

OpenStack Workload Reference Architecture: Big Data

Big Data analytics has established itself as an important process to support new or enhanced business models. Big Data is a term for data sets that are so large or complex that traditional data processing applications are inadequate to deal with them. Big Data analytics refers to the use of predictive analytics, user behavior analytics, or certain other advanced data analytics methods that extract value from data.

Since Big Data analytics can include and analyze all types of data sources, the results are valuable for most departments in an enterprise. Each might perform analytics with different business objectives. Considering the short innovation cycle of most digital business models, Enterprise IT is often under pressure to fulfill a multitude of demands quickly. A flexible, fast, efficient and easy-to-manage Big Data deployment is critical.

Cloud is one approach to tackle the dynamic situation caused by high volumes of analytics requests with rapid deployment time requirements. In an OpenStack-based cloud environment, a Big Data cluster can be provisioned in an automated manner. The value of Big Data on cloud contributes to it being one

of the top use cases for OpenStack. According to the April 2016 [OpenStack User Survey](#), 27 percent of users have deployed or are testing Big Data analytics solutions.

Apache Hadoop on OpenStack offers a Big Data infrastructure that scales out both compute and storage resources, and provides the secure and automated capabilities for the analytics process. The [Apache Hadoop project](#) is the de facto standard open source framework for Big Data analytics, used in the vast majority of deployments. Multiple Hadoop clusters are often deployed to respond to an enterprise's needs.

This reference architecture is intended for enterprise architects who are looking to deploy Big Data Hadoop clusters on an OpenStack cloud. It describes a generic Hadoop architecture and uses open source technologies:

- [OpenStack cloud software](#).
- [Ubuntu Linux](#) operating system.
- [Apache Ambari](#) – open source software to provision, manage and monitor Hadoop clusters.

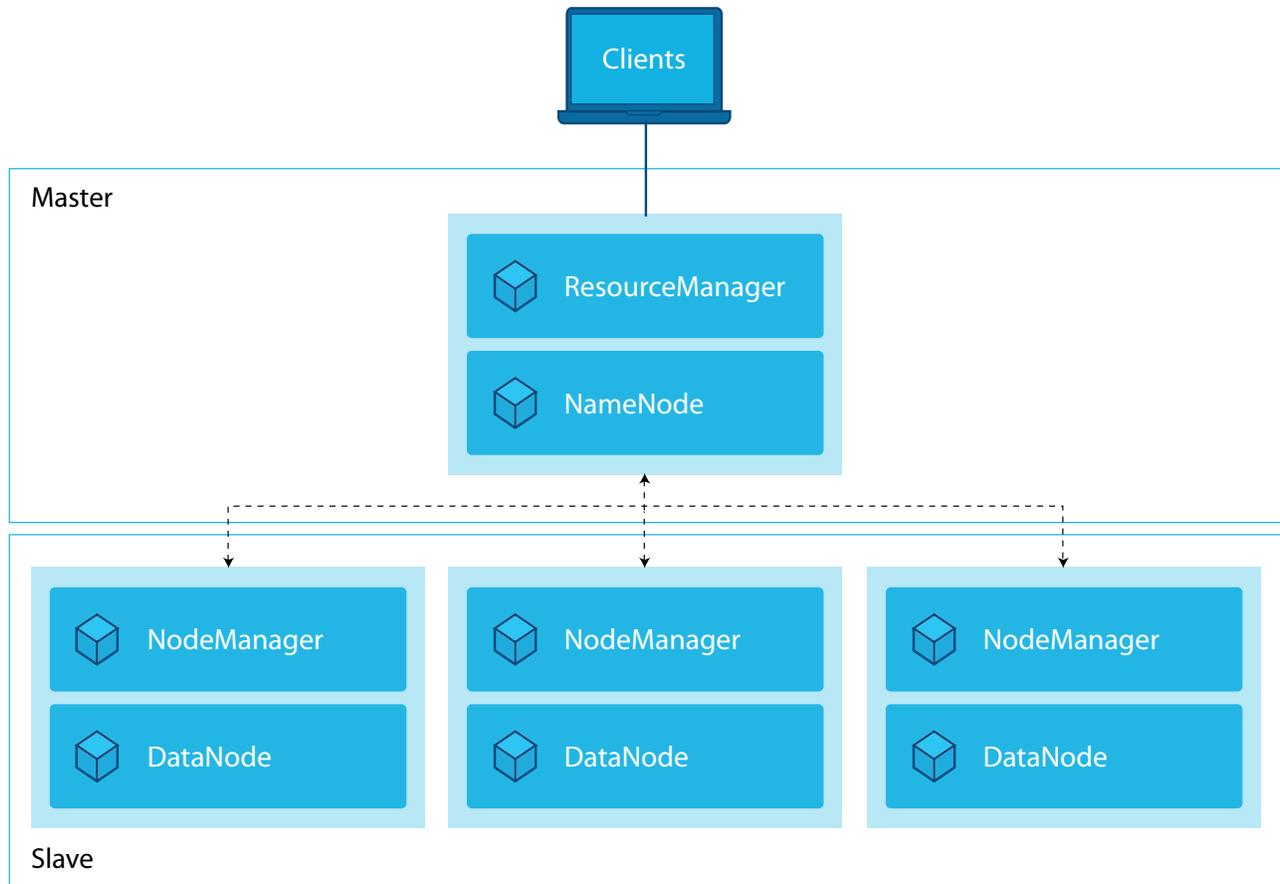
This reference architecture is for a general workload developed by members of the Enterprise Working Group and is not representative of the contributors' companies.

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This reference architecture describes and includes installation files for a basic Hadoop cluster. Additional services can be applied for a more complex configuration and will be covered in future works.

Figure 1: High-level overview of Hadoop architecture



OpenStack for Hadoop Clusters

This Hadoop architecture is derived from actual use cases and experience. Building a Hadoop-based Big Data environment can be a complex task. It is highly recommended to use common approaches to reduce this complexity, such as identifying the data processing models. These processing models demand high availability of resources, networking, bandwidth, storage, as well as security constraints in the enterprise context.

- **Batch processing model** – Analytics based on historic data
In the batch processing model, the analytic tasks are executed or queried in a scheduled or recurring manner. Typically the data is already available for analysis in a static repository such as large files or databases. The batch processing model is often used to analyze business data of a certain period. One example is an ETL (extract, transform, load) process to extract business data from various ERP systems for supply chain planning.

- **Stream processing model** – Business real-time analytics
In the stream processing model, data is continuously streamed and directly analyzed in real time. Actions can be triggered in case of occurrence of special or defined events. An example of a stream processing workload is fraud detection for credit card companies. A credit card transaction is transmitted online to the credit card company and is evaluated in real time based on certain parameters; for example, checking the card’s validity and the purchase amount against the limit. It is also possible to check the location of purchases and compare this to other recent purchases. For example, if purchases are made in the U.S. and Europe in a timespan of only a few hours, this indicates a high likelihood of fraud and action can be taken to decline the transaction.
- **Predictive processing model** – Predict outcome based on recent and historical data.
This model is used to predict an outcome, behavior or other actions for the future. Generally this analytic model consists of various predictive algorithms. One example is predictive maintenance. Data from machines, engines or other sensors is collected and analyzed so that predictive actions can be made to recommend the next maintenance cycle before a failure might occur.

Hadoop clusters use a master-slave architecture. The data is ingested into the cluster and stored in blocks in the Hadoop distributed file system (HDFS). The default block size is 64MB. The blocks of data are replicated to different nodes in the clusters. Part of the core Hadoop project, [YARN](#) provides a framework for job scheduling and cluster resource management. With YARN, multiple data processing applications can be implemented in the Hadoop cluster.

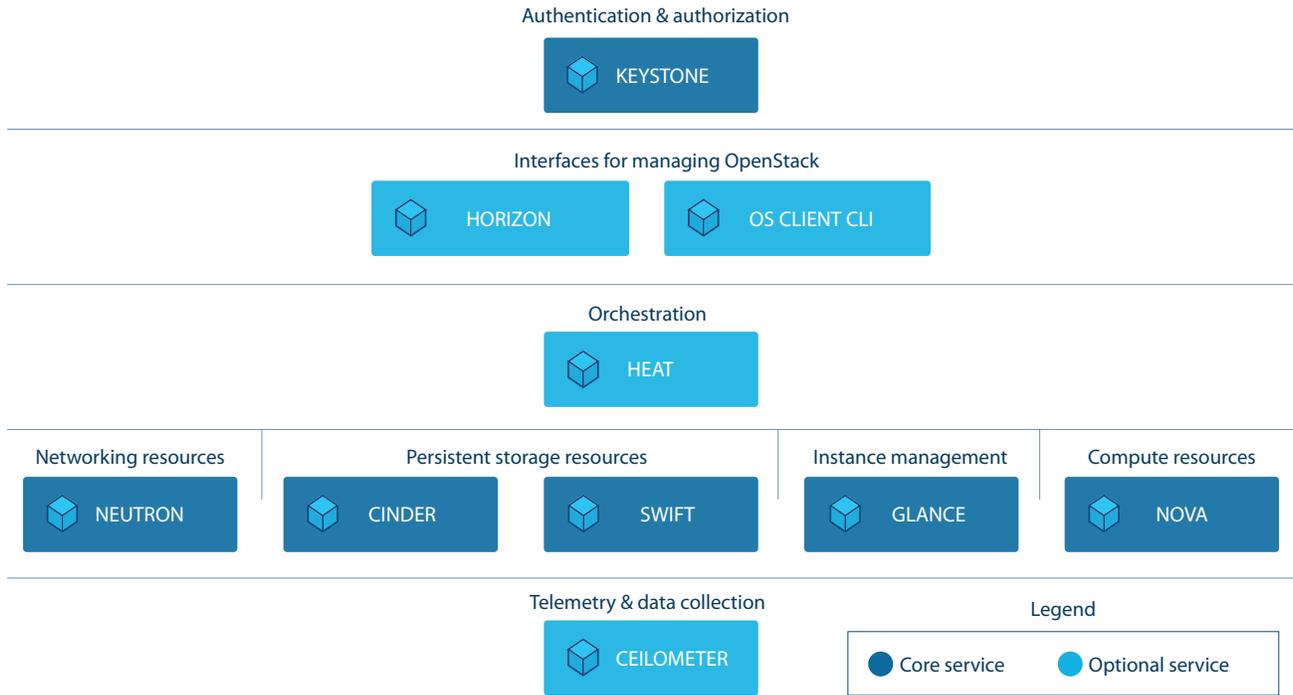
Typically a Hadoop cluster with YARN is composed of different types of cluster nodes:

- **NameNode** – The metadata about the data blocks are stored in the NameNode. This provides lookup functionality and tracking for all data or files in the Hadoop cluster. NameNode does not store the actual data. Generally the NameNode requires high memory (RAM) allocation. The NameNode belongs to the “master” part of Hadoop architecture.
- **DataNode** – This is also referred as the worker node and belongs to the “slave” part of a Hadoop architecture. It is responsible for storing and computing the data and responds to the NameNode for filesystem operations. Generally a DataNode requires high amount of storage space.
- **ResourceManager** – This is the master that manages the resources in the Hadoop cluster. It has a scheduler to allocate resources to the various applications across the cluster.
- **NodeManager** – This takes instruction from the ResourceManager and is responsible for executing the applications. It monitors and reports the resources (cpu, memory, disk) to the ResourceManager.

An OpenStack cloud is powered by many different services (also known as projects). Utilizing the core services and the Hadoop Common package, a Hadoop cluster can be deployed in a virtualized environment with minimal effort. Optional services such as the OpenStack Orchestration service (Heat) can be added to automate deployment. This reference architecture does not cover OpenStack Big Data Service (Sahara). Sahara provides a simple means to provision as well as scale previously provisioned Hadoop clusters. Sahara will be covered in future reference architecture documents.

Figure 2 shows the core and optional services in relation to one another, and the services to confirm are available in your OpenStack cloud.

Figure 2. Logical representation of OpenStack services in support of Hadoop clusters



Brief descriptions of the core and optional services are as follow. The [OpenStack Project Navigator](#) provides additional information.

COMPUTE (NOVA)

Manages the life cycle of compute instances, including spawning, scheduling, and decommissioning of virtual machines (VMs) on demand.

IMAGE SERVICE (GLANCE)

Stores and retrieves VM disk images. Used by OpenStack Compute during instance provisioning.

BLOCK STORAGE (CINDER)

Virtualizes the management of block storage devices and provides a self-service API to request and use those resources regardless of the physical storage location or device type. Supports popular storage devices.

NETWORKING (NEUTRON)

Enables network connectivity as a service for other OpenStack services, such as OpenStack Compute. Provides an API to define networks and their attachments. Supports popular networking vendors and technologies. Also provides LBaaS and Firewall-as-a-Service (FWaaS).

IDENTITY SERVICE (KEYSTONE)

Provides authentication and authorization for the other OpenStack services.

**OBJECT STORAGE
(SWIFT)**

Stores and retrieves arbitrary unstructured data objects via a RESTful HTTP-based API. Highly fault-tolerant with data replication and scale-out architecture.

Optional services

**ORCHESTRATION
(HEAT)**

Orchestrates multiple composite cloud applications by using either the native HOT template format or the AWS CloudFormation template format, through both an OpenStack-native REST API and a CloudFormation-compatible Query API.

**TELEMETRY
(CEILOMETER)**

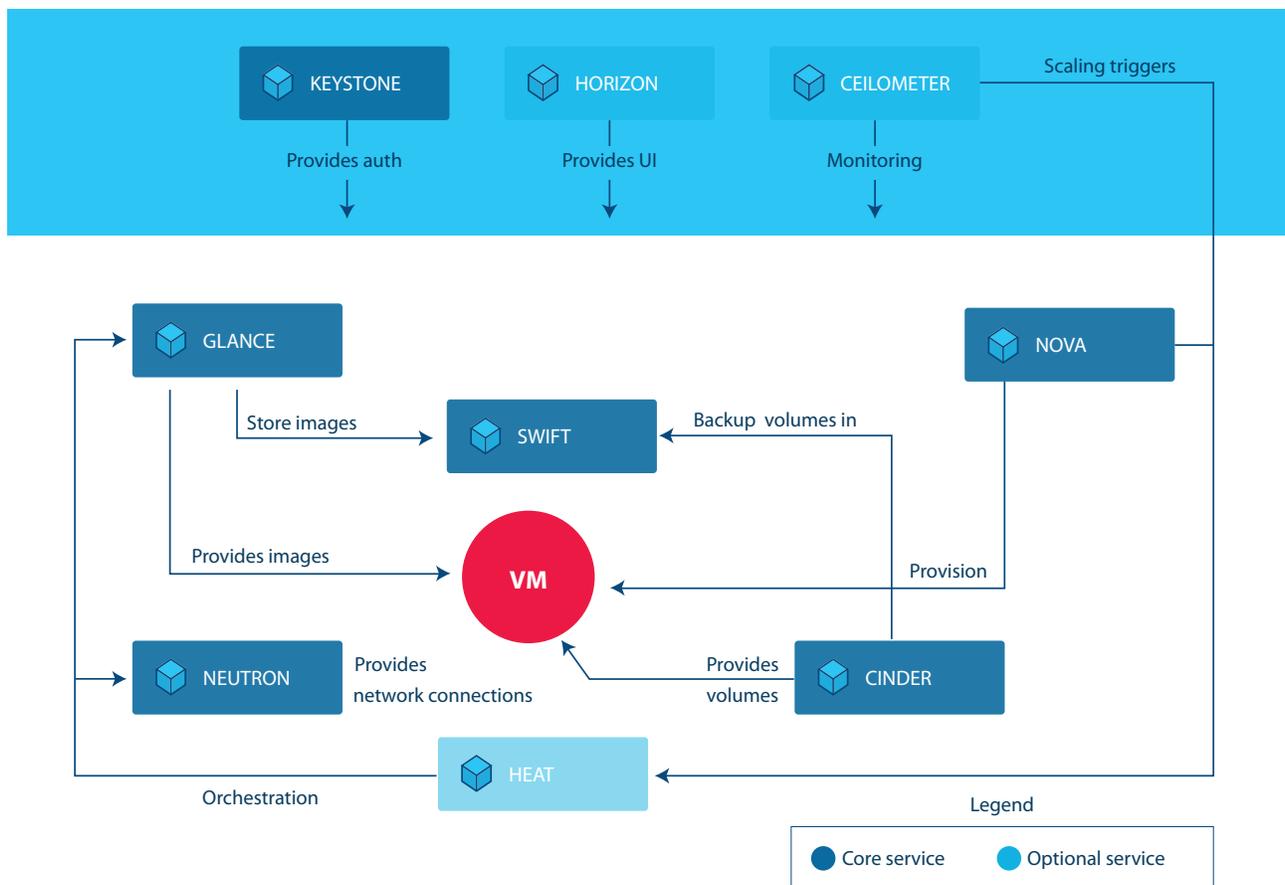
Monitors and meters the OpenStack cloud for billing, benchmarking, scalability, and statistical purposes.

**DASHBOARD
(HORIZON)**

Provides an extensible web-based self-service portal to interact with underlying OpenStack services, such as launching an instance, assigning IP addresses, or configuring access controls.

Figure 3 illustrates the basic functional interaction between these services. For further details: [OpenStack Conceptual Architecture Diagram](#).

Figure 3. Functional interaction between OpenStack components



Structuring a Hadoop Cluster with OpenStack

OpenStack provides the necessary compute, network and data storage services for building a cloud-based Hadoop cluster to meet the needs of the various processing models.

Networking

Multiple networks can be created for the Hadoop cluster connectivity. Neutron routers are created to route the traffic between networks.

- **Edge Network** – Provides connectivity to the client-facing and enterprise IT network. End users are accessing the Hadoop cluster through this network.
- **Cluster Network** – Provides inter-node communication for the Hadoop cluster.
- **Management Network** – Optionally provides a dedicated network for accessing the Hadoop nodes' operating system for maintenance and monitoring purposes.
- **Data Network** – Provides a dedicated network for accessing the object storage within an OpenStack Swift environment or to an external object storage such as Amazon S3. This is optional if object storage is not used.

Neutron security groups are used to filter traffic. Hadoop uses different ports and protocols depending on the services deployed and communications requirements. Different security groups can be created for different types of nodes, depending on the Hadoop services running on it. With OpenStack security groups, multiple rules can be specified that allow/deny traffic from certain protocols, ports, or IP addresses or ranges. Each virtual machine (VM) can be applied with one or more security groups. In OpenStack, each tenant has a default security group, which is applied to instances that have no other security group defined. Unless changed, this security group denies all incoming traffic.

Image Management

There are multiple options to provide operating system configuration for the Hadoop nodes. On-the-fly configuration allows greater flexibility but can increase spawning time. The operating system images can also be pre-configured to contain all of the Hadoop-related packages required for the different types of nodes. Pre-configuration can reduce instance build time, but includes its own set of problems, such as patching and image lifecycle management. In this example, the Heat orchestration features are used to configure the Hadoop nodes on-the-fly. Additional Hadoop and operating system packages are installed on-the-fly depending on the node type (e.g. NameNode, DataNode). These packages can be downloaded from Internet-based or local repositories. For a more secure enterprise environment, local package repository is recommended.

Data Management

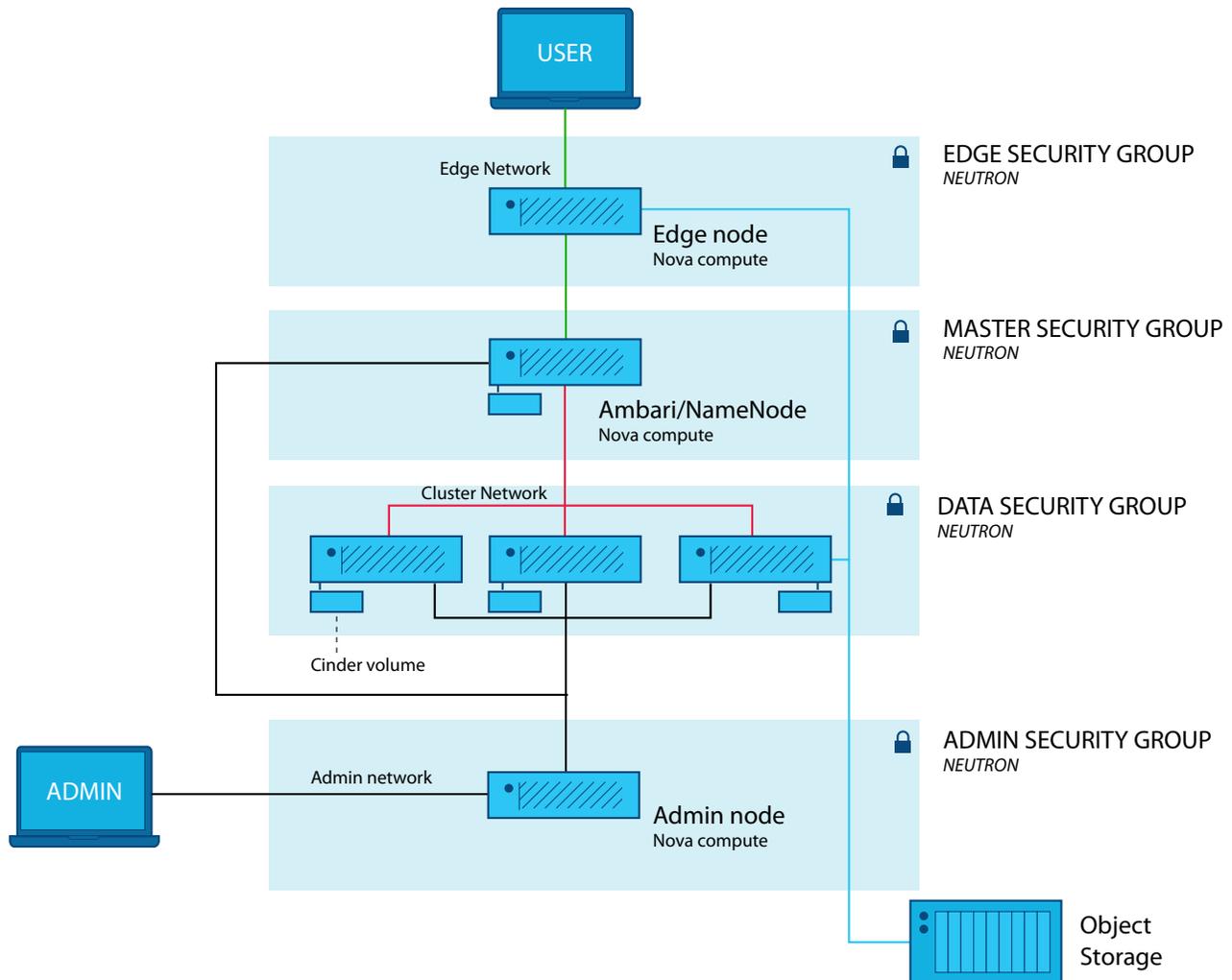
Similar to an external hard drive, Cinder volumes are persistent block-storage virtual devices that may be mounted and dismounted from the VM. Cinder volumes can be attached to only one instance at a time. A Cinder volume is attached to each Hadoop DataNode to provide the HDFS.

If the data to be processed by a Hadoop cluster needs to be accessed by other applications, the OpenStack Swift object storage can be used to store it. Swift offers a cost-effective way of storing unstructured data. Hadoop provides a built-in interface to access Swift or AWS S3 object storage; either can be configured to serve data over HTTP to the Hadoop cluster.

Orchestration

Heat uses template files to automate the deployment of complex cloud environments. Orchestration is more than just standing up virtual servers; it can also be used to install software, apply patches, configure networking and security, and more. Heat templates are provided with this reference architecture that allow the user to quickly and automatically setup and configure a Hadoop cluster for different data processing models (types of analytics).

Figure 4: A Hadoop cluster on OpenStack



Demonstration and Sample Code

This section describes the Heat template provided for this workload. The template is used to configure all of the Hadoop nodes. It has been created for reference and training and is not intended to be used unmodified in a production environment.

An Ambari Hadoop environment is created on a standard Ubuntu 14.04 server cloud image in QEMU copy on write (qcow2). The qcow2 cloud image is stored in the Glance repository. The Apache Ambari

open source project makes Hadoop management simpler by providing an easy-to-use Hadoop management web UI backed by its RESTful APIs. Basically, Ambari is the central management service for open source Hadoop. In this architecture, an Ambari service is installed on the Master Node (NameNode). The Heat template also installs additional required services such as the name server, Network Time Protocol (NTP) server, database, and the operating system configuration customization required for Ambari. Floating IP can be allocated to the Master Node to provide user access to the Ambari service. In addition, an Ambari agent service is deployed on each node of the cluster. This provides communication and authentication functionality between the cluster nodes.

The following nodes are installed by the Heat template:

- **Master Node (NameNode)** – This node houses the cluster-wide management services that provide the internal functionality to manage the Hadoop cluster and its resources.
- **Data Nodes** – Services used for managing and analyzing the data, stored in HDFS, are located on these nodes. Analytics jobs access and compute the data on the Data Nodes.
- **Edge Node** – Services used to access the cluster environment or the data outside the cluster are on this node. For security, direct user access to the Hadoop cluster should be minimized. Users can access the cluster via the command line interface (CLI) from the Edge Node. All data-import and data-export processes can be channeled on one or more Edge Nodes.
- **Admin Node** – Used for system-wide administration.

Multiple networks (edge, cluster, management, data) described in previous sections are created by the Heat orchestration. A Neutron security group is attached to each instance of the cluster node. The template also provisions Cinder volumes and attaches one Cinder volume to each node. Swift is not configured in this template and will be covered in future work.

The Heat template, **BigData.yaml**, can be downloaded from <http://www.openstack.org/software/sample-configs/#big-data>. Please review the README file for further details.

Scope and Assumptions

The Heat template provided for this reference architecture assumes that the Hadoop cluster workload is deployed in a single-region, single-zone OpenStack environment. The deployment in a multi-zone/multi-region environment is outside the scope of this document.

The Heat template is configured to address the minimum infrastructure resources for deploying a Hadoop cluster. Architecting a Hadoop cluster is highly dependent on the data volume and other performance indicators defined by the business use cases, such as response times for analytic processes and how and which services will be used.

The sample environment uses the Java environment. As such, the Heat template installer will be required to accept the Java license agreement.

As mentioned, Sahara is not used in this implementation. Sahara is the OpenStack Big Data Service that provisions a data-intensive application cluster such as Hadoop or Spark. The Sahara project enables users to easily provision and manage clusters with Hadoop and other data processing frameworks on OpenStack. An update to this reference architecture to include Sahara is under consideration.

Summary

There are many possible choices or strategies for deploying a Hadoop cluster and there are many possible variations in OpenStack deployment. This document and the accompanying Heat templates serve as a general reference architecture for a basic deployment and installation process via Openstack orchestration. They are intended to demonstrate how easily and quickly a Hadoop Cluster can be deployed, using the core OpenStack services. Complementary services will be included in future updates.

These additional resources are recommended to delve into more depth on overall OpenStack cloud architecture, the OpenStack services covered in this reference architecture, and Hadoop and Ambari. The vibrant, global OpenStack community and ecosystem can be invaluable for their experience and advice, especially the users that have deployed Big Data solutions. Visit openstack.org to get started or click on these resources to begin designing your OpenStack-based Big Data analytics system.

RESOURCE	OVERVIEW
OpenStack Marketplace	One-stop resource to the skilled global ecosystem for distributions, drivers, training, services and more.
OpenStack Architecture Design Guide	Guidelines for designing an OpenStack cloud architecture for common use cases. With examples.
OpenStack Networking Guide	How to deploy and manage OpenStack Networking (Neutron).
OpenStack Virtual Machine Image Guide	This guide describes how to obtain, create, and modify virtual machine images that are compatible with OpenStack.
Complete OpenStack documentation	Index to all documentation, for every role and step in planning and operating an OpenStack cloud.
Community Application Catalog	Download this Linux/Apache Ambari Hadoop sample application and other free OpenStack applications here.
Apache Hadoop project	The de facto standard open source framework for Big Data analytics, used in this reference architecture.
Apache Ambari project	This reference architecture and files deploy Big Data using Ambari, an open source package for installing, configuring and managing a Hadoop cluster.
Welcome to the community!	Join mailing lists and IRC chat channels, find jobs and events, access the source code and more.
OpenStack User Groups	Find a user group near you, attend meetups and hackathons—or organize one! A great place to meet Stackers with Big Data experience.
OpenStack events	Global schedule of events including the popular OpenStack Summits and regional OpenStack Days.

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