration in place, we can now perform the DRBD initialization



pcmk-1 is now in the Primary state which allows it to be written to. Which means it's a good point at which to create a filesystem and populate it with some data to serve up via our WebSite resource.

7.3.4. Populate DRBD with Data



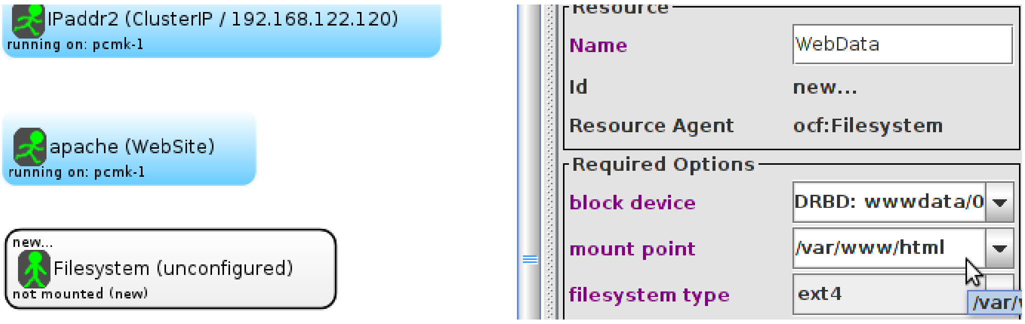
Now mount the newly created filesystem so we can create our index file

```
# mount /dev/drbd1 /mnt/
# cat <<-END >/mnt/index.html
 <html>
  <body>My Test Site - drbd</body>
 </html>
END
```

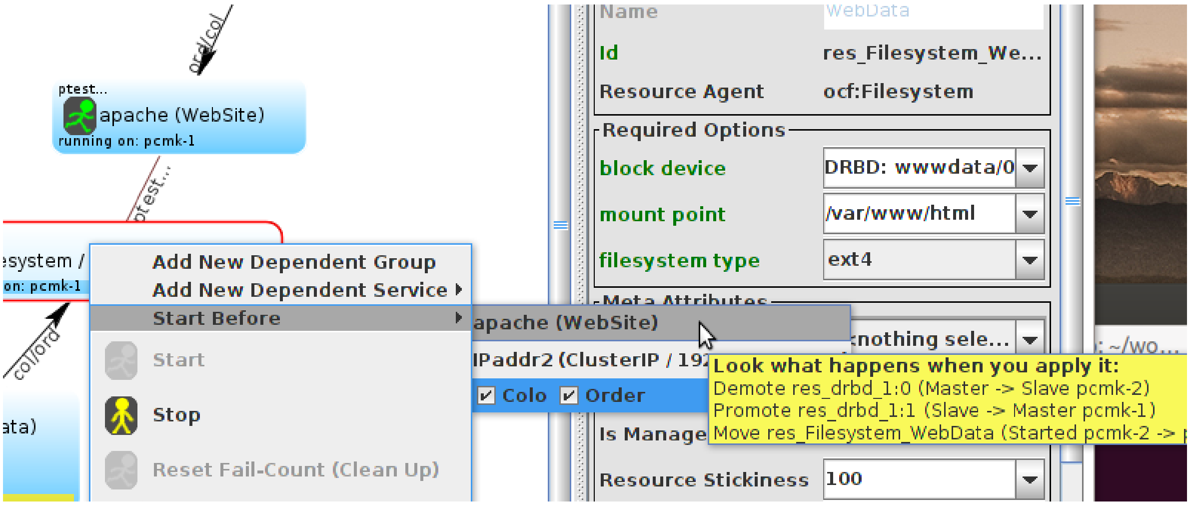
```
# umount /dev/drbd1
```

7.4. Configure the Cluster for DRBD

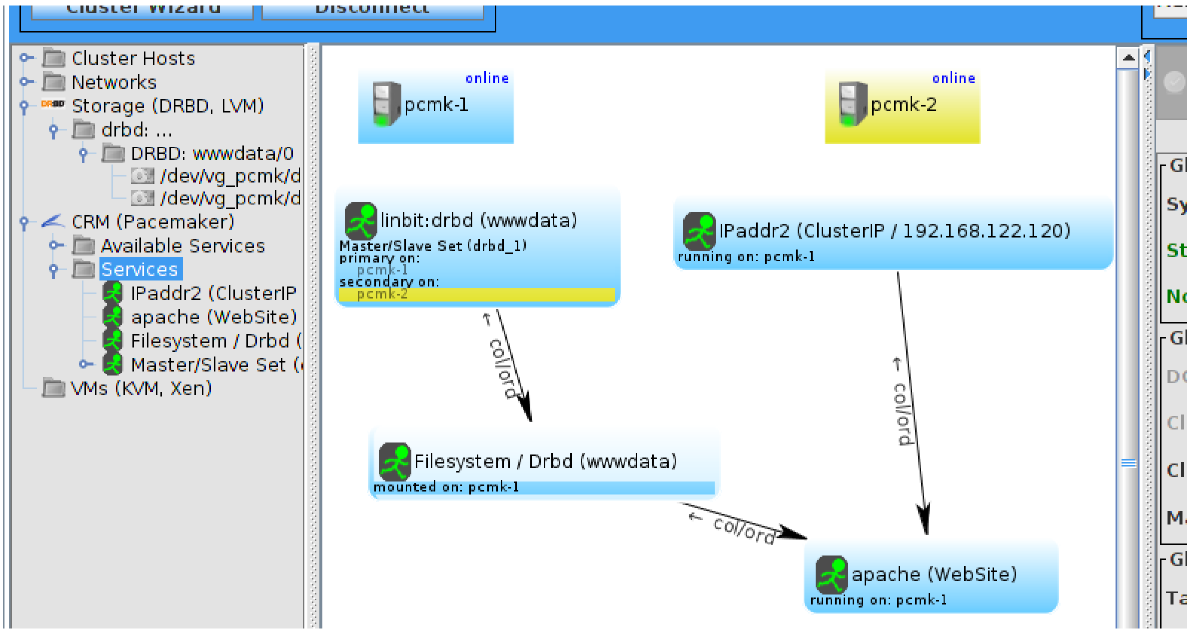
Now we can create our DRBD clone and display the revised configuration.



We also need to tell the cluster that Apache needs to run on the same machine as the filesystem and that it must be active before Apache can start.



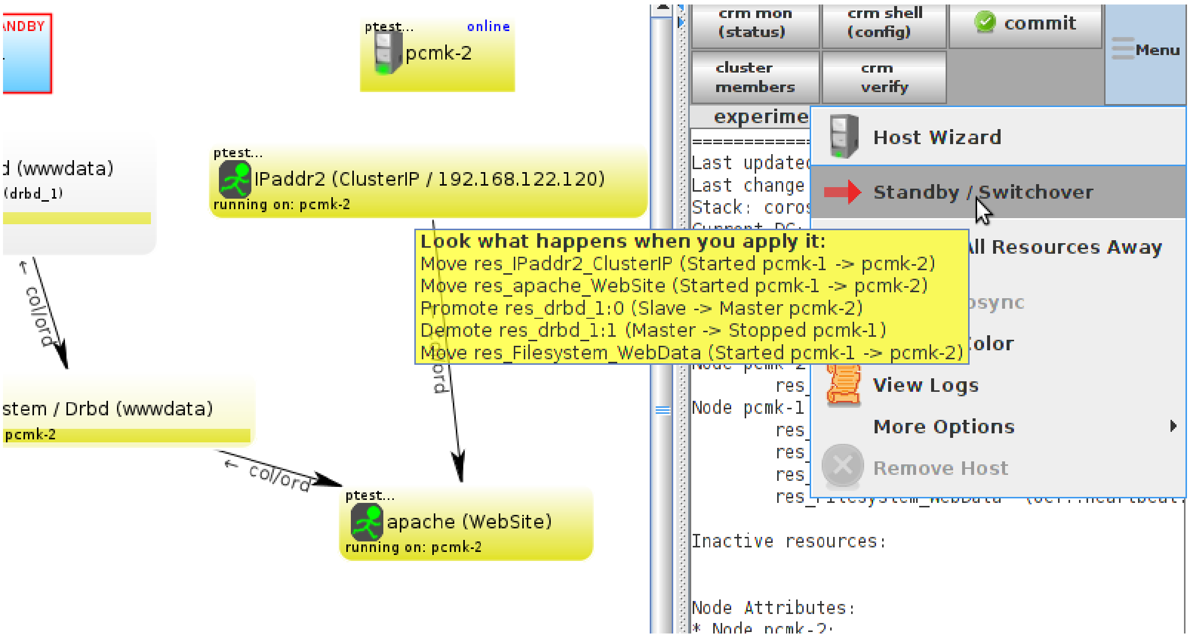
After reviewing the new configuration, we again upload it and watch the cluster put it into effect.



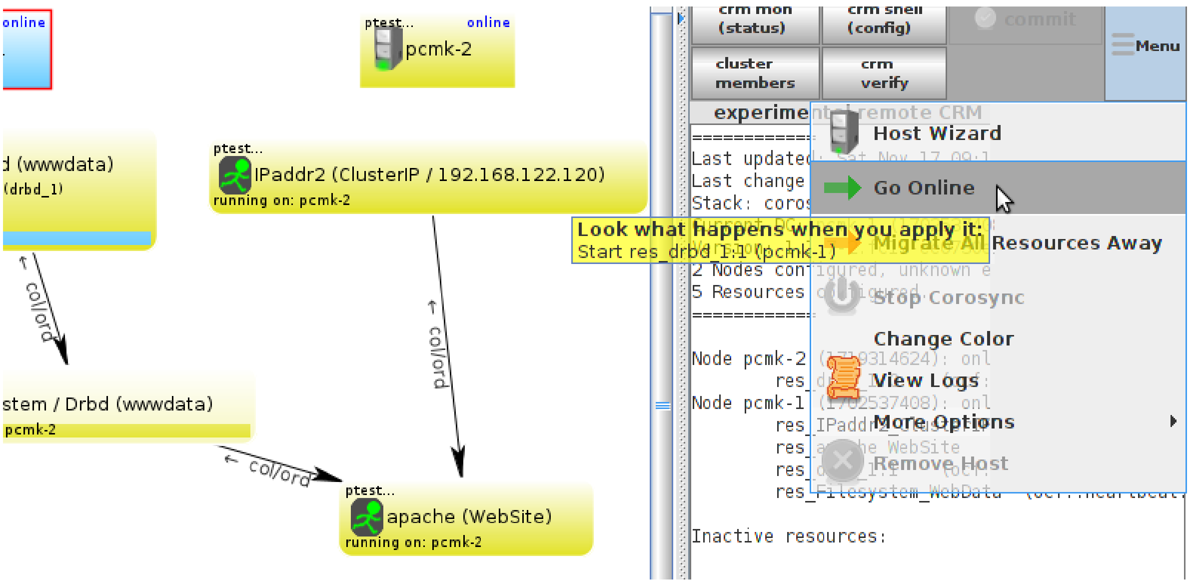
7.4.1. Testing Migration

We could shut down the active node again, but another way to safely simulate recovery is to put the node into what is called "standby mode". Nodes in this state tell the cluster that they are not allowed to run resources. Any resources found active there will be moved elsewhere. This feature can be particularly useful when updating the resources' packages.

Put the local node into standby mode and observe the cluster move all the resources to the other node. Note also that the node's status will change to indicate that it can no longer host resources.



Once we've done everything we needed to on pcmk-1 (in this case nothing, we just wanted to see the resources move), we can allow the node to be a full cluster member again.



Notice that our resource stickiness settings prevent the services from migrating back to pcmk-1.

Conversion to Active/Active

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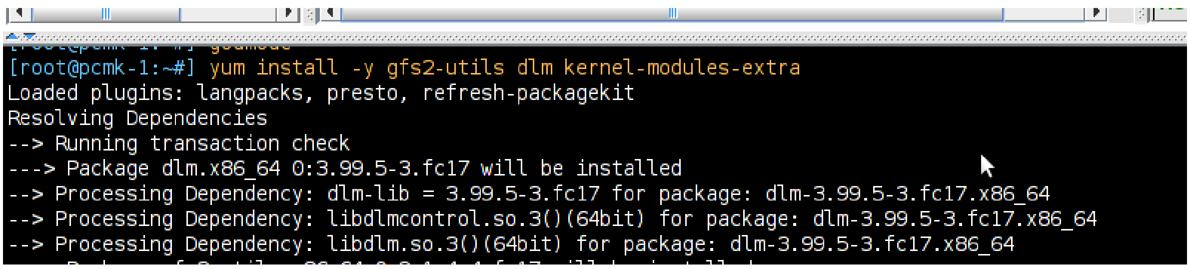
8.1. Requirements

The primary requirement for an Active/Active cluster is that the data required for your services is available, simultaneously, on both machines. Pacemaker makes no requirement on how this is achieved, you could use a SAN if you had one available, however since DRBD supports multiple Primaries, we can also use that.

The only hitch is that we need to use a cluster-aware filesystem. The one we used earlier with DRBD, ext4, is not one of those. Both OCFS2 and GFS2 are supported, however here we will use GFS2 which comes with Fedora 17.

8.1.1. Installing the required Software

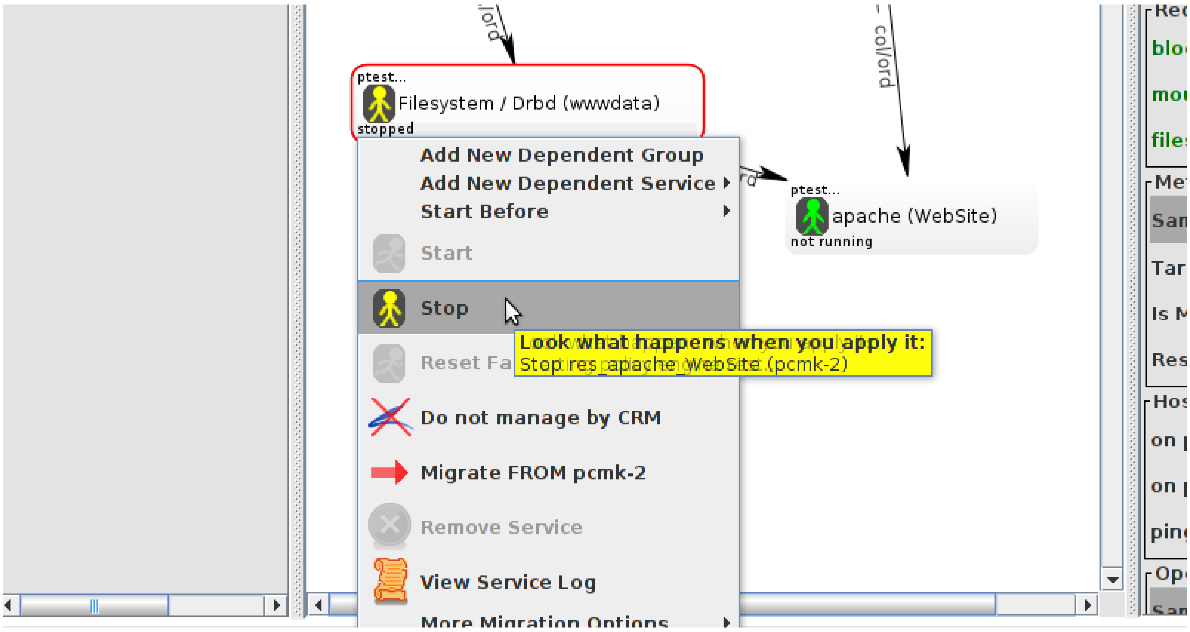


```
[root@pcmk-1:~#] yum install -y gfs2-utils dlm kernel-modules-extra
Loaded plugins: langpacks, presto, refresh-packagekit
Resolving Dependencies
--> Running transaction check
---> Package dlm.x86_64 0:3.99.5-3.fc17 will be installed
--> Processing Dependency: dlm-lib = 3.99.5-3.fc17 for package: dlm-3.99.5-3.fc17.x86_64
--> Processing Dependency: libdlmcontrol.so.3()(64bit) for package: dlm-3.99.5-3.fc17.x86_64
--> Processing Dependency: libdlm.so.3()(64bit) for package: dlm-3.99.5-3.fc17.x86_64
```

8.2. Create a GFS2 Filesystem

8.2.1. Preparation

Before we do anything to the existing partition, we need to make sure it is unmounted. We do this by telling the cluster to stop the WebFS resource. This will ensure that other resources (in our case, Apache) using WebFS are not only stopped, but stopped in the correct order.



Note

Note that both Apache and WebFS have been stopped.

8.2.2. Create and Populate an GFS2 Partition

Now that the cluster stack and integration pieces are running smoothly, we can create an GFS2 partition.

Warning

This will erase all previous content stored on the DRBD device. Ensure you have a copy of any important data.

We need to specify a number of additional parameters when creating a GFS2 partition.

First we must use the -p option to specify that we want to use the the Kernel's DLM. Next we use -j to indicate that it should reserve enough space for two journals (one per node accessing the filesystem).

Lastly, we use -t to specify the lock table name. The format for this field is **`clustername:fsname`**. For the **`fsname`**, we need to use the same value as specified in *corosync.conf* for **`cluster_name`**. Just pick something unique and descriptive and add somewhere inside the **`totem`** block. For example:

```
totem {
        version: 2

        # cypto_cipher and crypto_hash: Used for mutual node authentication.
        # If you choose to enable this, then do remember to create a shared
        # secret with "corosync-keygen".
        crypto_cipher: none
```

```
        crypto_hash: none
        cluster_name: mycluster
  ...
```

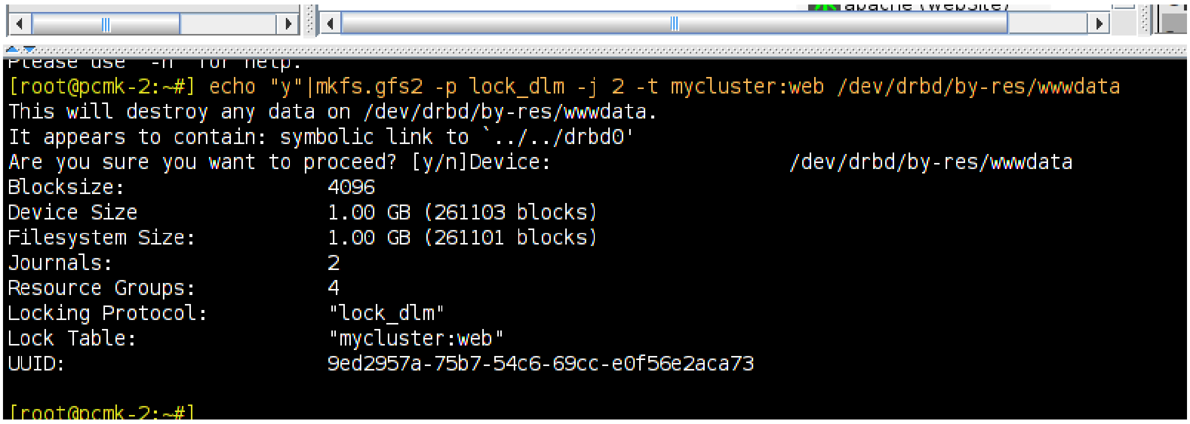
Important

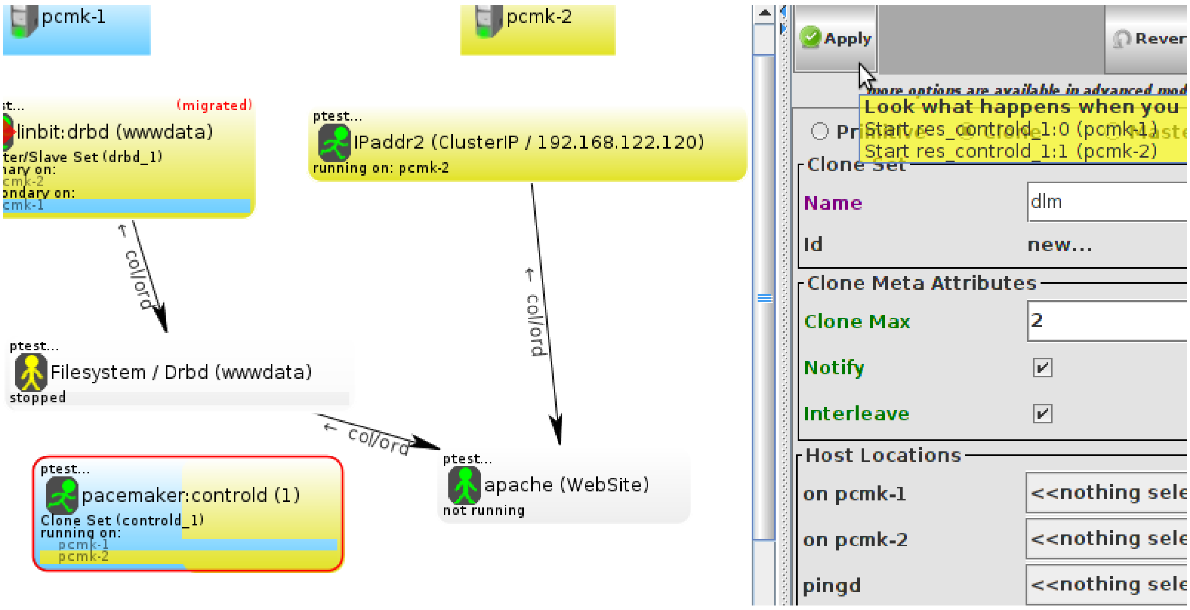
Do this on each node in the cluster and be sure to restart them before continuing.

Important

We must run the next command on whichever node last had */dev/drbd* mounted. Otherwise you will receive the message:

```
/dev/drbd1: Read-only file system
```

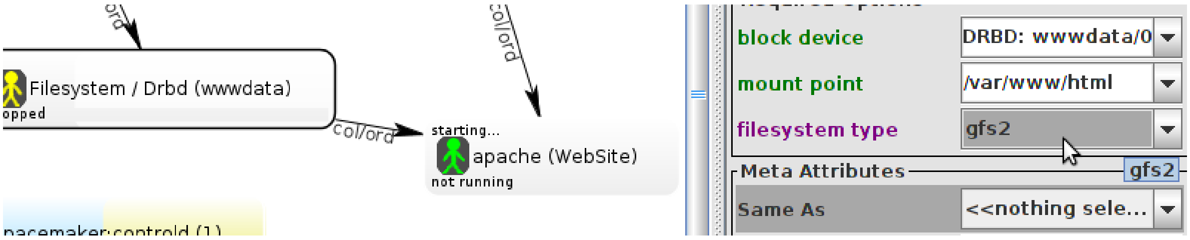




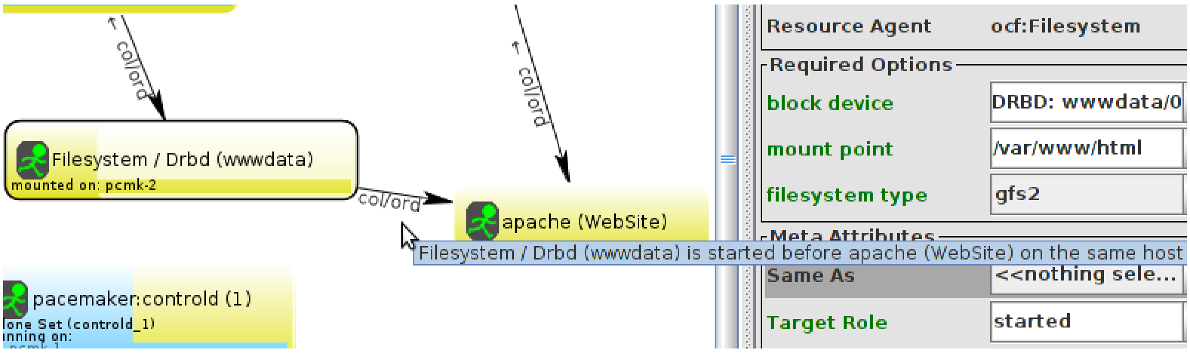
Then (re)populate the new filesystem with data (web pages). For now we'll create another variation on our home page.

```
# mount /dev/drbd1 /mnt/
# cat <<-END >/mnt/index.html
<html>
<body>My Test Site - GFS2</body>
</html>
END
# umount /dev/drbd1
# drbdadm verify wwwdata#
```

8.3. Reconfigure the Cluster for GFS2



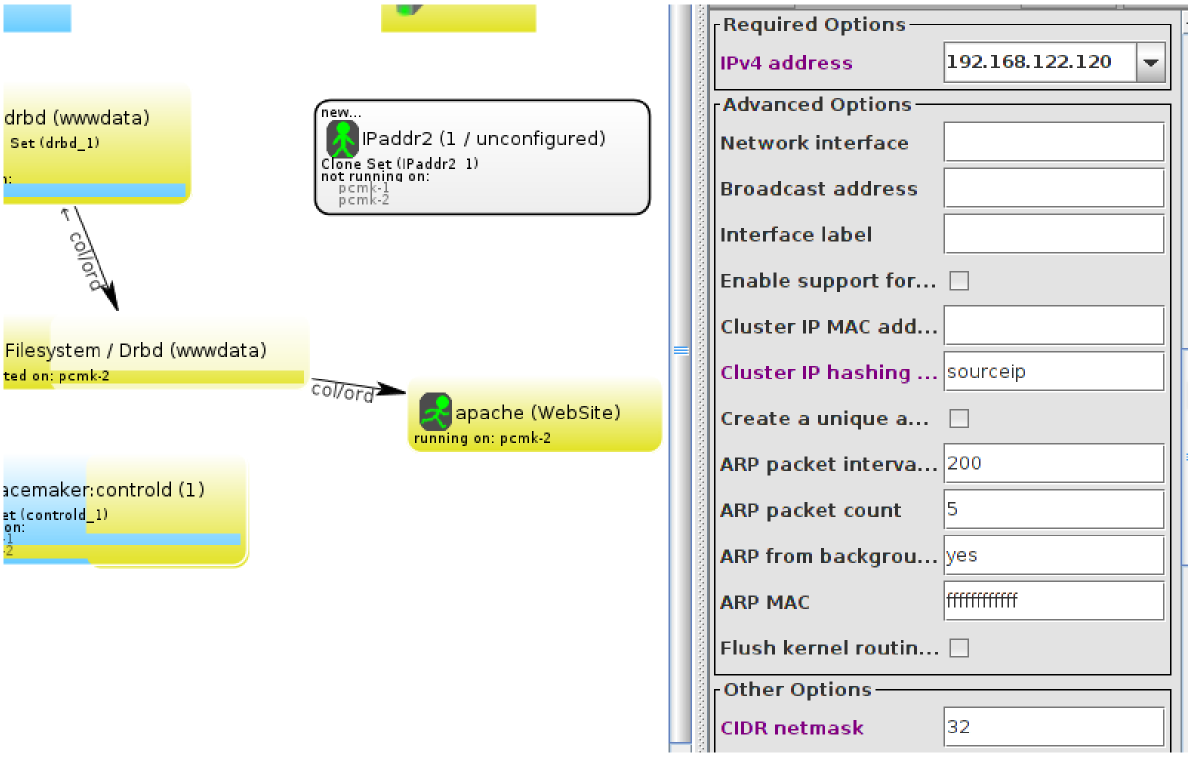
Now you can start the filesystem.



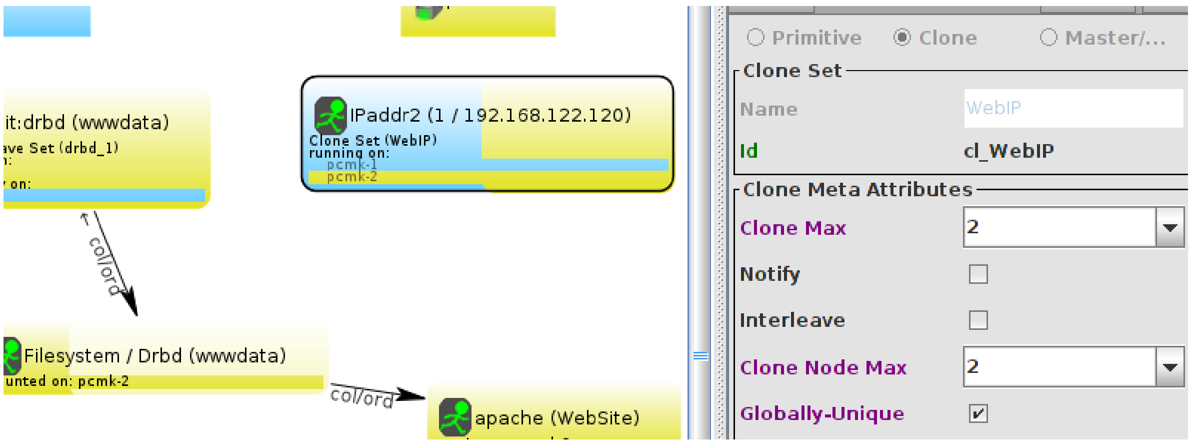
8.4. Reconfigure Pacemaker for Active/Active

Almost everything is in place. Recent versions of DRBD are capable of operating in Primary/Primary mode and the filesystem we're using is cluster aware. All we need to do now is reconfigure the cluster to take advantage of this.

There's no point making the services active on both locations if we can't reach them, so lets first clone the IP address. Cloned IPaddr2 resources use an iptables rule to ensure that each request only gets processed by one of the two clone instances. The additional meta options tell the cluster how many instances of the clone we want (one "request bucket" for each node) and that if all other nodes fail, then the remaining node should hold all of them. Otherwise the requests would be simply discarded.

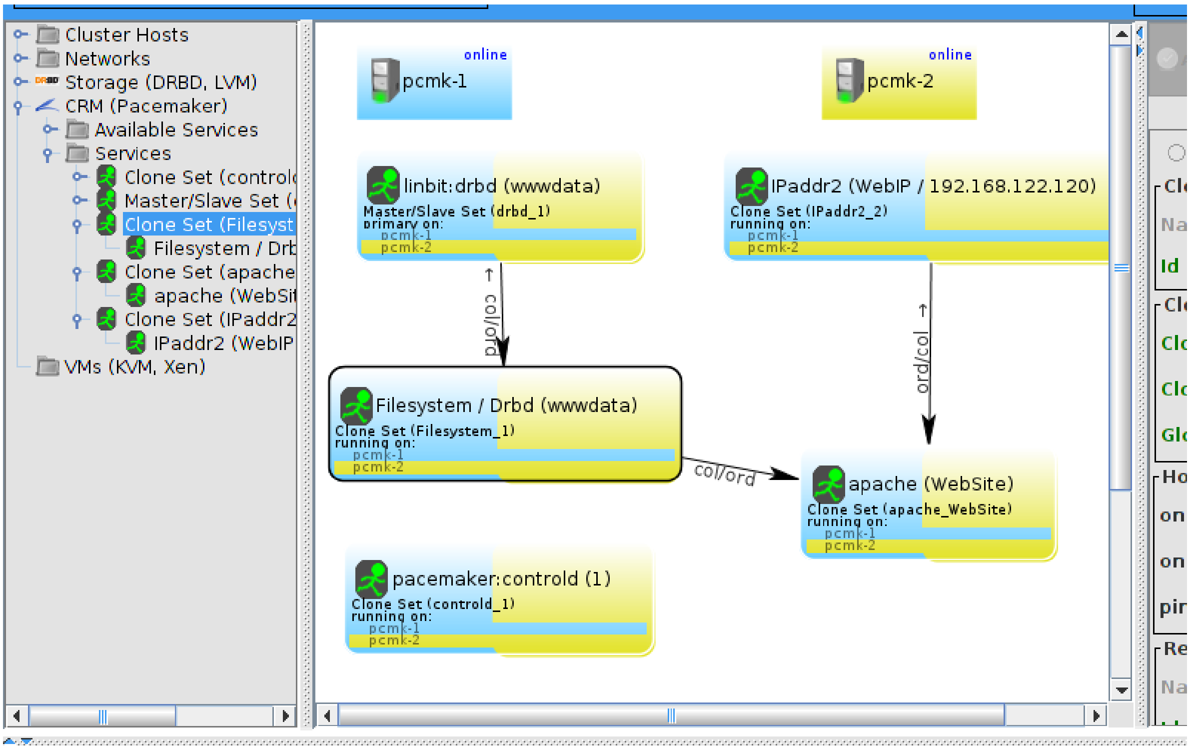


Now we must tell the ClusterIP how to decide which requests are processed by which hosts. To do this we must specify the clusterip_hash parameter.



Next we need to convert the filesystem and Apache resources into clones.

The last step is to tell the cluster that it is now allowed to promote both instances to be Primary (aka. Master).



8.4.1. Testing Recovery

Note

TODO: Put one node into standby to demonstrate failover

Configure STONITH

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9.1. 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.

9.2. 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.

9.3. Configuring STONITH

1. 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.

2. 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.

3. 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.

4. 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.

9.4. 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

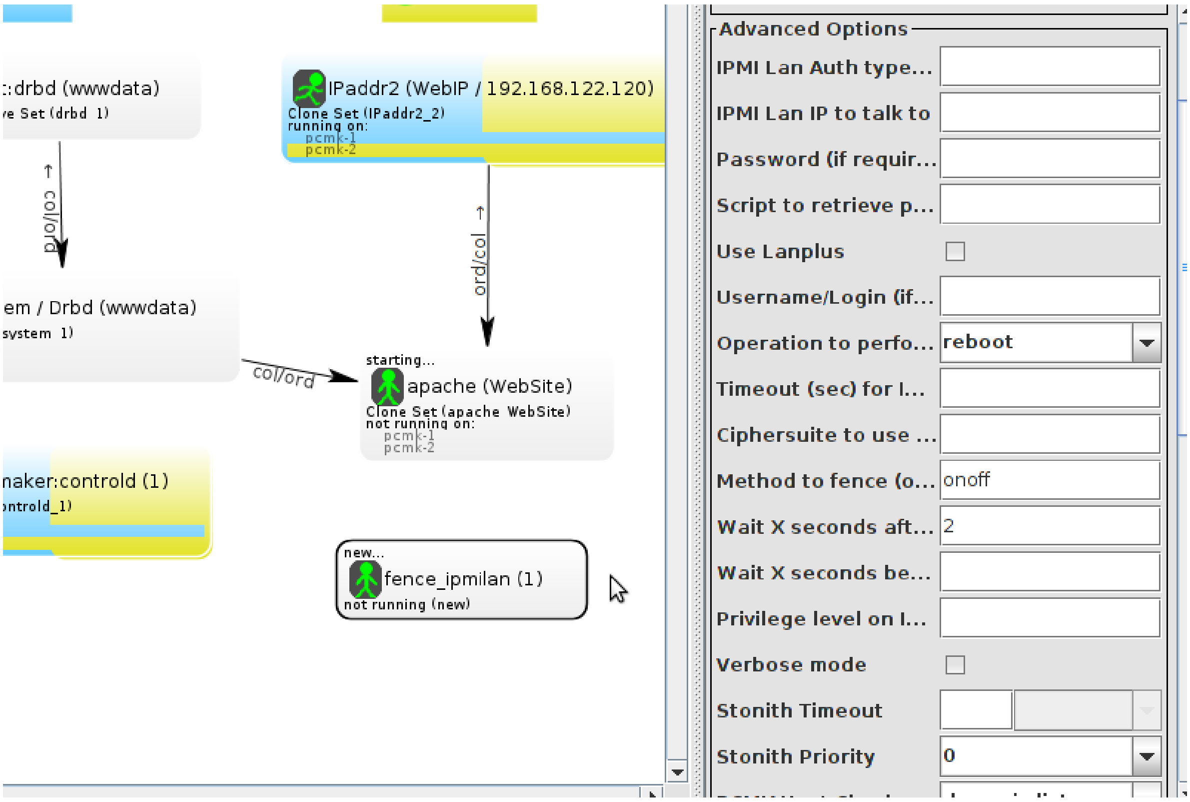


Figure 9.1. Obtaining a list of STONITH Parameters

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

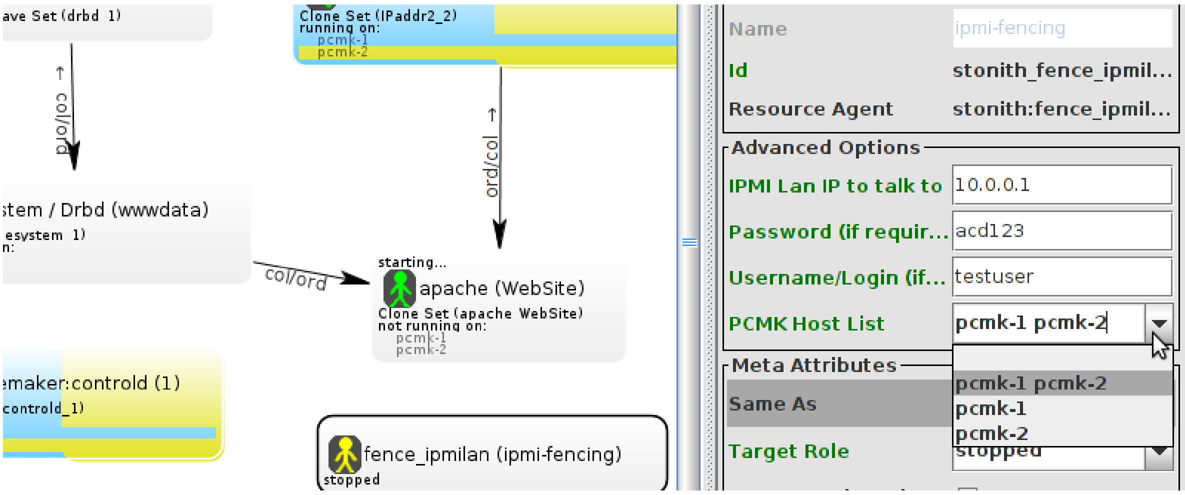
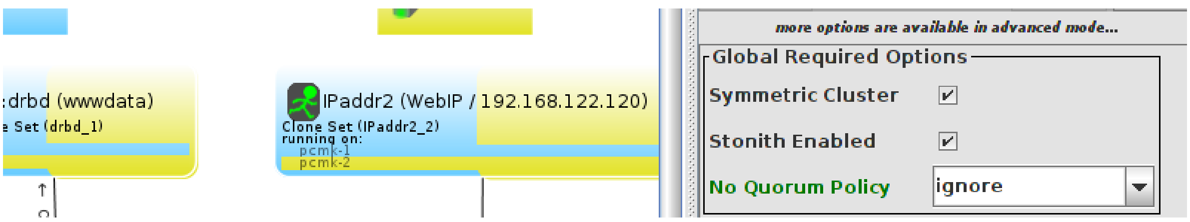


Figure 9.2. Sample STONITH Resource

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.



Appendix A. Configuration Recap

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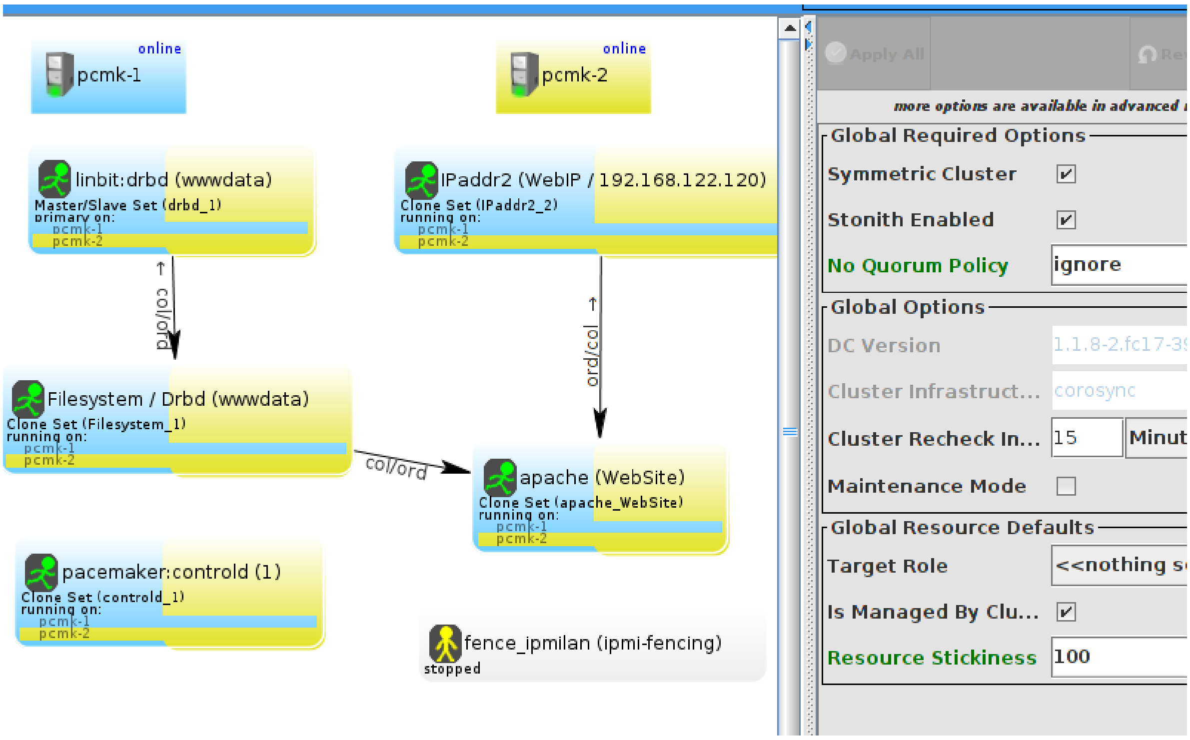
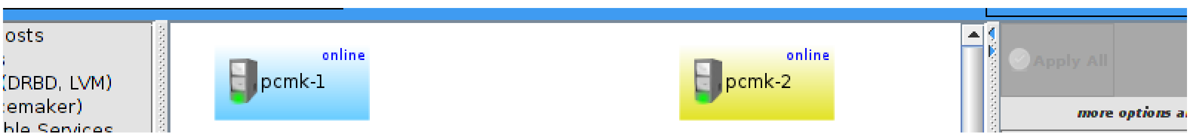
A.1. Final Cluster Configuration



A.2. Node List

The list of cluster nodes is automatically populated by the cluster.



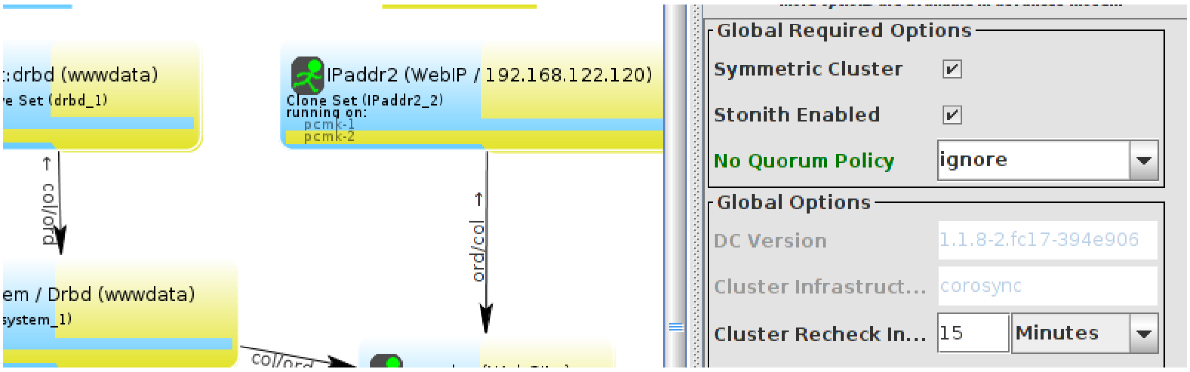
A.3. Cluster Options

This is where the cluster automatically stores some information about the cluster

- dc-version - the version (including upstream source-code hash) of Pacemaker used on the DC
- cluster-infrastructure - the cluster infrastructure being used (heartbeat or openais)
- expected-quorum-votes - the maximum number of nodes expected to be part of the cluster

and where the admin can set options that control the way the cluster operates

- stonith-enabled=true - Make use of STONITH
- no-quorum-policy=ignore - Ignore loss of quorum and continue to host resources.

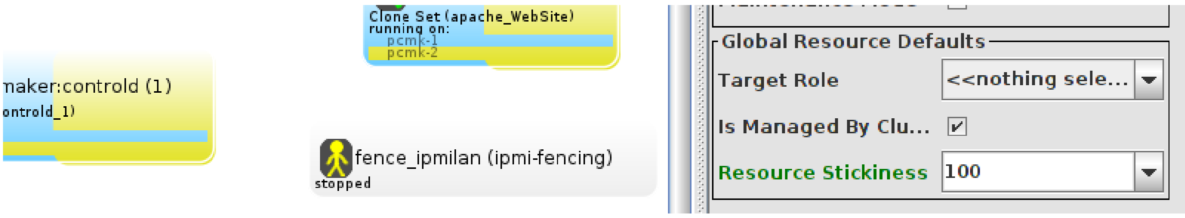


A.4. Resources

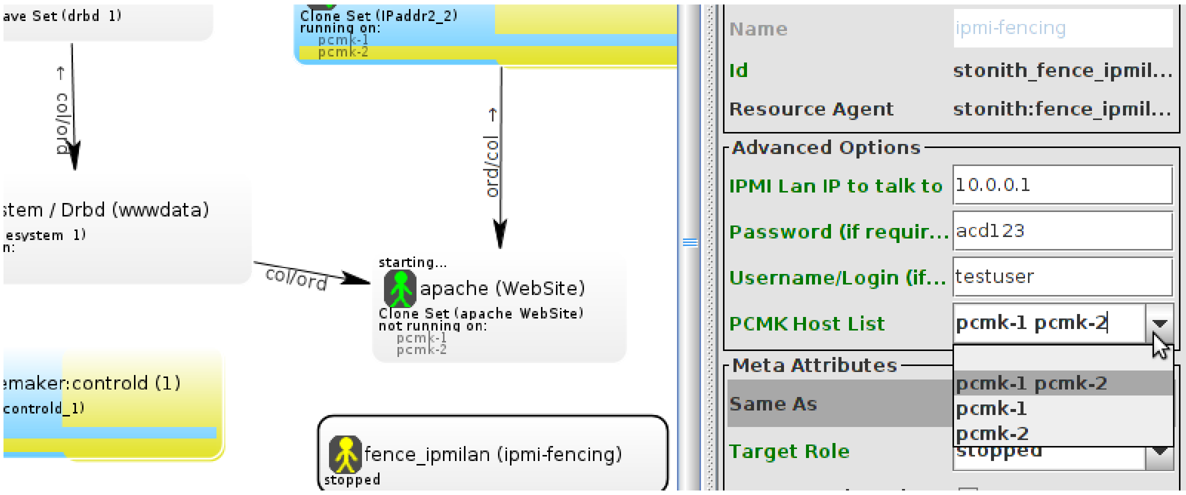
A.4.1. Default Options

Here we configure cluster options that apply to every resource.

- resource-stickiness - Specify the aversion to moving resources to other machines

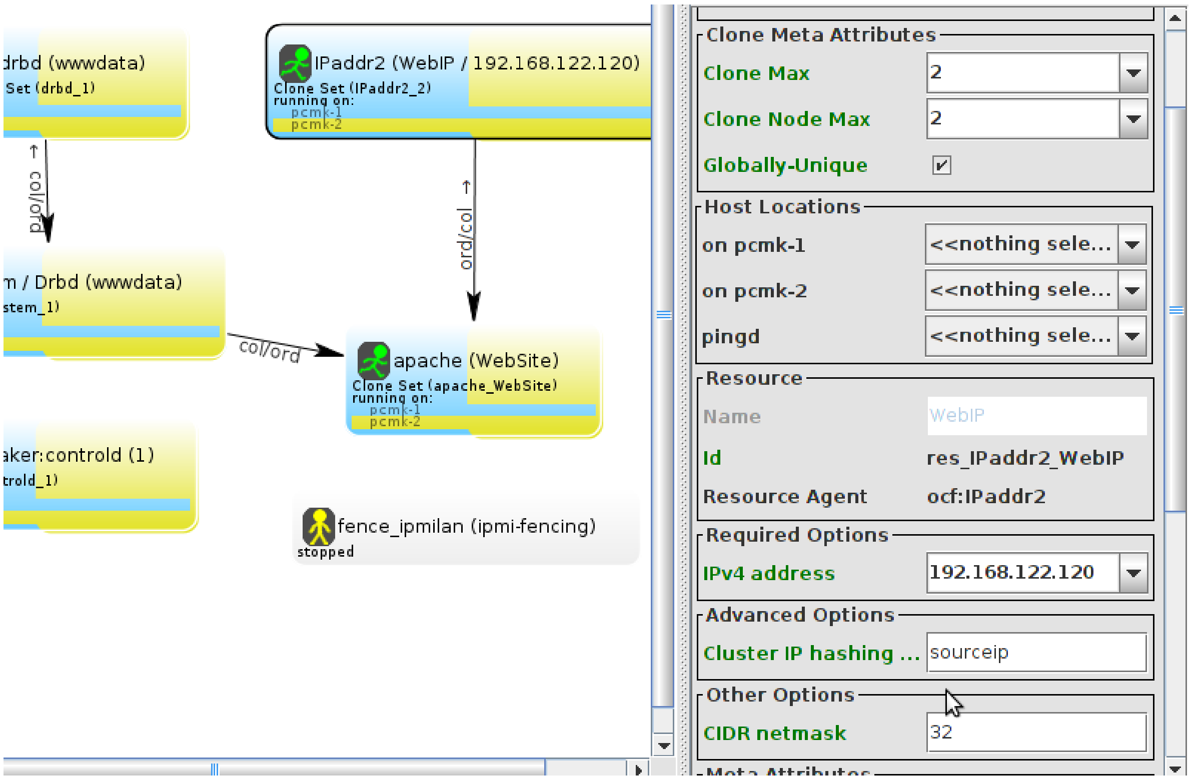


A.4.2. Fencing



A.4.3. Service Address

Users of the services provided by the cluster require an unchanging address with which to access it. Additionally, we cloned the address so it will be active on both nodes. An iptables rule (created as part of the resource agent) is used to ensure that each request only gets processed by one of the two clone instances. The additional meta options tell the cluster that we want two instances of the clone (one "request bucket" for each node) and that if one node fails, then the remaining node should hold both.

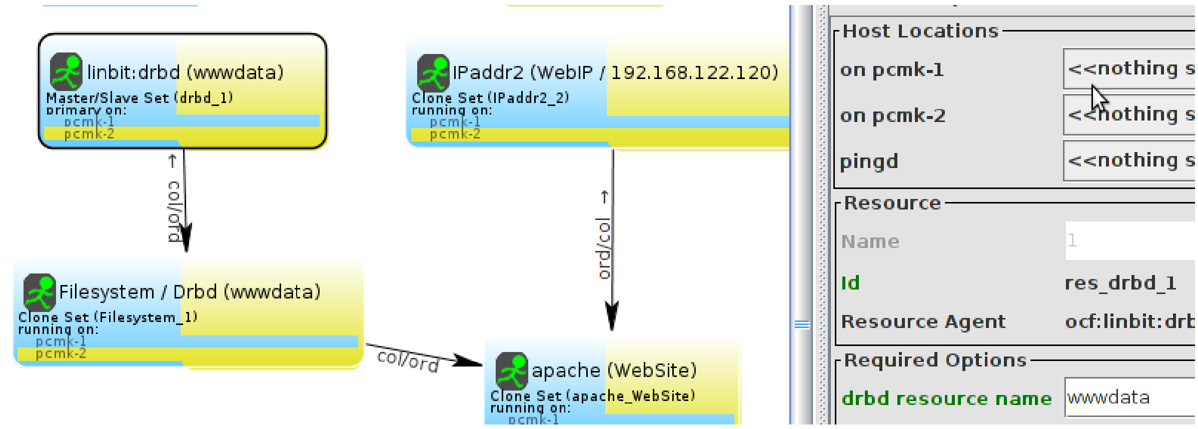


Note

TODO: The RA should check for globally-unique=true when cloned

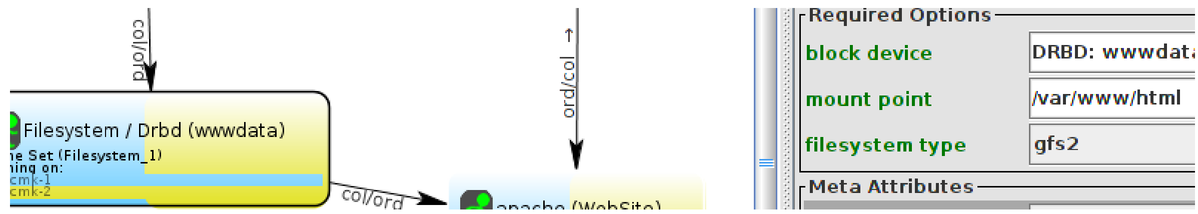
A.4.4. DRBD - Shared Storage

Here we define the DRBD service and specify which DRBD resource (from drbd.conf) it should manage. We make it a master/slave resource and, in order to have an active/active setup, allow both instances to be promoted by specifying master-max=2. We also set the notify option so that the cluster will tell DRBD agent when it's peer changes state.



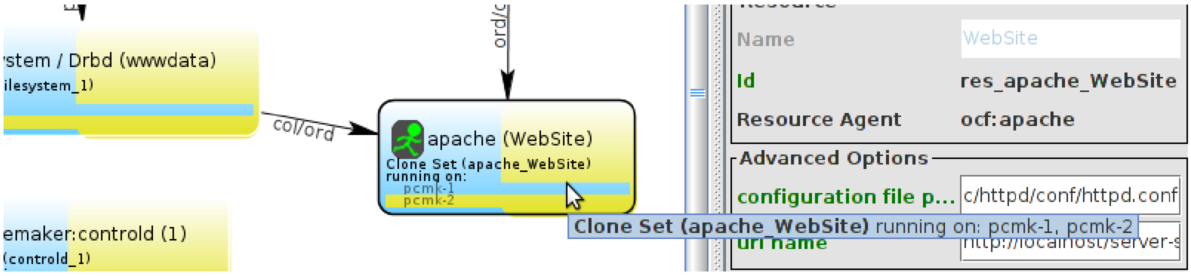
A.4.5. Cluster Filesystem

The cluster filesystem ensures that files are read and written correctly. We need to specify the block device (provided by DRBD), where we want it mounted and that we are using GFS2. Again it is a clone because it is intended to be active on both nodes. The additional constraints ensure that it can only be started on nodes with active gfs-control and drbd instances.



A.4.6. Apache

Lastly we have the actual service, Apache. We need only tell the cluster where to find it's main configuration file and restrict it to running on nodes that have the required filesystem mounted and the IP address active.


stem / Drbd (wwwdata)
col/ord
ord/c
apache (WebSite)
Clone Set (apache_WebSite)
running on:
pcmk-1
pcmk-2
emaker:controld (1)
Name
WebSite
Id
res_apache_WebSite
Resource Agent
ocf:apache
Advanced Options
configuration file p...
c/httpd/conf/httpd.conf
Clone Set (apache_WebSite) running on: pcmk-1, pcmk-2

Appendix B. Sample Corosync Configuration

Sample corosync.conf for two-node cluster using a node list.

```
# Please read the corosync.conf.5 manual pagetotem {version: 2secauth: offcluster_name:
 myclustertransport: udpu}nodelist {  node {        ring0_addr: pcmk-1        nodeid:
 1  }  node {        ring0_addr: pcmk-2        nodeid: 2  }}quorum {  provider:
 corosync_votequorum}logging {  to_syslog: yes}
 pagetotem
 {version:
 2secauth:
 offcluster_name:
 myclustertransport:


udpu}nodelist
 {  node
 {        ring0_addr:
 pcmk-1        nodeid:
 1
 }  node
 {        ring0_addr:
 pcmk-2        nodeid:
 2


}}quorum
 {  provider:


corosync_votequorum}logging
 {  to_syslog:
```

Appendix C. Further Reading

- Project Website *http://www.clusterlabs.org*
- Cluster Commands A comprehensive guide to cluster commands has been written by SuSE and can be found at: *http://www.suse.com/documentation/sle_ha/book_sleha/?page=/documentation/sle_ha/book_sleha/data/book_sleha.html*
- Corosync *http://www.corosync.org*

Appendix D. Revision History

Revision 1	**Mon May 17 2010**	**Andrew Beekhof** *andrew@beekhof.net*

Import from Pages.app

Revision 2	**Wed Sep 22 2010**	**Raoul Scarazzini** *rasca@miamammausalinux.org*

Italian translation

Revision 3	**Wed Feb 9 2011**	**Andrew Beekhof** *andrew@beekhof.net*

Updated for Fedora 13

Revision 4	**Wed Oct 5 2011**	**Andrew Beekhof** *andrew@beekhof.net*

Update the GFS2 section to use CMAN

Revision 5	**Fri Feb 10 2012**	**Andrew Beekhof** *andrew@beekhof.net*

Generate docbook content from asciidoc sources

Revision 6	**Tues July 3 2012**	**Andrew Beekhof** *andrew@beekhof.net*

Updated for Fedora 17

Revision 7	**Fri Sept 14 2012**	**David Vossel** *dvossel@redhat.com*

Updated for pcs

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