

Cloud Tutorial

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Audience:

This document is a hands-on guide to the VSC cloud computing platform, which relies on the open-source software [OpenStack](#). It should complement the official documentation at <https://docs.openstack.org>.

Contact Information:

For all questions concerning the VSC cloud computing platform, please contact cloud@vscentrum.be.

We welcome your feedback, comments and suggestions for improving the OpenStack Tutorial

Glossary

NFS Network File System, a protocol for sharing file systems across a network, often used on Unix(-like) operating systems.

NIC Network Interface Controller, a (virtualized) hardware component that connects a computer to a network.

REST REpresentational State Transfer is a software architectural style that defines a set of constraints to be used for creating web services.

YAML A human-readable text-based data serialization format.

Heat Heat is the OpenStack orchestration service, which can manage multiple composite cloud applications using templates, through both an OpenStack-native REST API and a CloudFormation-compatible Query API.

Heat Orchestration Template A Heat Orchestration Template (HOT) is a text file which describes the infrastructure for a cloud application. Because HOT files are text files in a YAML-based format, they are readable and writable by humans, and can be managed using a version control system. HOT is one of the template formats supported by Heat, along with the older CloudFormation-compatible CFN format.

Horizon Horizon is the name of the OpenStack Dashboard.

OpenStack OpenStack (<https://www.openstack.org>) is a free and open-source software platform for cloud computing, mostly deployed as infrastructure-as-a-service (IaaS), whereby virtual servers and other resources are made available to customers.

OpenStack Dashboard OpenStack Dashboard (Horizon) provides administrators and users with a graphical interface to access, provision, and automate deployment of cloud-based resources. The design accommodates third party products and services, such as billing, monitoring, and additional management tools. The dashboard is also brand-able for service providers and other commercial vendors who want to make use of it. The dashboard is one of several ways users can interact with OpenStack resources. Developers can automate access or build tools to manage resources using the native OpenStack API or the EC2 compatibility API..

OpenStack Instance OpenStack Instances are virtual machines, which are instances of a system image that is created upon request and which is configured when launched. With traditional virtualization technology, the state of the virtual machine is persistent, whereas OpenStack supports both persistent and ephemeral image creation.

OpenStack Volume OpenStack Volume is a detachable block storage device. Each volume can be attached to only one instance at a time.

share A share is a remote, mountable file system. Users can mount and access a share on several hosts at a time.

stack In the context of OpenStack, a stack is a collection of cloud resources which can be managed using the Heat orchestration engine.

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Introduction

The VSC cloud platform uses the open-source software [OpenStack](#), version “rocky”. This guide explains the specifics of the VSC environment, and provides a hands-on introduction to OpenStack. For reference, you should consult the OpenStack project’s own documentation at <https://docs.openstack.org>.

Chapter 1

Access to the VSC Cloud

Access to the VSC Cloud is linked to the central VSC account system (account.vscentrum.be), so you do not need a separate login or password. In order to use the cloud services,

- you need an active VSC account and
- your account must be a member of one or more OpenStack projects.

New users can obtain an account by following [the procedure described here](#). Once you have an account, contact cloud@vscentrum.be if you want to start a new OpenStack project, or join an existing one.

You can interact with the VSC Cloud using the OpenStack Dashboard, a web interface, or the OpenStack command line interface, which you can use from any system, and which is installed for you on the UGent login node `login.hpc.ugent.be`. You can log in to the Dashboard using the VSC accountpage, as illustrated in the next section. To get access from the command line interface, you'll need to obtain an application credential, as explained in section [1.2](#).

These restrictions do not apply to someone who simply wishes to access an existing VM running in the cloud. VSC Cloud projects can decide themselves who gets access to their VM's, and how.

1.1 Dashboard Login

You can access the OpenStack web interface, or Dashboard, via cloud.vscentrum.be.

To log in, choose the (default) authentication method *VSC Accountpage* and click **Connect**.

From here on, follow the standard procedure to log in to your VSC account, using your home institution's single sign-on system. You can find a detailed description in the HPC introduction at hpcugent.github.io/vsc_user_docs. The following chapters explain how to accomplish basic tasks using the Dashboard.

1.2 Application Credentials

If you want to use the OpenStack command line interface — or, for advanced users, use the OpenStack APIs directly — you need to identify yourself using an application credential. An application credential contains a secret piece of information which grants access to an OpenStack project on your behalf.

You can create an application credential using the dashboard:

1. Log in to the dashboard, and, if you are a member of more than one project, select the project for which you want to create an application credential.
2. Open the **Identity** tab, and click **Application Credentials**.
3. You can now see an overview of your application credentials (initially none). Click **Create Application Credential**.
4. Fill out the **Create Application Credential** dialog:

Name, Description Choose a name (mandatory) and description that remind you of the purpose of this credential.

Secret We recommend to leave this empty, in which case OpenStack will generate a random secret for you.

Expiration Date, Expiration Time It is good practice make the token expire. An expiration date limits the impact if the secret is accidentally exposed, and you can always create a new credential when an old one is expired.

Roles A role defines a set of access rights. By selecting a subset of roles for this credential, you can limit the access rights granted by this credential. It is a good idea to select only the minimal set of roles required for the task you want to accomplish.

Click **Create Application Credential**.

5. A summary dialog with the credential's id, name, and secret is displayed. If you close the window, you can't retrieve the secret anymore, so you should save it now. A convenient solution is to download the openrc file, a shell script that sets the appropriate environment variables for the command line interface.

The newly created credential is now shown in the overview. If you accidentally expose a credential somewhere, you should delete it here to prevent unauthorized access to the system.

Chapter 2

The OpenStack Dashboard

After login, you can see the Overview tab of Horizon, the OpenStack Dashboard.



This chapter briefly describes the different components of the dashboard. You can read the official documentation at <https://docs.openstack.org/horizon/rocky/user>.

Note: The VSC cloud uses a customized dashboard. Some features mentioned in the official OpenStack documentation were intentionally removed, please contact cloud@vscentrum.be if you need access to one of these disabled features.

Project tab

Resources (instances, data volumes, networks, ...) in OpenStack are organized into different projects, and every user is a member of one or more projects. Every project member has full access to all of the project's resources.

From the Project tab, you can access the following categories:

API Access View API endpoints.

Compute

- Overview: View reports for the project.
- Instances: View, launch, create a snapshot from, stop, pause, or reboot instances, or connect to them through VNC.
- Images: View images and instance snapshots created by project users, plus any images that are publicly available. Create, edit, and delete images, and launch instances from images and snapshots.
- Key Pairs: View, create, edit, import, and delete key pairs.
- Server Groups: Server groups provide a mechanism to group servers according to certain policy.

Volumes

- Volumes: View, create, edit, and delete volumes.
- Snapshots: View, create, edit, and delete volume snapshots.

Network

- Networks: Create and manage public and private networks.
- Security Groups: View, create, edit, and delete security groups and security group rules..
- Floating IPs: Allocate an IP address to or release it from a project

Orchestration

- Stacks: Use the REST API to orchestrate multiple composite cloud applications.
- Resource types: Show a list of all the supported resource types for HOT templates.
- Template versions: The version of a Heat template specifies the format of the template and also the corresponding features that will be validated and supported.
- Template generator: A graphical interface to build and edit templates.

Shares

- Shares: Create and manage shares.

Identity tab

From the Identity tab, you can access the following categories:

Projects View, create, assign users to, remove users from, and delete projects.

Users View, create, enable, disable, and delete users.

Application Credentials With application credentials, a user can grant applications limited access to their cloud resources.

Chapter 3

Upload and manage images

A virtual machine image, referred to in this document simply as an image, is a single file that contains a virtual disk that has a bootable operating system installed on it. Images are used to create virtual machine instances within the cloud. The image files themselves are never modified, but you can copy the image into a persistent instance (see chapter 6).

As a user of the VSC cloud, you can upload and manage your own virtual machine images. For information about creating image files, see the [OpenStack Virtual Machine Image Guide](#).

Note: Shared storage in the VSC cloud is connected to a separate network, which is only accessible from within the OpenStack environment. Therefore, if you want to access your VM from outside of OpenStack, and use the shared storage at the same time, you must make sure your VM image is configured use multiple network interface cards (NICs).

You can choose who can access an image you have created. The following access policies for images exist:

public Public images are provided by the VSC, and can be accessed by all users.

private If you create a private image, only members of the same project have access.

shared You can also choose to share your image with a list of other projects.

community Community images are user-created images which are freely accessible to all other users.

Note: You can also use the **openstack** and **glance** command-line clients or the Image service to manage images.

Upload an image

Follow this procedure to upload an image to a project:

1. Open the Compute tab and click Images category.
2. Click Create Image.

The Create An Image dialog box appears.

3. Enter the following values:

Image Name Enter a name for the image.

Image Description Enter a brief description of the image.

Image Source

File Browse for the image file on your file system and add it.

Format Select the image format (for example, QCOW2) for the image.

Image Requirements

Architecture Specify the architecture. For example, **i386** for a 32-bit architecture or **x86_64** for a 64-bit architecture.

Kernel, Ramdisk Can be left empty, as this is determined by the image file.

Minimum Disk (GB), Minimum RAM (MB) Choose suitable values, according to the requirements of your image's operating system.

Protected If set to **Yes**, users need to unlock the image before they are able to delete it.

Metadata You can add resource metadata in this tab. The glance Metadata Catalog provides a list of metadata image definitions.

4. Click **Create Image**. The image is queued to be uploaded. It might take some time before the status changes from Queued to Active.

Update an image

Follow this procedure to update an existing image.

1. Open the project tab and click the Images category.

2. Select the image that you want to edit.
3. In the Actions column, open the drop-down menu and select **Edit Image**.
4. In the Edit Image dialog box, you can perform various actions. For example:
 - Change the name of the image.
 - Change the description of the image.
 - Change the format of the image.
 - Change the minimum disk of the image.
 - Change the minimum RAM of the image.
 - Change the protected status of the image.
 - Change the metadata of the image.
5. Click **Edit Image**.

Chapter 4

Instance types and flavors

VSC Tier1 Cloud provides several virtual machine instance types and flavors to fit different use cases. Each instance type provides several flavor sizes to give different combinations of CPU, memory, GPU and network resource.

4.1 Instance Types

The following table provides the current main instance types available from VSC Tier1 Cloud infrastructure:

UPSv1	CPUv1	GPUv1
<ul style="list-style-type: none">• AMD Epyc 7542 2.9GHz• vCPU oversubscription 2:1• 25Gbit Ethernet• Uninterruptible Power Supply (UPS)	<ul style="list-style-type: none">• Intel Xeon CPU E5-2670 2.60GHz• 10Gbit Ethernet	<ul style="list-style-type: none">• AMD Epyc 7542 2.9GHz• 25Gbit Ethernet• NVIDIA Tesla 4 GPU

Table 4.1: Instance types hardware profiles

Each instance type is appropriate for different workloads. From regular CPU usage (**CPUv**<version> instance types), to high performance GPU computations (**GPUv**<version>) or VMs connected to uninterruptible power supplies (**UPSv**<version>). VMs using UPS flavor types will be keep up and running even if the data centre suffers an unexpected power cut.

VSC Tier-1 Cloud instance types also provide different kind of network performance specifications. All the instance types are able to connect to the available networks: public network, VSC network and shared filesystem network (NFS). VSC and shared file system networks are only available by project's request.

VSC network gives an optimal path towards other VSC sites (ideal for high performance connections between different clusters and services within VSC). On the other hand, the shared

filesystem network is required by the OpenStack shared filesystem service (Manila) (see chapter 9 for more information).

4.2 Flavor Sizes

A flavor size is a set of virtualized hardware resources to a virtual machine (VM) instance like system memory size, virtual CPU (vCPU) or the root filesystem size.

The flavor's root size is the amount of disk space used by the root (/) partition, an ephemeral disk that the base image is copied into (see section 6.1 for more information about VM persistent/non-persistent instances).

The flavor's root ephemeral storage is only used when booting from a non-persistent VM but not from a persistent storage volume or persistent VM. The flavor's root ephemeral size is not taken into account to calculate the project's local storage quota either. You can also create a persistent volume and choose the desired filesystem size for your persistent VM during the instantiation. VM persistent volumes could be resized later if that is necessary (see next chapter 6 for more information).

VSC Tier-1 Cloud VM flavors are grouped by instance types (see table 4.1). The current flavor sizes are available for each instance type and can be used in different combinations to fit different workload hardware requirements.

Flavor Size	RAM	Root Disk	vCPUs
small	2Gb	20Gb	1
medium	4Gb	30Gb	2
large	8Gb	40Gb	4
xlarge	16Gb	40Gb	8
1_2xlarge	62Gb	40Gb	8
2xlarge	62Gb	40Gb	16
3xlarge	120Gb	80Gb	16

Table 4.2: Flavor sizes

E.g. **GPUv1.large** OpenStack flavor will instantiate a VM with 4 AMD Epyc 7542 2.9GHz CPUs, with a NVIDIA Tesla 4 GPU, 8GB of ram, 40Gb of root disk and connected to the UPS.

Chapter 5

Configure access and security for instances

The security and accessibility of your cloud resources is governed by a few different aspects, which we discuss more detail in the following sections:

- Instances must connect to the project's `_vm` network in order to communicate (see section [5.1](#)).
- Each cloud project can use one floating IP, a public IP address which you'll need to link to the resources you want to access (see section [5.2](#)).
- By default, the UGent firewall blocks most IP addresses and ports. Only the port range 50000-60000 for the floating IP addresses is open by default. Contact cloud@vscentrum.be if you need to access other ports from the outside world.
- The OpenStack environment has its own internal firewalls, which block most ports of your instances by default. If you want to access specific ports of your instances, you must create "Security Groups" which allow access to those ports (see section [5.3](#)).
- You can use one or more SSH keys from your VSC account to access your instances (see section [5.4](#)).

For other access methods, or SSH authentication for a wider set of users, you'll need to set up some form of identity management yourself. This system administration task is beyond the scope of our tutorial.

5.1 The `_vm` and `_nfs` networks

Each project in the VSC cloud has its own network `<projectname>_vm` and — if the project uses shares — `<projectname>_nfs`. Each is a subnet of 254 addresses, with an ip range `10.10.x.0/24`, where `x` is a number that depends on the project and network. To see the subnets for your project's networks, open the Network tab, and select Networks.

Instances should use the `_vm` network for communication, and the `_nfs` network if they need access to shared file systems (see chapter [9](#)). When an instance is created in OpenStack and

connected to the `_vm` or `_nfs` networks, it is automatically assigned a fixed IP address in that network. This IP address is permanently associated with the instance until the instance is terminated.

5.2 Floating IP addresses

The `_vm` and `_nfs` networks can only be reached from within the OpenStack environment. If you need to access an instance from the outside, you need to use one of your project's floating IP addresses, which are public IP addresses. Unlike fixed IP addresses, floating IP addresses can have their associations modified at any time, regardless of the state of the instances involved.

This section explains how to make your instance accessible via a public IP address by two different methods. The preferred method is to use port forwarding to access multiple instances using the same IP address, but you can also use a “floating IP association” for quick tests.

Floating ip port forwarding

OpenStack's networking API, called Neutron, makes it possible to forward different ports of the same floating ip to arbitrary ports in one of OpenStack's virtual networks. This is the recommended way to use floating ip's in the VSC cloud. For the floating IP's available in the VSC Cloud, the high port range 50000-60000 is open to the outside world, so it is most convenient to work with ports from this range. Contact cloud@vscentrum.be if you need public access to another port for a specific ip address.

You'll need to forward a separate port for every service you wish to reach. For example, if you want to access an instance using SSH, you'll need to create a port forwarding rule from a selected port of the floating IP, to the port in the `_vm` network where your instance's SSH server is listening (typically port 22).

You can quickly set up such forwarding rules using `neutron_port_forward`, a command line tool available on the UGent login node, `login.hpc.ugent.be`. In order to use it, you must create an application credential for the role “User”, and save it as an openrc file (see section 1.2 on page 9). Transfer the openrc file to your VSC storage space, so `neutron_port_forward` can read it. To set up new port forwarding rules, run the script providing the path to the openrc file as an argument to the `-o` option, and a file describing your port forwarding configuration as argument to the `-m` option:

```
$ neutron_port_forward -o <openrc file.> -m <ini-file>
```

The following is an example configuration file:

```
1 [DEFAULT]
2 floatingip=193.190.85.40
3 network=_vm
4
5 [classa]
6 pattern=classa-(\d+)
7 22=52000:100:22
8 5900=55900
9
10 [classb]
```

```
11 pattern=classb-(\d+)
12 80=52080
```

Here we define defaults for the floating ip and target network, and two classes. Instances are assigned to a class if their name matches the regular expression given in `pattern`. The value of `pattern` must be a valid Python regular expression, and the first capturing group (if any) must match an integer.

Port forwarding rules are given in the form `target=source(:multiplier:offset)`. This will set up a forwarding rule from the floating IP port

$$(\text{source} + \text{multiplier} * i + \text{offset}) \rightarrow \text{target},$$

where i is the integer matched by the first capturing group, and “target” is a port of the fixed IP for the instance in the chosen network, in this case the `_vm` network. “multiplier” and “offset” are optional and default to 1 and 0 respectively. In our example, this results in the following set of port forwarding rules for the public IP address 193.190.85.40:

```
52122 → classa-1:22
52222 → classa-2:22
...
55901 → classa-1:5900
55902 → classa-2:5900
...
52081 → classb-1:80
52082 → classb-2:80
...
```

You can also see an overview of existing port forwarding rules for the ip addresses in your configuration file using `neutron_port_forward --show`. Each rule has an internal id, which you can see if you combine the options `--show` and `--id` as follows:

```
$ neutron_port_forward -o <openrc file.> -m <ini-file> --show --id
```

To remove port forwarding rules, use the option `--remove=<list of id's>` with a comma-separated list of the id's of the rules you want to remove. Rules are removed automatically if the target instance is deleted.

`neutron_port_forward` provides a few more options and advanced features, run the command with the `--help` option for more information.

Associate a floating ip

A floating IP address can also be associated to an instance, just like the fixed IP addresses. Because this approach uses one of the few available floating ip addresses for every instance you want to connect to, you should only use it for testing purposes, and disassociate the address when you are done.

Note: If you want to use a floating ip for port forwarding as in the previous section, it cannot be associated to an instance at the same time.

Use the following procedure to associate that address with a specific instance.

1. Open the Network tab.
2. Click the Floating IPs tab, which shows the floating IP addresses allocated to your project.
3. In the Floating IPs list, click Associate next to the address you want.
4. In the Manage Floating IP Associations dialog box, choose the following options:

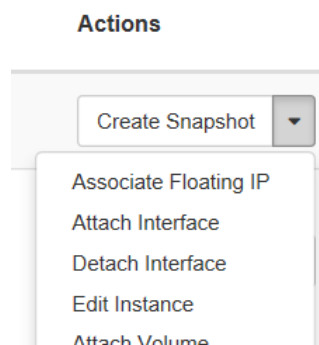
IP Address This field is filled automatically.

Port to be associated Select a port from the list. The list shows all the instances with their fixed IP addresses.

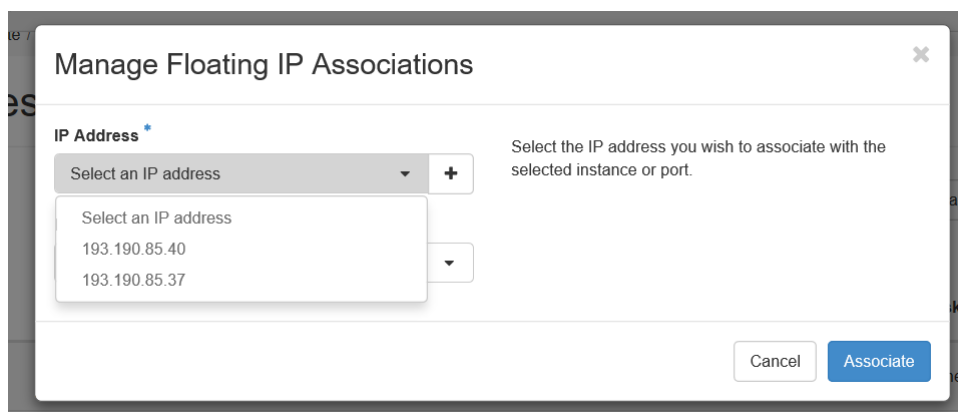
5. Click Associate.

Another way to associate a floating IP is after the user has already launched an instance which appears in the list of running instances in the Project->Compute->Instances tab:

1. Expand the drop-down menu on right next to the instance
2. Select Associate Floating IP



3. A pop-up window will appear and under IP Address select from the drop-down menu an IP address from the available pool.



4. Click Associate

If the IP has been successfully associated in the upper right corner of the browser screen will appear a green confirmation. If not successful a red notification will pop up that something went wrong.

Note: To disassociate an IP address from an instance, click the Disassociate button in the Actions column.

Warning: *Do not* use the Release Floating IP option in the Actions column or on the overview page. This will remove the floating IP from the pool assigned to your project, something which you, as a regular user, cannot undo. If you’ve accidentally released a floating IP, contact cloud@vscentrum.be to have it restored.

5.3 Security Groups

OpenStack security groups are sets of IP filter rules that define networking access. You can then assign one or more security groups to your instances.

In the VSC cloud, each project contains a default security group, which allows you to ping instances and connect using SSH on the default port 22. If you want to access other ports on your instances, create new security groups with the appropriate rules and assign them to the instances.

5.4 SSH key pairs

When an instance is launched, OpenStack can automatically install a public SSH key on it, so as to give anyone with the corresponding private key admin access. For this “key pair injection¹” to work, the image that the instance is based on must contain the **cloud-init** package, or have in place another mechanism in place that will interact with the OpenStack metadata server to install the appropriate key. For general instructions on SSH keys, we refer to chapter 2 of our [introduction to HPC](#).

If you have generated a key pair with an external tool, you can import it into OpenStack. The key pair can be used for multiple instances that belong to a project. For more information, see section 5.4.

Note: The public keys from your VSC account are automatically available in your VSC Cloud projects, so you can immediately inject one of your existing into your instances. Of course, you can also import new keys into OpenStack, which are not coupled to your VSC account. If you want to give other parties SSH access to VM’s, you must manage the keys using some other method. **Never** upload SSH keys for other users to your VSC account.

Note: Every OpenStack user account has its own collection of SSH keys for every project. To share a public key between multiple users of the same project, each user needs to import it in the OpenStack project.

¹The OpenStack documentation and interfaces consistently refer to “SSH pairs”, but of course only the public key of each pair is stored in the OpenStack environment, while the private key should be kept secure by the owner.

Add a key pair

1. Open the Compute tab.
2. Click the Key Pairs tab, which shows the key pairs that are available for this project.
3. Click Create Key Pair.
4. In the Create Key Pair dialog box, enter a name for your key pair, and click Create Key Pair.
5. Respond to the prompt to download the key pair.
6. Save the ***.pem** file locally.
7. To change its permissions so that only you can read and write to the file, run the following command:

```
$ chmod 0600 yourPrivateKey.pem
```

Note: If you are using the OpenStack Dashboard from a Windows computer, use PuTTYgen to load the ***.pem** file and convert and save it as ***.ppk**. For more information see the [WinSCP web page for PuTTYgen](#), and chapter 2 of the [introduction to HPC at VSC](#).

8. To make the key pair known to SSH, run the **ssh-add** command.

```
$ ssh-add yourPrivateKey.pem
```

Import a key pair

1. Open the Compute tab.
2. Click the Key Pairs tab, which shows the key pairs that are available for this project.
3. Click Import Key Pair.
4. In the Import Key Pair dialog box, enter the name of your key pair, copy the public key into the Public Key box, and then click Import Key Pair.

The Compute database registers the public key of the key pair.

The OpenStack Dashboard lists the key pair on the Key Pairs tab.

Chapter 6

Launch and manage instances

Instances are virtual machines that run inside the cloud. You can launch an OpenStack Instance from the following sources:

- Images uploaded to the Image service.

Note: Because images are read-only, any changes made while the instance is running will be lost when the instance is deleted, unless you choose to create a persistent volume for your instance when you launch it. Using a volume, the VM's state is saved, even when the current instance is deleted.

- Images which you previously copied to a persistent volume. The instance launches from the volume.
- Instance snapshots.

6.1 Launch an instance

1. Open the Compute tab and select the Instances category.

The dashboard shows the list of existing instances with their name, IP addresses, flavor, status, power state, ...

2. Click **Launch Instance**.
3. In the Launch Instance dialog box, specify the following values:

Details tab

Instance Name Assign a name to the virtual machine.

Note: The name you assign here becomes the initial host name of the server. If the name is longer than 63 characters, the Compute service truncates it automatically to ensure dnsmasq works correctly.

After the server is built, if you change the server name in the API or change the host name directly, the names are not updated in the dashboard.

Server names are not guaranteed to be unique when created so you could have two instances with the same host name.

Description You can assign a brief description of the virtual machine.

Availability Zone Large-scale OpenStack systems may consist of multiple availability zones, which are groups of hypervisors connected to different power sources. By assigning instances to different availability zones, users can protect themselves against power failures. However, the VSC cloud consists of just a single zone, called **nova**.

Count To launch multiple instances, enter a value greater than 1. The default is 1.

Launch Instance

Instance source is the template used to create an instance. You can use an image, a snapshot of an instance (image snapshot), a volume or a volume snapshot (if enabled). You can also choose to use persistent storage by creating a new volume.

Select Boot Source

Image

Create New Volume

Yes No

Delete Volume on Instance Delete

Yes No

Volume Size (GB)

1

Allocated

Name	Updated	Size	Type	Visibility
Select an item from Available items below				

Available 10

Select one

Q Click here for filters.

Name	Updated	Size	Type	Visibility
------	---------	------	------	------------

Source tab

Select Boot Source Your options are:

Image

Image snapshot

Volume

Volume snapshot

Depending on the type of boot source, the list of available items changes.

Create New Volume If you enable this option when launching from an image or instance snapshot, the image or snapshot will be copied to a volume. This way, the state of your instance persists after shutdown and reboot.

Flavor tab. Specify the size of the instance to launch.

Note: The flavor is selected based on the size of the image selected for launching an instance. For example, while creating an image, if you have entered the value in the Minimum RAM (MB) field as 2048, then on selecting the image, the default flavor is **CPUv1.small** (see section 4.1 for more information). If a '!' warning sign is displayed next to a resource for one of the flavors, that means that this flavor would exceed the project's quota for that resource, and therefore is not available.

Networks tab. Add one or more networks to the instance.

Network Ports tab. Activate the ports that you want to assign to the instance.

Security Groups tab. Activate the security groups that you want to assign to the instance.

Security groups are a kind of cloud firewall that define which incoming network traffic is forwarded to instances. See section 5 on page 23 for more information.

The default security group is assigned to the instance automatically.

Key Pair tab. Specify a key pair.

If the image uses a static root password or a static key set (neither is recommended), you do not need to provide a key pair to launch the instance.

Configuration tab. Specify a customization script that runs after your instance launches.

Server Groups tab. You can organize instances into groups with a scheduling policy. With an “affinity” policy, OpenStack will try to schedule those instances on the same hypervisors, which is useful for instances that need to communicate with each other a lot. With an “anti-affinity” policy, instances will be scheduled on different hypervisors, which you might use for instances that provide redundant copies of a single service.

Scheduler Hints tab. By providing scheduler hints, you can get more fine grained control over which hypervisor your instances are scheduled on.

Metadata tab. Add Metadata items to your instance.

4. Click **Launch Instance**.

The instance starts on a compute node in the cloud.

Note: If you did not provide a key pair, security groups, or rules, users can access the instance only from inside the cloud through VNC. Even pinging the instance is not possible without an ICMP rule configured.

You can also launch an instance from the Images or Volumes category when you launch an instance from an image or a volume respectively.

When you launch an instance from an image, OpenStack creates a local copy of the image on the compute node where the instance starts.

For details on creating images, see [Creating images manually](#) in the *OpenStack Virtual Machine Image Guide*.

6.2 Connect to an instance using SSH

Before you can connect to an instance using SSH, you must set up a floating IP for it, as discussed in section 5.2. Recall that only ports 50000 to 60000 of the floating IP’s can be directly reached from outside the UGent network.

Note: When you try to connect to a new instance using a port that was previously forwarded to a different instance — either due to a change in the port forwarding configuration, or because an old instance was deleted and replaced — your SSH client will show an error message because the “host key” of the new instance doesn’t match the known previous key. Section [Host keys](#) explains how to handle such errors.

Note: If you want to access ports outside the public range, you’ll need to connect to the UGent login node `login.hpc.ugent.be` first, and hop to your instance from there. To make this work without storing the required private key for the instance in your VSC storage space, you need to set up an SSH agent with key forwarding locally, i.e. on the machine where you store the private key of an authorized keypair for the instance. Section 2.1.4 of the HPC introduction explains how to set this up (hpcugent.github.io/vsc_user_docs).

0. (*Only if using a port blocked by the UGent firewall, see the note above:*) Use your VSC account to connect to the UGent login node, using the `ssh -A` option to enable agent forwarding:

```
$ ssh -A vsc12345@login.hpc.ugent.be
```

1. Copy the address of the floating IP where your instance can be reached. In our example, the address is 193.190.85.40.
2. Connect to the instance. Use OpenSSH's `-p` option to specify the port where the instance's SSH server can be reached, e.g. for port 50022:

```
$ ssh -p 50022 ubuntu@193.190.85.40
```

When you run the above command, your SSH client may display warnings or error messages. The section [Host keys](#) explains the meaning of these messages and how you should deal with them.

Note: The images we provide do not allow SSH logins for the root user. There is a default user instead, who can get administrative privileges using `sudo`. In our example, we have used the username `ubuntu` for Ubuntu images. Attempting to log in as root will return an error message with the proper user name.

Host keys

When connecting to instances using SSH, you will sometimes see warnings or errors related to “host keys”. This section briefly explains the meaning of those errors, and how to deal with them.

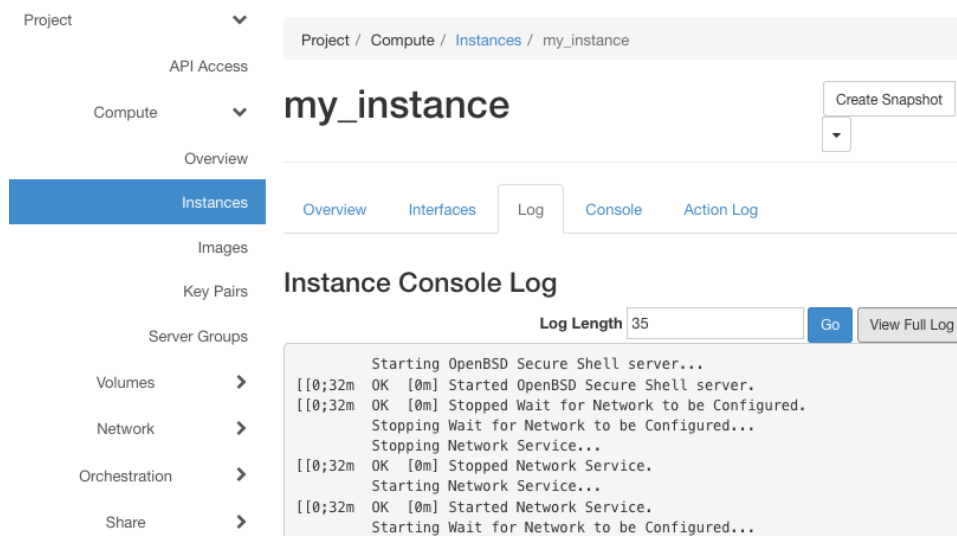
When you try to connect to an instance, you use the private key of your SSH keypair to prove your identity to that instance. If you do not have access to the right secret key, you can not prove your identity, at which point the your instance's SSH server will deny access. In the same way, the server must prove its own identity to you, using its own keypair or “host key”. Without such a verification procedure, third parties on the network between you and the instance could perform a so-called man-in-the-middle-attack, where they intercept the communication between you and the server you want to reach and steal valuable information.

To prevent such man-in-the-middle attacks, the SSH client on your system stores the host key for every IP address you have connected to, and verifies the key the next time you try to connect to that address. If all goes well, this check is silently performed in the background, but there are a number of situations where the check fails. In this case, you have to look up the host key of your instance in the OpenStack dashboard to verify that the connection is secure.

Looking up an instance's host key

In order to verify a host key, it suffices to compare the key's fingerprint, a short alphanumerical sequence computed from the keys content. You can use the Dashboard to look up the host key fingerprint for an instance as follows:

1. Open the Compute tab and select the Instances category.
2. Click on the name of the instance you want to connect to.
3. Click **Log**



4. Click **View Full Log**. You are taken to a new page with a long text listing.
5. Search for the words `-----BEGIN SSH HOST KEY FINGERPRINTS-----` to find the log file section containing the host key fingerprints, for example:

```

1 <14>Jun  6 09:57:01 ec2:
   #####
2 <14>Jun  6 09:57:01 ec2: -----BEGIN SSH HOST KEY FINGERPRINTS-----
3 <14>Jun  6 09:57:01 ec2: 1024 SHA256:gCa0hZAaOnpzxYM5WnAZINuZTI5NAoqd41U/
   dtxeGKE root@my-instance (DSA)
4 <14>Jun  6 09:57:01 ec2: 256 SHA256:nyujUIF37c674FPSkDdz0xgAU6S39UWbmMzBPmdmCmg
   root@my-instance (ECDSA)
5 <14>Jun  6 09:57:01 ec2: 256 SHA256:Mcznquek1A3BFz6KEXSxsivpdkX1mY3LnymEA7C8Xxg
   root@my-instance (ED25519)
6 <14>Jun  6 09:57:01 ec2: 2048 SHA256:4DagYc9cZvANKSjbTL0pB+3
   ULqHg09zW4E8wvDrB4Do root@my-instance (RSA)
7 <14>Jun  6 09:57:01 ec2: -----END SSH HOST KEY FINGERPRINTS-----
8 <14>Jun  6 09:57:01 ec2:
   #####

```

In this example, the fingerprints are character sequences starting with “SHA256”, such as the ECDSA key fingerprint `SHA256:nyujUIF37c674FPSkDdz0xgAU6S39UWbmMzBPmdmCmg`. The following sections describe the most common cases where you’ll need these fingerprints.

Note: The following examples show output and commands for OpenSSH, the most common client on Linux and macOS. If you are working from a windows system using using PuTTY, we refer to sections 8.4 and 8.6 of the windows version of the [introduction to HPC](#) for the corresponding warning messages.

Connecting for the first time

The first time you connect to a new ip address:port combination, your SSH client does not know the host key for this address, and therefore it can’t verify the identity of the server. When using OpenSSH, the warning looks as follows (again using address 193.190.85.40 and port 50022 as an example):

```
The authenticity of host '[193.190.85.40]:50022 ([193.190.85.40]:50022)'
can't be established.
ECDSA key fingerprint is SHA256:nyujUIF37c674FPSkDdz0xgAU6S39UWbmMzBPmdmCmg.
Are you sure you want to continue connecting (yes/no)?
```

Verify the fingerprint in order to make sure that it is safe to proceed:

1. Look up the fingerprint of the instance you want to access, according to the procedure described in the section [Looking up an instance's host key](#).
2. Verify that the fingerprint you find in the Dashboard matches the fingerprint shown in the warning message.

In this example, we see that the ECDSA key fingerprint reported by the SSH client matches the fingerprint of our instance from the previous section, namely

SHA256:nyujUIF37c674FPSkDdz0xgAU6S39UWbmMzBPmdmCmg.

3. If the fingerprints are identical, type “yes” to log in. **If the fingerprints do not match, type “no”, and contact cloud@vscentrum.be.**

New instance at a known address

Another case where the host key verification fails, is when you try to access a new instance at an IP address and port previously used by another instance. This can happen if you modify your port forwarding configuration, or if a running instance connected to a certain port is deleted and replaced by a new one. In this case, OpenSSH will show a warning such as this:

```
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!    @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
It is also possible that a host key has just been changed.
The fingerprint for the ECDSA key sent by the remote host is
SHA256:hI2HcqFxsCKwEauq2QvBmgDN4nCPjllaRsYoCb7tJQw.
Please contact your system administrator.
Add correct host key in [...]/.ssh/known_hosts to get rid of this message.
Offending ECDSA key in [...]/.ssh/known_hosts:57
ECDSA host key for [193.190.85.40]:50322 has changed and you have requested strict
checking.
Host key verification failed.
```

The file `known_hosts` in your OpenSSH configuration directory contains a list of all hosts you have previously connected to, together with their host keys. The warning above tells you that the server you are connecting to is not using the same key anymore. In this case, you should take the following steps:

1. Look up the fingerprint of the instance you want to access, according to the procedure described in the section [Looking up an instance's host key](#).
2. Verify that the fingerprint you find in the Dashboard matches the fingerprint shown in the warning message.

3. If the fingerprint matches, the new key is legitimate. Remove the previous known key from the `known_hosts` file as follows (still using address 193.190.85.40 and port number 50322 as an example):

```
$ ssh-keygen -R [193.190.85.40]:50322
```

This command causes OpenSSH to forget the previous key. On your next attempt to connect to that address, OpenSSH will treat it as a new host and ask you to verify the fingerprint as described in section [Connecting for the first time](#).

If the fingerprint does not match, do not attempt to connect, and contact cloud@vscentrum.be.

6.3 Track usage for instances

You can track usage for instances for each project. You can track costs per month by showing meters like number of vCPUs, disks, RAM, and uptime for all your instances.

1. Open the Compute tab and select the Overview category.
2. To query the instance usage for a period of time, select a time range and click **Submit**.
3. To download a summary, click **Download CSV Summary**.

6.4 Create an instance snapshot

1. Open the Compute tab and select the Instances category.
2. Select the instance from which to create a snapshot.
3. In the actions column, click **Create Snapshot**.
4. In the Create Snapshot dialog box, enter a name for the snapshot, and click **Create Snapshot**.

The Images category shows the instance snapshot.

To launch an instance from the snapshot, select the snapshot and click Launch. Proceed with launching an instance.

6.5 Manage an instance

1. Open the Compute tab and select the Instances category.
2. Select an instance.
3. In the menu list in the actions column, select the state.

You can resize or rebuild an instance. You can also choose to view the instance console log, edit instance or the security groups. Depending on the current state of the instance, you can pause, resume, suspend, soft or hard reboot, or terminate it.

Difference between *suspend*, *pause*, *shelve*, *shut off*, *delete*

Pause Stores the state of the VM in the (RAM) memory.

Suspend Stores the state of the VM on the disk, all memory is written to disk, and the server is stopped.

Shut off The server is powered down by the user, either through the OpenStack Compute API, or from within the server by issuing a *shutdown -h* command. In this state the user retains all computational resources associated with the VM. The instance can be later restarted.

Shelve Shelving stops the instance and takes a snapshot of it. Then depending on the value of the *shelved_offload_time* config option, the instance is either deleted from the hypervisor (0), never deleted (-1), or deleted after some period of time (> 0). Shelve preserves all associated data and VM resources but does not retain anything in memory.

Delete The VM is deleted and removed from OpenStack together with any associated processes and resources. However, for instances backed by a persistent volume, this volume is not deleted. When such an instance is deleted, you can restore it by launching a new instance from the volume, or delete the volume as well (see section 7).

For more details see the OpenStack documentation on [Virtual Machine States and Transitions](#) and [Server concepts](#).

Chapter 7

Create and manage volumes

An OpenStack Volume is a block storage device which you attach to instances to enable persistent storage. You can attach a volume to a running instance or detach a volume and attach it to another instance at any time. You can also create a snapshot from a volume, or delete it.

Create a volume

1. Open the Volumes tab and select the Volumes category.
2. Click **Create Volume**.

In the dialog box that opens, enter or select the following values.

Volume Name Specify a name for the volume.

Description Optionally, provide a brief description for the volume.

Volume Source Select one of the following options:

- No source, empty volume: Creates an empty volume. An empty volume does not contain a file system or a partition table.
- Snapshot: If you choose this option, a new field for Use snapshot as a source displays. You can select the snapshot from the list.
- Image: If you choose this option, a new field for Use image as a source displays. You can select the image from the list.
- Volume: If you choose this option, a new field for Use volume as a source displays. You can select the volume from the list. Options to use a snapshot or a volume as the source for a volume are displayed only if there are existing snapshots or volumes.

Type Leave this field blank.

Size (GB) The size of the volume in gibibytes (GiB).

Availability Zone Select the Availability Zone from the list. By default, this value is set to the availability zone given by the cloud provider (for example, **us-west** or **apac-south**). For some cases, it could be **nova**.

3. Click **Create Volume**.

The dashboard shows the volume on the Volumes tab.

Attach a volume to an instance

After you create one or more volumes, you can attach them to instances. You can attach a volume to one instance at a time.

1. Open the Volumes tab and click Volumes category.
2. Select the volume to add to an instance and click **Manage Attachments**.
3. In the Manage Volume Attachments dialog box, select an instance.
4. Enter the name of the device from which the volume is accessible by the instance.

Note: The actual device name might differ from the volume name because of hypervisor settings.

5. Click **Attach Volume**.

The dashboard shows the instance to which the volume is now attached and the device name.

You can view the status of a volume in the Volumes tab of the dashboard. The volume is either Available or In-Use.

Now you can mount, format, and use the volume from this instance.

Detach a volume from an instance

1. Open the Volumes tab and select the Volumes category.
2. Select the volume and click **Manage Attachments**.
3. Click **Detach Volume** and confirm your changes.

A message indicates whether the action was successful.

Create a snapshot from a volume

1. Open the Volumes tab and select the Volumes category.
2. Select a volume from which to create a snapshot.
3. In the Actions column, click **Create Snapshot**.
4. In the dialog box that opens, enter a snapshot name and a brief description.
5. Confirm your changes.

The dashboard shows the new volume snapshot in Volume Snapshots tab.

Edit a volume

1. Open the Volumes tab and select the Volumes category.
2. Select the volume that you want to edit.
3. In the Actions column, click **Edit Volume**.
4. In the Edit Volume dialog box, update the name and description of the volume.
5. Click **Edit Volume**.

Note: You can extend a volume by using the Extend Volume option available in the More dropdown list and entering the new value for volume size.

Delete a volume

When you delete an instance, the data in its attached volumes is not deleted.

1. Open the Volumes tab and select the Volumes category.
2. Select the check boxes for the volumes that you want to delete.
3. Click **Delete Volumes** and confirm your choice.

A message indicates whether the action was successful.

Chapter 8

Orchestration Using Heat

Heat is the name of the OpenStack orchestration engine, which can manage complete configurations of all servers, volumes, users, networks and routers that make up a cloud application. Instead of managing every component separately, we can create, start, stop or clean up our complete application in a single step. In OpenStack, such a collection of resources is called a stack.

Heat has its own dashboard interface, which you can find under the **Orchestration** tab. Official documentation for Heat and its dashboard interface can be found at the following locations:

- <https://docs.openstack.org/heat/rocky>
- <https://docs.openstack.org/heat-dashboard/rocky>

8.1 Heat Orchestration Templates

A stack's resources and their mutual dependencies can be specified in a text file, called a Heat Orchestration Template (HOT). The syntax of these templates conforms to the YAML standard, for which many text editors provide specialized editing modes. The 'Template Guide' in the Heat documentation contains a specification of the HOT format, as well as information on how to describe the various types of resources in a template.

VSC provides some example templates at github.com/hpcugent/openstack-templates, which can serve as a starting point for your own templates, or as examples.

The following example describes a stack consisting of a single VM:

```
1 heat_template_version: 2018-08-31
2
3 description: This template instantiates a basic VM.
4
5 parameters:
6     user_key:
7         type: string
8         label: ssh_user_key
9         description: Public user ssh key to be injected in the cluster VMs
10        constraints: [ custom_constraint: nova.keypair ]
11    vm_flavour:
```

```

12     type: string
13     label: vm_flavour
14     description: Flavour for the VM
15     constraints: [ custom_constraint: nova.flavor ]
16 vm_image:
17     type: string
18     label: vm_image
19     description: Required VM image
20     constraints: [ custom_constraint: glance.image ]
21 user_network:
22     type: string
23     label: user_network
24     description: Add the required VM network
25     constraints: [ custom_constraint: neutron.network ]
26
27 resources:
28     my_server:
29         type: OS::Nova::Server
30         properties:
31             name: MyServer
32             metadata:
33                 server: master
34                 color: red
35             security_groups: [ default ]
36             networks: [ network: { get_param: user_network } ]
37             key_name: { get_param: user_key }
38             image: { get_param: vm_image }
39             flavor: { get_param: vm_flavour }

```

Our example contains four main sections:

heat_template_version The HOT specification has evolved since its initial release. The key `heat_template_version` indicates the version of the syntax used in this template. It's value can be a release date or (in recent version) the name of the version.

description Providing a description is optional, but recommended.

parameters Another optional section, `parameters` allow users to configure various properties when instantiating a new stack, without having to edit the template itself. A parameter value can be used elsewhere in the template using the function `get_param`. In this example, we use parameters to choose an SSH key, instance size ("flavor"), image, and a network.

resources This section contains all the resources used by the Stack. In this case, there is just a single VM instance (`OS::Nova::Server`).

Optional additional sections are **parameter_groups**, **outputs**, and **conditions**.

8.2 The Template Generator

The Heat dashboard provides a graphical interface where users can draw templates by dragging resources onto a canvas, and connecting them. Users can then download a template generated from this interface, or immediately instantiate it as a stack.

Note: Currently, there are a number of issues with the template generator, which require manual edits to the generated templates. Therefore, the template generator is currently not very useful. We will update this section as soon as these problems are solved.

8.3 Managing stacks

The **Stacks** button in the **Orchestration** tab takes you to the overview page where you can launch, suspend, resume and delete stacks.

The screenshot shows the 'Stacks' overview page. On the left is a sidebar with a navigation menu: Project, API Access, Compute, Volumes, Network, Orchestration (expanded), Resource Types, Template Versions, Template Generator, Share, and Identity. The 'Stacks' option under Orchestration is highlighted. The main content area has a breadcrumb 'Project / Orchestration / Stacks' and a title 'Stacks'. Below the title are buttons for 'Stack Name =', 'Filter', '+ Launch Stack', 'Preview Stack', 'Delete Stacks', and 'More Actions'. A table displays one stack named 'mystack' with columns for Stack Name, Created (0 minutes), Updated (Never), Status (Create Complete), and Actions (Check Stack). The table is preceded by the text 'Displaying 1 item'.

The overview page contains a list of all currently existing stacks (either running or suspended), and buttons to perform the following actions:

Launch a stack

1. Click **Launch Stack** to open the following wizard:

The 'Select Template' wizard is shown with a close button in the top right. It contains the following fields and sections: 'Template Source' with a dropdown set to 'URL'; 'Template URL' with a text input containing 'https://raw.githubusercontent.com/hpcugent/opensta'; 'Environment Source' with a dropdown set to 'File'; and 'Environment File' with a 'Browse...' button and the text 'No file selected.'. A 'Description:' section on the right explains that a template is used to automate deployment and provides instructions on using template source options. At the bottom right are 'Cancel' and 'Next' buttons.

2. Provide a template and — optionally — an environment for the stack.

Template Source You can provide a template using one of the following options:

File Provide a local file on your system.

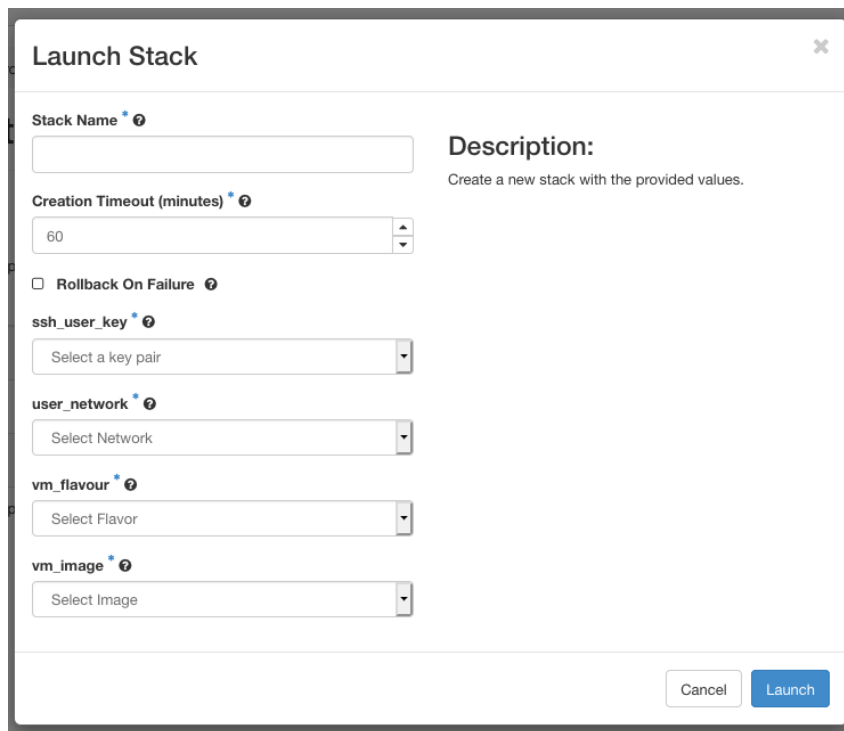
Direct Input Enter the template in a text field.

URL Provide a URL to have OpenStack download the template from that location.

In our example, we provide a URL from the repository github.com/hpcugent/openstack-templates, to instantiate the example from section 8.1. If you want to provide a template directly from GitHub, make sure to provide a “Raw” URL, `https://raw.githubusercontent.com/...`

Environment Source Optionally, you can also provide an environment file. This is another YAML file, which contains customizations for your Heat templates, such as default values for parameters, or custom resource types you have created (see ‘[Environments](#)’ in the Heat template guide). You can provide a **File** or choose **Direct Input**.

3. If you click **Next**, OpenStack will process the template. You can now enter a name for the stack, and provide values for all the template parameters:



4. Click **Launch** to instantiate the stack.

Preview Stack

Preview Stack starts a wizard similar to the “Launch Stack” wizard, but completing the wizard will only make the system perform a sanity check of your template, without instantiating the stack. If the check passes, you can inspect the parameters of the stack that would be created. The wizard does not allow you to enter input parameter values, so any mandatory input parameters should be provided in an environment.

Delete Stacks

Delete Stacks deletes all selected stacks from the list .

Warning: Deleting a stack also deletes all of the resources (volumes, ports) created by that stack, unless a different policy was set in the **deletion_policy** property for those resources (see the '[Resources section](#)' in the HOT specification).

More Actions

The button **More Actions** hides the following additional actions:

Check Stacks verifies if the resources for selected stacks are still running.

Suspend Stacks suspends all resources of the selected stacks.

Resume Stacks resumes the selected (suspended) stacks.

You can quickly suspend, resume or delete a single stack using the drop-down menu in the **Actions** column of the overview. This menu also contains the option **Change Stack Template**, which allows you to update a Stack by providing a new template.

Chapter 9

Shared file systems using Manila

OpenStack's Manila service makes it possible to create and manage shared NFS file systems for virtual machines. This service is not automatically enabled for every VSC cloud project, so you should contact cloud@vscentrum.be if you want to use shared file systems in your project.

Creating a Shared File System

Creating a shared file system using the Horizon interface is quite straightforward:

1. Open the Share tab, and click Shares. A list of existing shares (if any) is shown.
2. Click the **Create Share** button to open the following dialog:

Fill out the following fields:

Share Name Choose a name.

Description Optionally, add a description.

Share Protocol Use the default NFS protocol.

Size (GiB) Set the size of the shared file system to be created. The total available storage and the amount currently used are shown on the right.

Share Type Here, you must select “cephfsnfstype” (the only choice).

Metadata You can attach additional metadata to your shared file system, which can be queried later on.

Other fields are not mandatory. By default, the shared file system will only be visible within the current project (Visibility: “private”). Be careful with the option “Make visible for all”: enabling it will set the visibility of your shared file system to “public”, making it visible for any other project in the VSC cloud as well.

3. Click **Create** to complete this step.

At this point, the shared file system exists within OpenStack, but it cannot be used until we define access rules for it.

Defining NFS access rules

You must define rules that define which machines on the network may obtain read or write access to your shared file system. By default, in absence of any rules, a shared file system cannot be accessed by anyone.

1. Open the drop-down menu in the **Actions** column for your share, and click **Manage Rules**.
2. You can now see all Share Rules for this shared file system. For a newly created file system, the list will be empty. Click **Add rule**.
3. Fill out the **Add Rule** dialog:

Access Type Only “ip” is supported.

Access Level Choose if you want to give read and write (“rw”) or read-only (“ro”) permission with this rule.

Access To Here, you can specify an ip address, or an address range, to which the rule applies. The addresses should be specified according to the format of an NFS exports configuration file. The following table contains a few examples, assuming the project’s `_nfs` network has the subnet `10.10.x.0/24`, for some value of x (see section 5.1):

10.10.x.13	Allow this single ip address.
0.0.0.0/0	Allow any ip address.
10.10.x.0/24	Allow any ip address from the project’s <code>_nfs</code> network. For a non-public shared file system this has the same effect as the previous rule, because such a shared file system can only be accessed from within our project’s <code>_nfs</code> network anyway.
10.10.x.0/28	Allow addresses 10.10.x.0 until 10.10.x.15.

Click **Add** to add the rule.

Your rule now appears in the list. You can add as many rules as you wish, to set the access level for different addresses or address ranges.

Accessing a shared file system

When the proper access rules for the shared file system are in place, you can access it from an instance with a matching ip. In order to be able to mount the shared file system, your instance needs

- a NFS client, installed by default on images provided by the VSC cloud, and
- access to the `_nfs` network. Because your instance likely has to connect to the `_vm` network as well, your VM should have two NIC’s. Again, this is taken care of in the default images.

When you are ready to mount the network file system on an instance, look up the network location of your file system using the Dashboard:

1. Open the Share tab and click Shares. The list of all shared file systems in your project is shown.
2. Click the name of the shared file system you wish to access.
3. In the section “Share Overview”, look for the item **Export locations**.
4. Copy the content of the **Path:** field.

Once you know the location of your shared file system, you can mount it on any VM with the appropriate access rights, e.g. to mount a shared file system with location `10.2.0.2:/volumes/_nogroup/918...a78` at mount point `\mnt`:

```
$ sudo mount 10.2.0.2:/volumes/_nogroup/918...a78 /mnt
```