



AWS Whitepaper

Teaching Big Data Skills with Amazon EMR



Teaching Big Data Skills with Amazon EMR: AWS Whitepaper

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Teaching Big Data Skills with Amazon EMR

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Abstract

In today's competitive data analysis space, Apache Hadoop workloads have become more relevant to organizations of all sizes and purposes. As such, the skillsets associated with managing these workloads are in high demand. To keep up with this demand, universities have begun to offer classes that teach these concepts to the next generation of business and IT professionals. The IT staff supporting these organizations are often tasked with enabling students with an advanced, modern infrastructure to support a demanding curriculum. Due to short-term semesters, it is cost prohibitive for universities to invest in dedicated infrastructure for these classes, which can become quickly outdated.

This document discusses multiple deployment options available to higher-education organizations, enabling them to provide a modern AWS infrastructure to support a big data class offering using [Amazon EMR](#). Although not limited in scope to higher education, this content was designed with the higher-education instructional use-case in mind. If you are part of an academic institution that is a member of [AWS Educate](#), program benefits may be available. Contact your AWS Account Manager for more information on AWS Educate.

Overview

Amazon EMR provides a managed Apache Hadoop service that makes it easy to deploy Hadoop open source applications quickly, such as Apache Spark and Apache Hive, enabling the processing of large amounts of data in a cost-effective way.

The EMR service extracts the complexities associated with managing and scaling a Hadoop infrastructure by providing all infrastructure, configuration, and workload automation tasks for the customer. Amazon EMR helps simplify the setup of the infrastructure components such as cluster setup, auto-scaling data nodes and permissions, making it easier to focus on teaching rather than infrastructure support.

Common EMR Applications

Amazon EMR makes it simple to provision Hadoop infrastructure, but also simplifies the deployment of popular distributed applications such as Apache Spark, Apache Pig, and Apache Zeppelin. This document details three deployment strategies to provision EMR clusters that support these applications. For a full list of supported applications, see [Amazon EMR 5.x Release Versions](#).

This document focuses on a few key applications that are relevant to teaching an introduction to big data with EMR.

Apache Spark

Apache Spark is a unified analytics engine used in large-scale data processing. In simple terms, Spark allows users to run SQL queries and create data frames for analysis using various common languages, mainly Java, Python and Scala. Spark is a native component of EMR that is available to be automatically provisioned when deploying an Amazon EMR cluster.

Apache Pig

[Apache Pig](#) is an open-source Apache library that runs on top of Hadoop. It provides a scripting language used to modify large data sets with a high-level scripting language. Apache Pig enables the user to take commands that are similar to SQL (written in Pig Latin), and convert them to Tez jobs for execution in the Hadoop environment. Apache Pig works with structured and unstructured data in a variety of formats.

Apache Zeppelin with Shiro

Apache Zeppelin is an open-source, multi-language, web-based notebook that allows users to use various data processing back-ends provided by Amazon EMR. Zeppelin is flexible enough to provide functionality for data ingestion, discovery, analytics, and visualization. Zeppelin is included in Amazon EMR 5.0 and later, and provides built-in integration for Apache Spark. Configuration for how to set up Zeppelin is provided in the [Setting Up Access to Zeppelin Using Linux Credentials](#) section.

For multi-tenant deployments of Zeppelin, Apache Shiro is recommended as the authentication method. Shiro is a Java security framework that performs authentication, authorization, cryptography, and session management for Zeppelin notebooks.

Deployment Options

To support a big data course offering, you are tasked with providing a solution that offers simplified access to common big data software offerings, a scalable up-to-date infrastructure, and mechanisms that restrict access to other student's data. You must keep in mind that in most deployments:

- Students submit their assignments to a protected location with access permissions allocated to one student and access denied to any other students.
- All students can access any shared data as provided by the teacher such as for data sets.
- Teaching assistants should be able to access student profiles to provide any needed support.
- Tools and products such as Zeppelin, Hue, Hive, and Spark must scale as needed.

When deploying an EMR cluster for deployment in an educational setting, there are a few options to consider in achieving these goals. Depending on your organizational requirements, you may choose to deploy EMR in one of the following ways:

- [One AWS Account Hosting One EMR Cluster Per Student](#)
- [Individual Student AWS Accounts Hosting One EMR Cluster Per Student](#)
- [One AWS Account Hosting One EMR Cluster for All Students](#)

In each option, we assume that the IT staff requires unrestricted access to the cluster infrastructure, the instructor and support staff have access to all course data, and students are only provided

access to instructional data source(s) and their own data repository. The following table summarizes some of the operational tradeoffs of these options:

Table 1: Operational tradeoffs of different deployment options

| | One AWS Account Hosting One EMR Cluster Per Student | Individual Student AWS Accounts Hosting One EMR Cluster Per Student | One AWS Account Hosting One EMR Cluster for All Students |
|--------------------------------|---|--|--|
| Setup and Configuration | Institution provisions and configures EMR cluster for each student and provides each student with an Amazon EC2 key pair and IAM user to access the EMR cluster and AWS Management Console. | Student has full control over the AWS account and provisions and configures the EMR cluster. | Institution provisions and configures one EMR cluster as a multi-tenant cluster and provides each student with SSH keys to access the EMR cluster. |
| Security[*] | SSH access, IAM roles and policies, security groups are managed by the institution for each EMR cluster to ensure each student has access to their own environment and storage. | Student manages all security configuration (or organizational policy). | IAM access keys, SSH access, IAM roles and policies are managed by the institution for one shared EMR cluster to ensure each student has access to their own environment and storage |
| Billing | Link to institution Payer Account (if consolidated billing is used) | Account provisioned via the AWS Educate program or individual responsibility | Link to institution Payer Account (if consolidated billing is used) |

| | One AWS Account Hosting One EMR Cluster Per Student | Individual Student AWS Accounts Hosting One EMR Cluster Per Student | One AWS Account Hosting One EMR Cluster for All Students |
|---|--|--|--|
| Billing Alerts | Billing Alerts can be set up to monitor charges. | | |
| Maintenance and Administration | Medium (updates and setup need to be propagated to all EMR clusters to ensure each student is using the latest updated cluster) | High (student knowledge necessary to control the EMR cluster and data permissions) | Low (updates and setup only need to be managed on one EMR cluster) |
| Students Can Provision Additional Resources | No (IAM policies limiting access) | Yes (student owns the account) | No (IAM policies limiting access) |
| Cost | Cost will vary substantially based on your chosen consumption model (On Demand, Spot, Reserved Instances) and usage. We recommend having a detailed discussion with your AWS or Partner Solutions Architect to explore the most optimal cost model for your specific deployment | | |

* When considering AWS Identity and Access Management (IAM) role permissions, consider using EMR File System (EMRFS) to control access to Amazon Simple Storage Service (Amazon S3) resources:

Beginning with Amazon EMR release version 5.10.0, you can use a security configuration to specify IAM roles for EMRFS. This option allows you to customize permissions for EMRFS requests to Amazon S3 for clusters that have multiple users. You can specify different IAM roles for different users and groups, and for different Amazon S3 bucket locations based on the prefix in Amazon S3. When EMRFS makes a request to Amazon S3 that matches users, groups, or the locations that you specify, the cluster uses the corresponding role that you specify instead of the EMR role for Amazon Elastic Compute Cloud (Amazon EC2). For more information, see [Configure IAM Roles for EMRFS Requests to Amazon S3](#).

AWS Educate

As learners design innovative solutions to solve a variety of data analysis needs and use cases, they need access to technology resources to make their ideas come to life. AWS Educate is a great way to get learners started with AWS. AWS Educate is Amazon's global program to provide learners with the resources needed to accelerate cloud learning. For learners aged 14 and older, the program offers a self-paced, no-cost curriculum, with materials designed to accelerate cloud-related learning endeavors. It also provides a job board for employment opportunities for learners 18 and over.

To learn more or to sign-up, visit [AWS Educate](#) or contact your AWS Account Manager.

Amazon EC2 Option

Although this document focuses on teaching big-data concepts using Amazon EMR, another deployment option is to deploy Hadoop workloads on Amazon Elastic Compute Cloud (Amazon EC2) instances. In fact, the underlying compute platform that EMR runs on is EC2. However, the value of using the EMR managed service is the simplification of management of these nodes, and the deployment of the EMR software packages necessary to run these workloads in a single AWS point of management. In addition, the EMR service takes care of automatic scaling based on Hadoop workload metrics as well as mapping Unix user permissions to Amazon S3 access policies via EMR File System (EMRFS). Although technically possible to provision the same workloads on EC2 instances, EC2 provisioning is outside the scope of this post. We recommend that you consider EMR to simplify managing your environment and free up more time to develop Hadoop coursework.

One AWS Account Hosting One EMR Cluster Per Student

This approach is our recommended deployment model, because it allows for central IT administration of all course resources while also exposing students to the AWS environment, providing a better understanding of how the infrastructure is configured. This option can also be the foundation to implement a packaged offering that leverages [Service Catalog](#) to provide an end-to-end self-service deployment option for EMR clusters. A Service Catalog approach to deploying course infrastructure can further simplify the control and administration of your EMR clusters, providing students with a dashboard with only basic deploy and tear-down options.

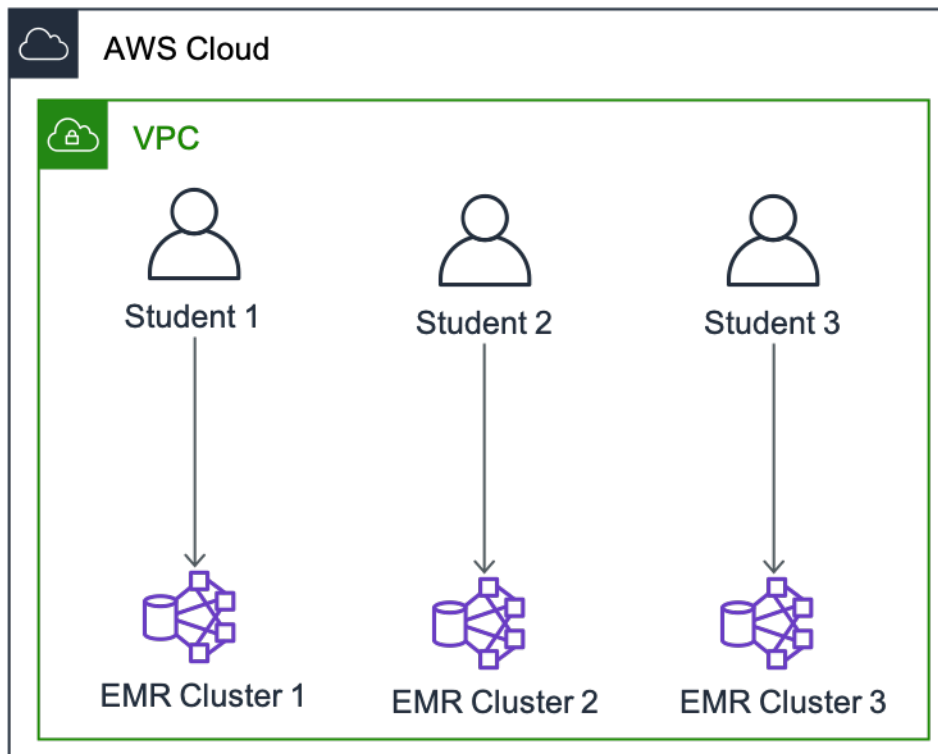


Figure 1: One AWS account hosting one EMR cluster per student

In this deployment option, an institution's IT department provisions a single AWS account to provide access to a separate EMR cluster for each student by using AWS Identity and Access Management (IAM). Each student maps to a unique IAM user and SSH keypair to be provided with least-privilege access to their own EMR cluster and data sources. With this deployment option, billing of the EMR resources can be tied back to a central, university-owned payer account using [Consolidated Billing for AWS Organizations](#) to simplify deployment. Customized billing alerts can also be created to alert IT administrators to resource usage that rises above a certain cost threshold.

In terms of administrative overhead, this deployment option can consume a large amount of resources without automation to tear down resources when not in use. Standardization of configuration can easily be achieved by using AWS CloudFormation. With CloudFormation, a new stack can be deployed for each student only when resources are needed.

In terms of cost, each student runs a small-sized EMR cluster for a short period for each assignment. Computing costs are based off a per second usage of resources with a minimum of 60 seconds, only for the resources that are used. It is the responsibility of the course administrator and students to terminate clusters that are not in use. This can be automated with an [AWS Lambda](#) function or by establishing a Time to Live (TTL) value on each [AWS CloudFormation](#) template. With this type of deployment, students are exposed directly to the AWS Management Console or API to provision their own clusters. This approach requires students to properly terminate resources when workloads are completed, or have administrators automate the de-provisioning of student EMR clusters with an automated script. See [Scheduling automatic deletion of AWS CloudFormation stacks](#) on the [AWS Infrastructure & Automation Blog](#).

Users and Authentication

In this deployment, user authentication and restricting access to data is easily controlled using IAM and S3 bucket policies. Each student is provided with a unique IAM login to the university AWS Management Console that is minimally scoped to authorize EMR cluster operations and permissions to read and upload to selected S3 buckets. If your university has an existing identity provider, you can integrate existing student logins with the AWS Management Console, eliminating the need for users to use a new IAM user. For more information, see [Identity Federation in AWS](#).

EMR releases 5.10.0 and later also support Kerberos authentication. For more information on using Kerberos authentication with an EMR cluster, see [Use Kerberos Authentication](#).

Students can then be provided with an AWS CloudFormation template that automatically provisions an EMR cluster for their use. These CloudFormation templates can be customized to reflect specific coursework per lesson, or provisioned once per semester, depending upon what the course syllabus requires.

Implementation

A simple way to implement this deployment is to use CloudFormation templates. Since all course resources are deployed from within the university AWS account, IT administrators have full control

over all permissions and user creation. You can create a CloudFormation template to establish the baseline infrastructure, such as the common VPC and all IAM users, groups, and policies. Once this baseline has been established, students can be provided with a separate CloudFormation template within their private folder to run only when EMR resources are required.

Outside the scope of this document, consider providing students with a custom Service Catalog offering that can simplify the deployment process. For more information on Service Catalog integration with EMR, see [Service Catalog EMR Reference architecture](#).

The deployment steps below are split into two CloudFormation templates:

- [Baseline Course Infrastructure](#)
- [Individual Student EMR Resources](#)

The Baseline Course Infrastructure deployment steps provision all of the AWS resources that are needed for the entire duration of the class (e.g., source and student S3 buckets, IAM users for students, IAM users for course administrators, associated groups for these users and the permissions necessary for each). The deployment also provisions the Amazon VPC infrastructure necessary to support these clusters, keeping any subnet size restrictions in mind based on class size. Finally, the deployment steps create a custom reusable security group to allow desired network access to the master-node web services required as part of the course syllabus. These resources are automatically created for you in the provided `emr-course-infrastructure.yaml` file located at the following link:

<https://s3.amazonaws.com/aws-bigdata-blog/artifacts/teaching-big-data/emr-course-infrastructure.yaml>.

With minor modification of this CloudFormation template, many policies and settings can be customized and deployed as needed.

Note

Depending on your design constraints, you may have some of these resources already provisioned. You should carefully evaluate the example IAM permissions to ensure that the access provided meets your security posture standards. Any access provided should conform to AWS Security Best Practices, particularly those of least privilege. For more information on these best practices, see the [AWS Security Best Practices whitepaper](#).

Deploying the Baseline Course Infrastructure

1. Click to launch the course infrastructure stack.



The CloudFormation page launches in the AWS Management Console. The Amazon S3 URL is pre-filled with the CloudFormation template URL.

The screenshot shows the 'Create stack' page in the AWS Management Console. The page is divided into four steps: Step 1 (Specify template), Step 2 (Specify stack details), Step 3 (Configure stack options), and Step 4 (Review). The 'Specify template' section is active and contains two main sections: 'Prerequisite - Prepare template' and 'Specify template'. In the 'Prerequisite' section, the 'Template is ready' radio button is selected. In the 'Specify template' section, the 'Amazon S3 URL' radio button is selected, and the text input field contains the URL: `https://s3.amazonaws.com/aws-bigdata-blog/artifacts/teaching-big-data/emr-course-infrastructure.yaml`. A red box highlights this input field. Below the input field, the 'S3 URL' is displayed as `https://s3.amazonaws.com/aws-bigdata-blog/artifacts/teaching-big-data/emr-course-infrastructure.yaml`. At the bottom right, there are 'Cancel' and 'Next' buttons, with the 'Next' button highlighted in orange.

Figure 2: Create stack page

2. Choose **Next**.
3. On the **Stack details** page, type an easily identified **Stack name**. For example, **emr-course-infrastructure**.

CloudFormation > Stacks > Create stack

Step 1
Specify template

Step 2
Specify stack details

Step 3
Configure stack options

Step 4
Review

Specify stack details

Stack name

Stack name

emr-course-infrastructure

Stack name can include letters (A-Z and a-z), numbers (0-9), and dashes (-).

Parameters

Parameters are defined in your template and allow you to input custom values when you create or update a stack.

CourseAdminGroupName
Default name for course administrator IAM group

courseAdmins

EnvironmentName
An environment name that will be prefixed to resource names

EMR

Password
Default Password for all student accounts. This will be changed upon first login.

PrivateSubnet1CIDR
Please enter the IP range (CIDR notation) for the private subnet in the first Availability Zone

10.192.20.0/24

PrivateSubnet2CIDR
Please enter the IP range (CIDR notation) for the private subnet in the second Availability Zone

10.192.21.0/24

PublicSubnet1CIDR
Please enter the IP range (CIDR notation) for the public subnet in the first Availability Zone

10.192.10.0/24

PublicSubnet2CIDR
Please enter the IP range (CIDR notation) for the public subnet in the second Availability Zone

10.192.11.0/24

SourceDataBucketName
Name for S3 bucket used to store shared source data

class-data-bucket-1

StudentDataBucketName
Name for S3 bucket used to store student submission data

student-data-bucket-1

StudentGroupName
Default name for student IAM group

students

VpcCIDR
Please enter the IP range (CIDR notation) for this VPC

10.192.0.0/16

Cancel Previous **Next**

Figure 3: Stack details page

4. Review the **Parameters** and change as needed. These values are used to create a new VPC, subnets, route tables, NAT gateway, Internet Gateway, S3 buckets, and IAM users, groups and policies.

Note

When specifying a S3 bucket name, make sure the bucket name is unique globally.

Along with the infrastructure setup, this step also creates three student IAM users and one course admin IAM user.

5. Click **Next**.
6. On the **Configure stack options** page, accept the default values or change as needed.
7. Choose **Next**.
8. On the **Review** page, review the selections and scroll to the **Capabilities** section. Select the check box **I acknowledge that AWS CloudFormation might create IAM resources with custom names**.

Capabilities

i The following resource(s) require capabilities: [AWS::IAM::Policy, AWS::IAM::Group]

This template contains Identity and Access Management (IAM) resources. Check that you want to create each of these resources and that they have the minimum required permissions. In addition, they have custom names. Check that the custom names are unique within your AWS account. [Learn more](#).

I acknowledge that AWS CloudFormation might create IAM resources with custom names.

Cancel Previous Create change set **Create stack**

Figure 4: Review page - acknowledgement

9. Choose **Create stack** and wait for the cluster to deploy. A CREATE_IN_PROGRESS status message appears (*Figure 5*).

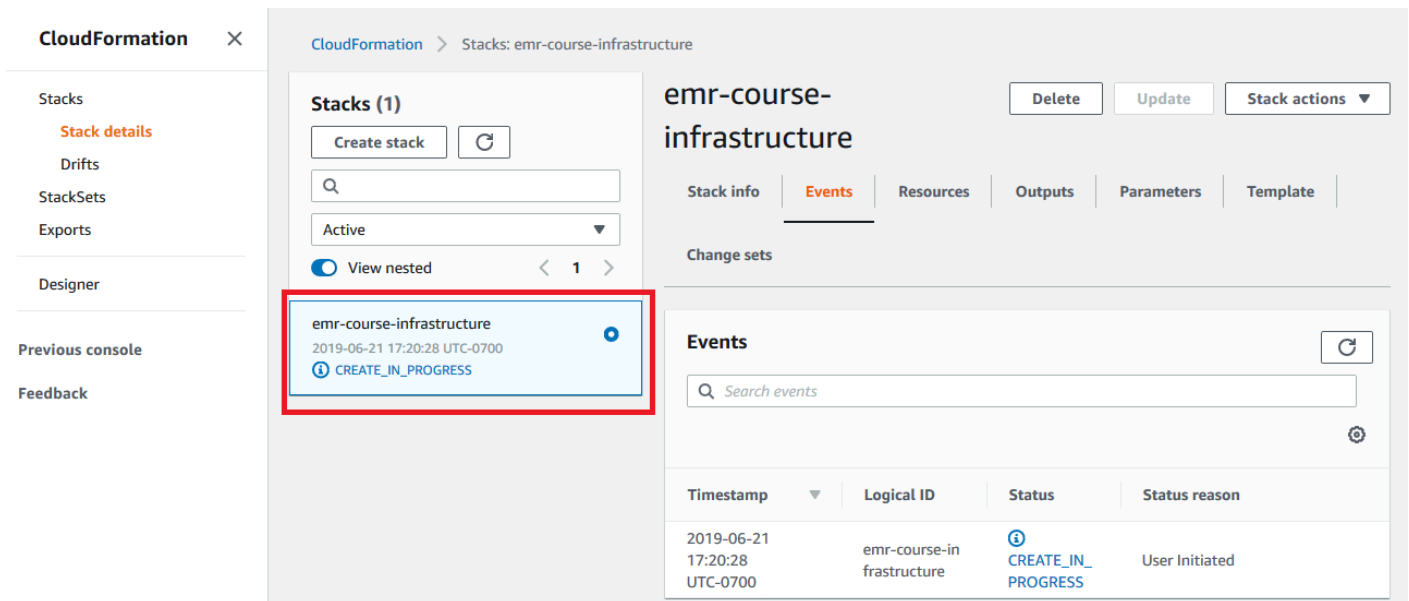


Figure 5: Cluster creation in progress

Once baseline infrastructure is created, a CREATE_COMPLETE status message appears (Figure 6).

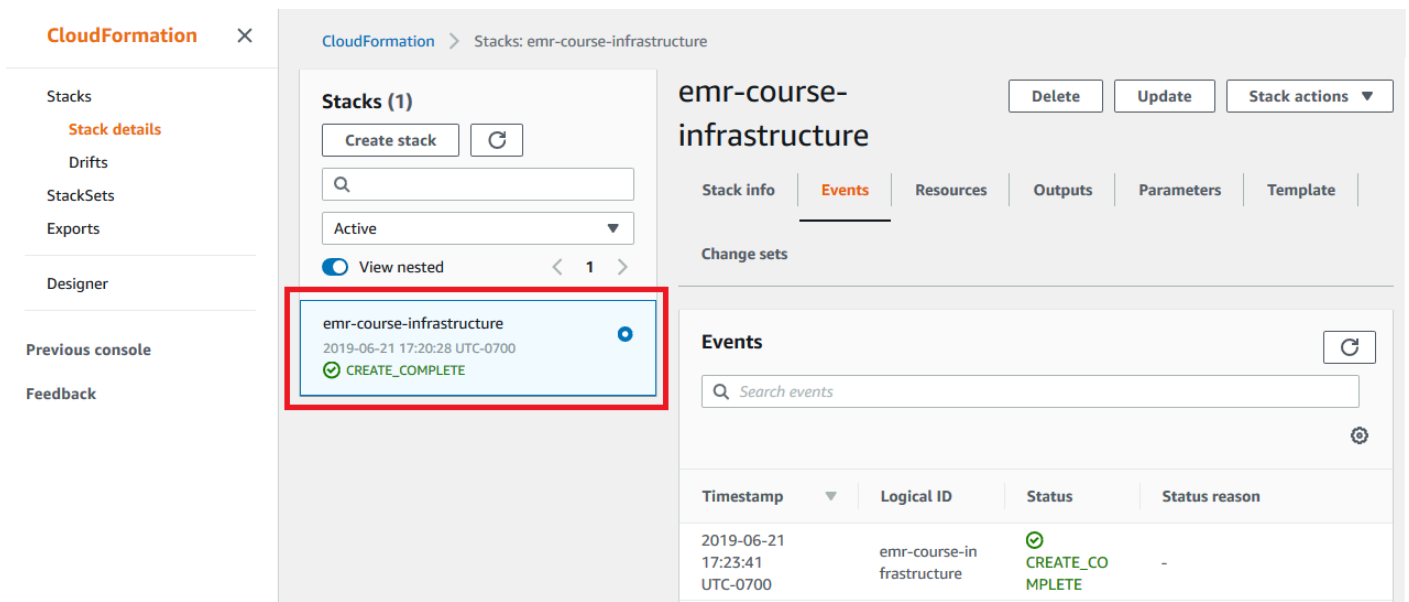


Figure 6: Cluster creation complete

10 Select the **emr-course-infrastructure** stack name, and in the right pane, choose the **Outputs** tab.

11 Make note of the following key | value.

- PublicSubnet1
- WebAccessSecurityGroup

CloudFormation > Stacks: emr-course-infrastructure

Stacks (1)

Create stack

Active

View nested < 1 >

emr-course-infrastructure
2019-06-21 17:20:28 UTC-0700
CREATE_COMPLETE

emr-course-infrastructure

Stack info | Events | Resources | **Outputs** | Parameters | Template | Change sets

Outputs (9)

Search outputs

| Key | Value | Description | Export name |
|------------------------|---------------------------------|--|-------------|
| PrivateSubnet1 | subnet-04799211 | A reference to the private subnet in the 1st Availability Zone | - |
| PrivateSubnet2 | subnet-0527011c | A reference to the private subnet in the 2nd Availability Zone | - |
| PrivateSubnets | subnet-04799211,subnet-0527011c | A list of the private subnets | - |
| PublicSubnet1 | subnet-0c22f18e | A reference to the public subnet in the 1st Availability Zone | - |
| PublicSubnet2 | subnet-0e779c00 | A reference to the public subnet in the 2nd Availability Zone | - |
| PublicSubnets | subnet-0c22f18e,subnet-0e779c00 | A list of the public subnets | - |
| StudentDataBucketName | student-data-bucket-1-emr | Location of Student Data Files | - |
| VPC | vpc-0e257400 | A reference to the created VPC | - |
| WebAccessSecurityGroup | sg-00000000 | Security group with no ingress rule | - |

Figure 7: Outputs

Update Security Group

Once your baseline infrastructure is set up, update your security group {emr-web-access-sg} with a few inbound rules. These rules allow you to access the EMR cluster and its resources.

To update the security group:

1. Sign in to the AWS Management Console and choose **Services**, then **VPC**.
2. In the left navigation pane, choose **Security Groups**.
3. In the list of security groups, select emr-web-access-sg. Choose the **Inbound rules** tab, then choose **Edit Inbound rules**.

Note

Use caution when you edit security group rules. Be sure to add rules that only allow traffic from trusted clients for the protocols and ports that are required. We do not recommend any inbound rules that allow public access, that is, traffic from sources specified as IPv4 0.0.0.0/0 or IPv6 :::/0.

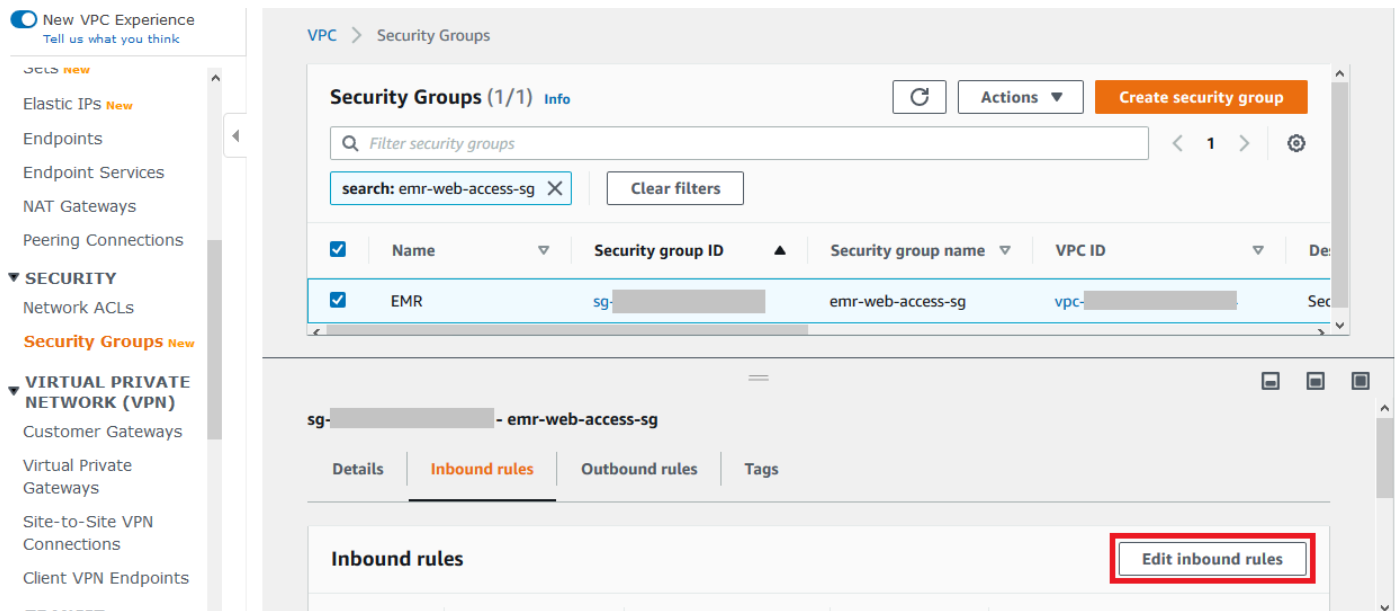


Figure 8: Edit inbound rules

4. Add the following inbound rules:

| Type | Protocol | Port | Source IP | Description |
|------------|----------|------|----------------------------|--|
| Custom TCP | TCP | 22 | {IP address or CIDR block} | For connecting to the Amazon EMR master node using SSH to run interactive queries, examine log files, submit Linux commands, and more. |
| Custom TCP | TCP | 80 | {IP address or CIDR block} | For accessing Ganglia |

| Type | Protocol | Port | Source IP | Description |
|------------|----------|-------|----------------------------|--|
| | | | | http://master-public-dns-name/ganglia/ |
| Custom TCP | TCP | 8088 | {IP address or CIDR block} | For accessing YARN Resource manager http://master-public-dns-name:8088/ |
| Custom TCP | TCP | 8890 | {IP address or CIDR block} | For accessing Zeppelin http://master-public-dns-name:8890/ |
| Custom TCP | TCP | 8888 | {IP address or CIDR block} | For access to Hue http://master-public-dns-name:8888/ |
| Custom TCP | TCP | 18080 | {IP address or CIDR block} | For accessing the Spark History server http://master-public-dns-name:18080/ |

5. Choose **Save rules**.

Deploying Individual Student EMR Resources

With the [Baseline Course Infrastructure](#) set up, students can now log in to the AWS Management Console and set up their EMR cluster.

Required Parameters and Values

Provide the students with the following information:

- Credentials to access the AWS Management Console

In this sample setup, we specified student usernames as **student01**, **student02**, and **student03**. Depending on the username convention that you use, the CloudFormation template can be updated as needed.

- Public SubnetID to deploy the EMR cluster

Use the value as noted in preceding [Step 11](#) for `PublicSubnet1`

- Security group to add to the EMR clusters

Use the value as noted in preceding [Step 11](#) for `WebAccessSecurityGroup`

To support the setup of EMR resources, students must create two things:

- An EC2 key pair to enable them SSH access to their EMR clusters

For simplicity, the name of the key pair can match the student AWS username

- A folder in the S3 bucket (as created in [Deploying the Baseline Course Infrastructure](#) setup) where students can store their data sets, code and project resources to support their course work. This bucket folder is only accessible to the specific student and course administrators.

Based on the IAM policies created earlier in the base course infrastructure setup, the folder name only accepts the AWS username of the student

Download PEM File for EMR Cluster Access

This file allows you to access your EMR clusters for each assignment.

1. Sign in to the AWS Management Console.

2. Choose the **AWS Region** drop-down box and select a Region where you want to set up Amazon EMR. (This exercise uses **US East (N. Virginia)**.)

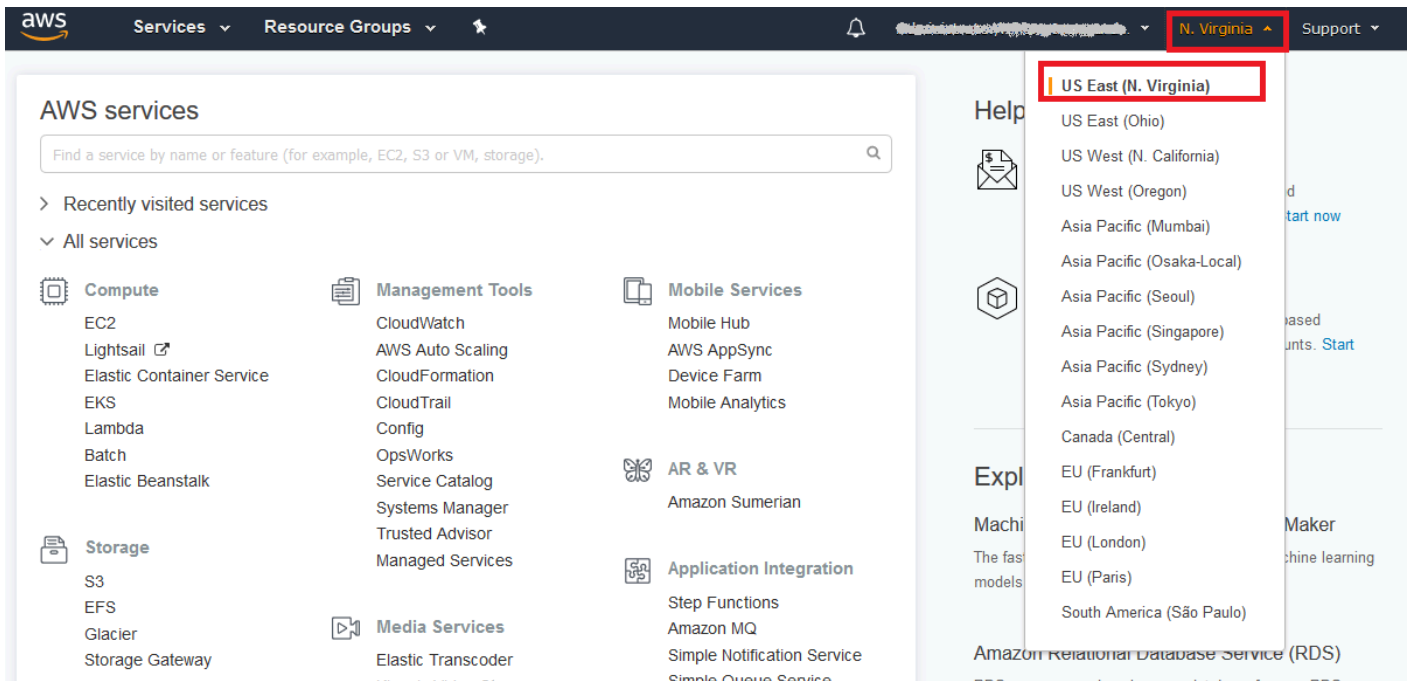


Figure 9: AWS Region selection

3. In the services list, under **Compute** choose **EC2**.
4. In the left navigation pane, under **Network & Security**, choose **Key Pairs**.
5. Choose **Create Key Pair** and name your key pair your AWS Management Console username (e.g. **student01**).
6. Choose **Create**. A PEM file is downloaded in your browser.
7. Save this PEM file to a safe location that you can access for the entire semester.

A sample template is provided in the `emr-student-cluster.yaml` file that you can access here:

<https://s3.amazonaws.com/aws-bigdata-blog/artifacts/teaching-big-data/emr-student-cluster.yaml>

With minor modification of this CloudFormation template, many policies and settings can be customized and deployed to many students. This template can be pre-populated into each student's private data repository or updated as the semester progresses. Your required configurations, instance sizes, and policies associated to various EMR functions will vary depending upon the course setup needs.

Note

The IAM permissions established for student users restricts S3 access only to the **StudentDataBucket** created from the course infrastructure CloudFormation template. Upload the `emr-student-cluster.yaml` file to this bucket to allow students to self-provision their own clusters. The following **Launch Stack** link only works for an admin user that has S3 permissions to all principles.

To learn more about the CloudFormation customizations available when deploying an EMR cluster, see: [AWS::EMR::Cluster](#). You may also want to consider other management choices that are discussed in the *Amazon EMR Management Guide*. For details, see [Plan and Configure Clusters](#).

Deploy Student Cluster

1. Click to launch the student cluster stack:



The CloudFormation page launches in the AWS Management Console. The Amazon S3 URL is pre-filled with the CloudFormation template URL.

CloudFormation > Stacks > Create stack

Step 1
Specify template

Step 2
Specify stack details

Step 3
Configure stack options

Step 4
Review

Create stack

Prerequisite - Prepare template

Prepare template
Every stack is based on a template. A template is a JSON or YAML file that contains configuration information about the AWS resources you want to include in the stack.

Template is ready Use a sample template Create template in Designer

Specify template
A template is a JSON or YAML file that describes your stack's resources and properties.

Template source
Selecting a template generates an Amazon S3 URL where it will be stored.

Amazon S3 URL Upload a template file

Amazon S3 URL

Amazon S3 template URL

S3 URL: `https://s3.amazonaws.com/aws-bigdata-blog/artifacts/teaching-big-data/emr-student-cluster.yaml`

Figure 10: Create stack

2. Choose **Next** and name the stack your AWS Management Console userID, making sure this name also matches the key name. For example, **student01**.
3. For **StudentDataBucketName**, **SubnetID** and **WebAccessSecurityGroup**, use the values provided by your administrator.
4. Choose **Next**.

The screenshot shows the 'Specify stack details' page in the AWS CloudFormation console. The page is divided into four steps: Step 1 (Specify template), Step 2 (Specify stack details), Step 3 (Configure stack options), and Step 4 (Review). The 'Specify stack details' step is active, and several fields are highlighted with red boxes:

- Stack name:** student01
- EMRClusterName:** student01
- KeyName:** student01
- StudentDataBucketName:** student-data-bucket-1
- SubnetID:** subnet-0c44941c (10.192.10.0/24) (EMR Public Subnet (AZ1))
- WebAccessSecurityGroup:** web-access-sg (sg-04100000) (EMR)

At the bottom right, there are three buttons: 'Cancel', 'Previous', and 'Next'. The 'Next' button is highlighted in orange.

Figure 11: Stack details

Note

A Failed to list topics error message may appear. This error occurs because the student IAM users are restricted to least privileges. For this example setup, you can ignore the error message. If students require additional permissions, you can modify the baseline course infrastructure CloudFormation template as needed.

Error

Failed to list topics: User: arn:aws:iam::777777777777:user/student01 is not authorized to perform: SNS:ListTopics on resource: arn:aws:sns:us-east-1:777777777777:* (Service: AmazonSNS; Status Code: 403; Error Code: AuthorizationError; Request ID: 8000a6a7-0712-3333-400d-fcb60f40d6e6)

Figure 12: Failed to list topics error

- On the **Configure stack options** page, accept the default values or change as needed.
- Choose **Next**.
- On the **Review** page, review the selections and scroll to the **Capabilities** section. Select the check box **I acknowledge that AWS CloudFormation might create IAM resources with custom names**.
- Choose **Create stack** and wait for the cluster to deploy. A CREATE_IN_PROGRESS message displays.

Once cluster is created, a CREATE_COMPLETE message displays.

Connect to EMR Master Node

- In the AWS Management Console, search for and choose **EMR**.
- In the EMR dashboard, choose **Clusters**.

| Name | ID | Status | Creation time (UTC-7) | Elapsed time | Normalized instance hours |
|-----------|-----------------|--------------------------|--------------------------|--------------|---------------------------|
| student01 | j-2CS7T824D5G9Q | Waiting Cluster ready | 2019-06-21 18:59 (UTC-7) | 10 minutes | 0 |

Figure 13: List of EMR clusters

- Choose the EMR cluster corresponding to your student login (e.g. student01).
- On the **Summary** tab, next to **Master public DNS**, choose **SSH**.

Amazon EMR

Clusters

Security configurations

VPC subnets

Events

Notebooks

Help

What's new

Clone Terminate AWS CLI export

Cluster: student01 **Waiting** Cluster ready to run steps.

Summary Application history Monitoring Hardware Configurations Events Steps Bootstrap actions

Connections: [Enable Web Connection](#) – Spark History Server, Resource Manager ... (View All)

Master public DNS: 100.27.6.161 [SSH](#)

Tags: -- [View All / Edit](#)

| Summary | Configuration details | Network and hardware |
|---|---|--|
| <p>ID: j-2CS7T824D5G9Q</p> <p>Creation date: 2019-06-21 18:59 (UTC-7)</p> <p>Elapsed time: 10 minutes</p> <p>Auto-terminate: No</p> <p>Termination protection: Off Change</p> | <p>Release label: emr-5.23.0</p> <p>Hadoop Amazon distribution:</p> <p>Applications: Spark 2.4.0, Pig 0.17.0</p> <p>Log URI: --</p> <p>EMRFS consistent view: Disabled</p> <p>Custom AMI ID: --</p> | <p>Availability zone: us-east-1a</p> <p>Subnet ID: subnet-00000000</p> <p>Master: Running 1 m5.xlarge</p> <p>Core: Running 1 m5.xlarge</p> <p>Task: --</p> |

Security and access

Key name: student01

EC2 instance profile: student01-profile: EMRClusterInstanceProfile-YJ41M9G13UH6

EMR role: student01-EMRClusterServiceRole-1G1P4NWWOXXKX

Auto Scaling role: EMR_AutoScaling_DefaultRole

Visible to all users: All [Change](#)

Security groups for Master: (ElasticMapReduce-master) [More](#)

Security groups for Core & Task: (ElasticMapReduce-slave)

Figure 14: Cluster summary

- Choose the appropriate tab for your operating system and follow the instructions to connect to the master node.

SSH

Connect to the Master Node Using SSH

You can connect to the Amazon EMR master node using SSH to run interactive queries, examine log files, submit Linux commands, and so on. [Learn more](#)

Windows **Mac / Linux**

- Open a terminal window. On Mac OS X, choose Applications > Utilities > Terminal. On other Linux distributions, terminal is typically found at Applications > Accessories > Terminal.
- To establish a connection to the master node, type the following command. Replace ~/student01.pem with the location and filename of the private key file (.pem) used to launch the cluster.

```
ssh -i ~/student01.pem hadoop@100.27.6.161
```
- Type yes to dismiss the security warning.

[Close](#)

Figure 15: SSH instructions for Mac/Linux

Once you have successfully connected to the EMR master node, EMR appears on the console screen.

The example student EMR cluster is now deployed. Students can now use these resources for their coursework.

Individual Student AWS Accounts Hosting One EMR Cluster Per Student

In this deployment option, each student is required to provision (or use an existing personal) AWS account to deploy a personal EMR cluster. These accounts can be student personal accounts with personal billing responsibility or sub-accounts as part of a university AWS Organization with consolidated institution billing. If these accounts are part of an AWS Organization, they can be programmatically provisioned as child accounts within the university organization with granular IAM controls native to this provisioning.

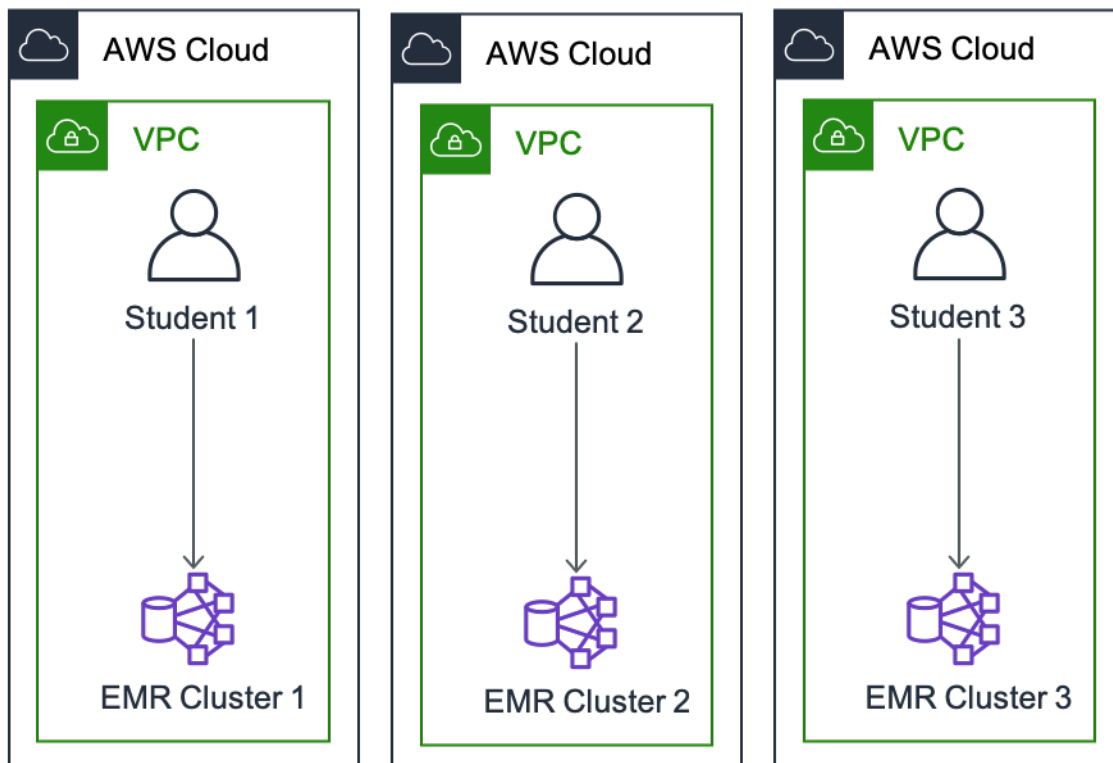


Figure 15: Individual student AWS accounts hosting one EMR cluster per student

The difference between this option and the [One AWS Account Hosting One EMR Cluster Per Student](#) option is that the segmentation of resources takes place in separate AWS accounts. With an individual account, security controls depend upon the account security policies and control mechanism. If using an individual student account without controls, all security control and cost management shifts from the IT administrative staff to the AWS student account owner. For a personal account, students are fully in charge of their own resources and costs. If an AWS Organization is used, Service Control Policies (SCP) can restrict the services and actions that

users, groups, and roles in student accounts can access. In both scenarios, it is critical for students to understand how to control the costs of their EMR clusters so that they are only in use when running workloads.

Users and Authentication

In this deployment model, students control IAM permissions within their own accounts, and all access rights to the data contained within them (pending any organizational control policies if the account is a part of AWS Organizations). As an account owner, each student may have full administrative (or root) access. If resources are deployed in a personal account, students are financially responsible for these resources as well. In a personal account, configuring IAM permissions to limit functions outside of the EMR service is not required. However, for students to submit their coursework to be graded by course administrators, you must determine where student data will reside and who maintains ownership of it. You may elect to provide a student-data bucket owned by your institution, or have data reside in student accounts. If student data resides in an institution account, you must configure bucket policies to restrict access. These policies require that you obtain account information from each student-owned account to determine who will have access to the student objects/buckets. If data resides in a student account, similar policies to allow course administrators to read student submissions are required, but in the opposite direction. For students that are not very familiar with AWS, this approach may add additional administrative challenge if personal accounts are used.

For more information on how to manage access permissions for S3 resources, see [Amazon Simple Storage Service Developer Guide](#).

Implementation

To deploy this scenario, use the previous CloudFormation templates to establish a course infrastructure and an individual cluster in each student account.

One AWS Account Hosting One EMR Cluster for All Students

In this deployment option, an institution's IT department deploys a single EMR cluster on an IT administrative account. Security, billing, and cluster configuration are all controlled by the university IT administrative staff. Provisioned resources are only accessible via SSH or web-interfaces as no AWS Management Console access would be provided to students. This option is the most centralized administrative model that affords IT administrative staff with the most control over access and cost. The main tradeoff is the need to manage permissions within this account by creating individual IAM roles to correspond to the granular access rights required by each cluster user (student, instructor and support staff). EMR cluster resources must also be maintained to remain on for the entire duration of the course, or an established time window when students may access course resources.

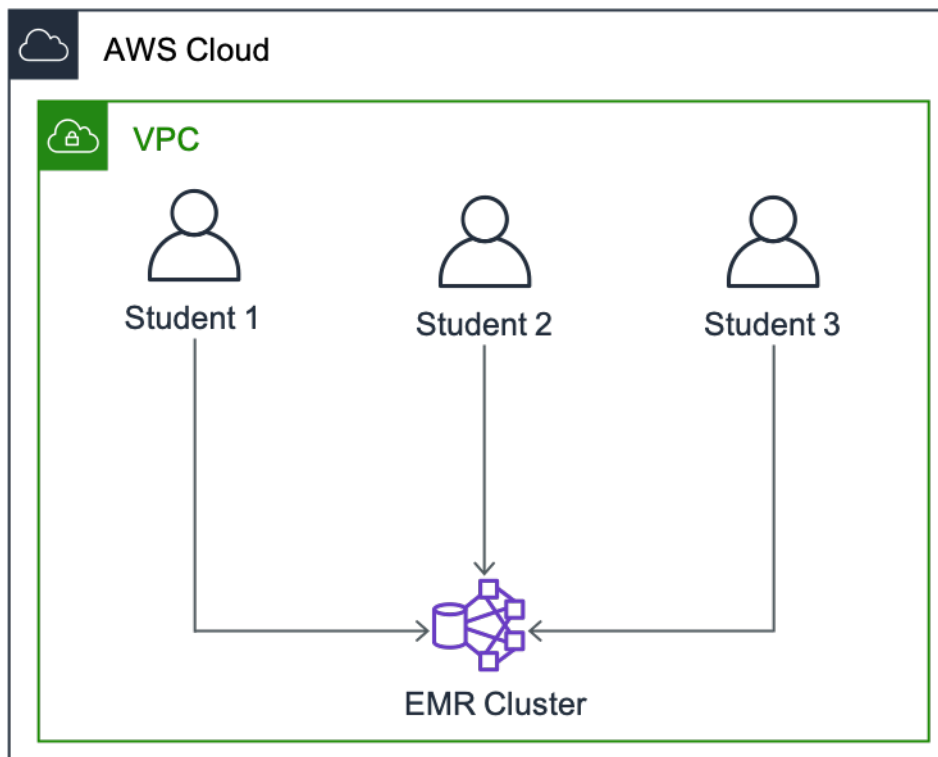


Figure 16: One AWS Account hosting one EMR cluster for all students

Users and Authentication

In this deployment option, a new Linux user is created for each unique user of the EMR cluster. Since users only have SSH access to the master node of the EMR cluster, you must authenticate

users on this node using traditional Linux authentication methods. One suggested way of doing this is by generating SSH key pairs and configuring them as the means of user authentication upon cluster creation. These credentials can be generated natively from the Linux shell of the EMR cluster master node or can be created with EC2 key pairs. This process can also be automated.

Implementation

To set up an EMR cluster to be multi-tenant, the EMR Master node must have SSH keys and users created so that each user has their own profile on the EMR cluster. To do this, create a Linux user for each user and set up each user with their own SSH keys. For more information on how to connect to the EMR cluster, see [Use an Amazon EC2 Key Pair for SSH Credentials](#).

Once the EMR cluster is ready and available to use, login to the EMR cluster using the Hadoop username using the associated SSH key-pair of the EMR cluster. After successfully logging in to the EMR cluster, use the following steps to create the users and enable each user with SSH keys. Two forms of usernames are referenced as examples in code and command samples:

- **Hadoop:** the master management user to access the EMR cluster for administration.
- **student01:** the test user created.

Table 2: Sample command flow to show user creation and SSH key association:

| Step | Command | Description |
|------|---|--|
| 1 | <code>sudo adduser student01</code> | Creates new user student01 . |
| 2 | <code>sudo su - student01</code> | Switch to newly created user student01 . |
| 3 | <code>mkdir .ssh</code> | Create new directory to store SSH key. |
| 4 | <code>chmod 700 .ssh</code> | Update read/write/execute permissions for the directory. |
| 5 | <code>touch .ssh/authorized_keys</code> | Create a new file called authorized_keys . |

| Step | Command | Description |
|------|--|---|
| 7 | <code>chmod 600 .ssh/authorized_keys</code> | Update read/write/execute permissions on the authorized_keys file. |
| 8 | <code>cat >> .ssh/authorized_keys</code> | Copy and paste the SSH key that you would like to use and save the file (Ctrl+D). |

Set Up Access to S3 Using Linux Credentials

If EMR needs access to S3 buckets (such as if the instructor created data sets to be accessed by all students or student specific buckets/folders), instead of needing to create IAM AccessID/Secret Keys for students to access Amazon S3 and having to distribute and keep rotating those keys, IAM roles and policies can be used and mapped to the local Linux users created in the Master node. This is available by enabling EMRFS authorization for S3 access. For more details, see [Configure IAM Roles for EMRFS Requests to Amazon S3](#).

Note

This option can only be configured on cluster creation and cannot be updated. By default, the EMR role for EC2 determines the permissions for accessing EMRFS data in Amazon S3. The IAM policies that are attached to this role apply regardless of the user or group making the request through EMRFS, which is important to consider if users have SSH access to cluster nodes. The default is **EMR_EC2_DefaultRole**. For more information, see [Service Role for Cluster EC2 Instances \(EC2 Instance Profile\)](#).

Set up HDFS Permissions using Linux Credentials

For the Linux users created above to have access to their own Hadoop Distributed File System (HDFS) directories, the user specific HDFS directories must be created using the `hdfs` commands. For command details, see [HDFS Permissions Guide](#).

1. Create Home directory for each user.

```
hdfs dfs -mkdir /user/INSERT_USER_NAME
```

2. Apply ownership for the newly created home directory to the user

```
hdfs dfs -chown INSERT_USER_NAME:INSERT_USER_NAME /user/INSERT_USER_NAME
```

Example:

```
hdfs dfs -mkdir /user/student01
hdfs dfs -chown student01:student01 /user/student01
```

For HDFS, there is a completely separate permission silo. As such, you want to provision separate group ownership to each user and then have separate entries for each group in each student's `facl`. Depending on the current state of permissions or if you want to automate new cluster creation, you might want to overwrite a full `facl`, for example:

HDFS command syntax to set ACL permissions:

```
hdfs dfs -setfacl [-R] [-b |-k -m |-x <acl_spec> <path>] |[-set <acl_spec> <path>]
```

Example (student01 access rights):

```
hdfs dfs -chown student01:student01 /user/student01

hdfs dfs -setfacl -R -set
user:student01:rwx,group:instructors:rwx,group:administrators:rwx,group:teachingassistants:rwx
/user/student01
```

Additionally, apply similar ACL permissions to lock down the superuser and any administrator accounts or directories that you create.

Note

The `/tmp hdfs` directory can store information (such as queries and keys) that is readable in plain text. Make sure to lock this directory down so that only class administrators/instructors have access to this directory. You can do this by limiting read access only to the needed users/groups.

For example, to lock down access to only the instructors, you can use permissions such as:

```
hdfs dfs -setfacl -set user::rwx,group:instructors:rwx,other::-wx /tmp
```

Set up Access to Zeppelin Using Linux Credentials

Zeppelin supports multi-tenant by using a component called Shiro. [Apache Shiro](#) is a security framework that provides support for authentication, authorization, cryptography and session management. You can use Shiro to set up authentication for Zeppelin. There are three steps to this setup:

Step 1 — Enabling formed auth security

1. Navigate to the ZEPPELIN_CONF_DIR path on the EMR master node. The ZEPPELIN_CONF_DIR path will be set to /usr/lib/zeppelin directory.
2. Go to the conf directory by typing `cd conf` and open the `shiro.ini` file for editing (vi or nano editor) by typing the command such as `sudo vi shiro.ini`
3. In `shiro.ini`, comment and un-comment the below settings in the `[urls]` section. This tells Zeppelin to allow access only to users who authenticate to Zeppelin and not allow any anonymous user access.

Zeppelin is enabled with anonymous access by default. To disable anonymous access, comment out the below configuration setting by adding a `#` before the setting.

```
#/* = anon
```

Then, un-comment the below configuration setting by removing the `#` from the setting:

```
/* = authc
```

Additionally, in the same `shiro.ini` file, a few settings must be updated to ensure these configuration options are only available to users who are part of admin roles.

```
/api/interpreter/* = authc, roles[admin]  
/api/configurations/* = authc, roles[admin]  
/api/credential/* = authc, roles[admin]
```

Note

These settings already exist in the `shiro.ini` file (located at the end of the file). After these updates, the `shiro.ini` file appear like the following:

```
[urls]
# authentication method and access control filters
#/api/version = anon
/api/interpreter/* = authc, roles[admin]
/api/configurations/* = authc, roles[admin]
/api/credential/* = authc, roles[admin]
#/* = anon
/* = authc
```

4. Open `shiro.ini` file and add users in the **[users]** section of the file. For example:

```
[users]
Hadoop, password1, admin
student01, password2, role
```

Step 2 — Disabling anonymous access

1. In the Zeppelin conf directory, locate the `zeppelin-site.xml` file. If this file does not exist, copy (do not rename) the `zeppelin-site.xml.template` file to `zeppelin-site.xml`.

```
#command example below:
sudo cp zeppelin-site.xml.template zeppelin-site.xml
```

2. Open the `zeppelin-site.xml` file in `vi` or `nano` editor and set the property `zeppelin.anonymous.allowed` to `false`.

This setting disables any anonymous access to Zeppelin. All users are forced to enter credentials to log in to Zeppelin.

Step 3 — Restarting Zeppelin service for changes to take effect

1. Stop the Zeppelin service by running the below command on the Linux command prompt.

```
sudo systemctl stop zeppelin
```

2. Start the Zeppelin service by running the below command on the Linux command prompt.

```
sudo systemctl start zeppelin
```

Set up Access to HUE Using Linux Credentials

HUE is an open source user interface for Hadoop that makes it easier to run and develop Hive queries, manage files in HDFS, run and develop Apache Pig scripts, and manage tables.

HUE looks for an exact match of the HUE username to the HDFS user and associated permissions to allow file operations. HUE users can be created manually using the HUE user interface, or can be scripted using Python.

Note

Superuser must be created by first login to HUE console.

The following commands can be used to script the HUE user creation process using Python:

1. Open the HUE shell by running the following command on the Linux prompt

```
sudo /usr/lib/hue/build/env/bin/hue shell
```

2. Import django libraries for USER and GROUP

```
from django.contrib.auth.models import User
from django.contrib.auth.models import Group
```

3. Create HUE user and store the user in an object.

```
objUser = User.objects.create_user (username='INSERT_USER_NAME',
password='INSERT_USER_PASSWORD', first_name='INSERT_FIRST_NAME',
last_name='INSERT_LAST_NAME')
```

4. Get HUE group in an object – this example uses students as the group name.

```
objGroup = Group.objects.get (name='students')
```

5. Attach the newly created HUE user to HUE group.

```
objGroup.user_set.add (objUser)
```

6. Apply the settings.

```
objUser.save()
```

7. Quit the HUE shell.

```
quit()
```

Set up Interpreters in Zeppelin as Multi-Tenant Setup

Zeppelin Interpreter is a plug-in that enables Zeppelin users to use a specific language and data-processing-backend. For example, you can use Apache Spark or JDBC in Zeppelin for any data processing.

Apache Spark Interpreter

Apache Spark is a unified analytics engine used in large-scale data processing. In simple terms, Spark allows users to run SQL queries and create data frames for analysis using various common languages, mainly Java, Python and Scala. Spark is a native component of EMR that is available to be automatically provisioned when deploying an AWS EMR cluster.

Here are the steps to set up Spark in Zeppelin:

1. Open the `/usr/lib/zeppelin/conf/zeppelin-env.sh` file and add the below lines to the environment file:

```
ZEPPELIN_IMPERSONATE_SPARK_PROXY_USER=false
```

2. Create/update the SPARK interpreter in Zeppelin.

Use the configuration settings as available in the [Spark Interpreter for Apache Zeppelin](#) documentation.

a. For the master property, set the value to `yarn-client` instead of `local[*]`.

- b. Set up User Impersonate for the Interpreter by selecting isolated user process in the interpreter option
- c. Restart the Spark interpreter using the Zeppelin UI.
- d. Stop and start Zeppelin.

```
sudo stop zeppelin
sudo start zeppelin
```

JDBC Interpreter

Zeppelin can be used to communicate with databases. For example, you can configure Zeppelin to use a JDBC interpreter to access Hive. For more information, see [Using the jdbc Interpreter to Access Hive](#).

1. Install JDBC interpreter using the following command.

```
sudo cp /usr/lib/hive/jdbc/hive-jdbc-2.3.2-amzn-1-standalone.jar /usr/lib/zeppelin/interpreter/jdbc/
```

For additional information on configuring the JDBC interpreter, see [Hive Interpreter for Apache Zeppelin](#).

1. Configure Zeppelin impersonation for Hive:
 - a. In the Zeppelin UI, navigate to the {jdbc} section of the Interpreter page.
 - b. Click **Edit**, then add a `hive.proxy.user.property` property and set its value to `hive.server2.proxy.user`.
 - c. Click **Save**, then click **Restart** to restart the JDBC interpreter.

Connectivity to database

A connection to a database may need a connection-string having username/password. In our case, we need to use the Linux user/password to enable such connection. This is enabled by setting up `Credentials` in Zeppelin. This will be set up per user to use their Linux user/password and will be used as impersonation to enable access to their own HDFS via JDBC. For more information, see this documentation:

- [Data Source Authorization in Apache Zeppelin](#)
- [Configuring User Impersonation for Access to Hive](#)

Create the `/usr/lib/zeppelin/conf/credentials.json` file as part of the EMR cluster setup – so all the users are configured on cluster setup. The data in this json file will look like the following code sample (showing with sample Linux user names for reference).

```
{
  "credentialsMap": {
    "Hadoop": {
      "userCredentials": {
        "jdbc.jdbc": {
          "username": "Hadoop",
          "password": "password1"
        }
      }
    },
    "student01": {
      "userCredentials": {
        "jdbc.jdbc": {
          "username": "student02",
          "password": "password2"
        }
      }
    }
  }
}
```

Ensure all settings are in place by restarting the JDBC interpreter and then restarting Zeppelin.

Run JDBC commands in Zeppelin

Since we are using Hive properties for the JDBC interpreter, the notebook command will always start with `%jdbc (hive)`.

Creating databases and tables – these can be stored in `/user/hive/warehouse` or in a specified directory such as `/user/student02/` (using the `location` parameter) — as long the logged in user has access to those directories. Default is always `/user/hive/warehouse`. In both location cases, the user that created the databases/tables is the one that will have access as the user is the owner of those files (per HDFS ACLs).

Sample example jdbc notebook note below. This creates a database testdb01 and then creates a table table01 in database testdb01. Additionally, stores the database + table into the /user/student02 location in HDFS.

```
%jdbc (hive)
create database testdb01 location '/user/student02/';
CREATE TABLE testdb01.table01 (
    person_id string,
    gender string,
    birthdate string,
    uuid string,
    fullname string,
    given_name string,
    middle_name string,
    family_name string,
    family_name2 string,
    family_name_suffix string
);
```

To load data to this table from a file, you can use the below command:

```
%jdbc (hive)
LOAD DATA INPATH '/user/student02/file_sample.csv' OVERWRITE INTO TABLE
testdb01.table01;
```

Back up Zeppelin Notebook Notes

Backing up notebooks is always a good idea, especially when EMR workloads are moved to different clusters, or migrated to a cluster with augmented capacity. See the following steps to make a backup of Zeppelin notebook notes to S3.

When a user creates a notebook, the notebook gets stored in the ZEPPELIN_NOTEBOOK_DIR (path specified in the /usr/lib/zeppelin/conf/zeppelin-env.sh file).

For example: `export ZEPPELIN_NOTEBOOK_DIR = /var/lib/zeppelin/notebook`

Additionally, since the notebooks are saved as private (not public), Zeppelin manages the access permissions in an authorization file. This notebook authorization file (notebook-authorization.json) is located in the /usr/lib/zeppelin/conf directory.

To backup these files/directories and copy them to a new EMR cluster:

1. Copy these files/directories to a S3 bucket (using the AWS S3 CLI [Copy \[cp\] parameter](#)).
2. Once the new EMR cluster is ready, SSH into the cluster and copy the files and directories from S3 to the Zeppelin directories on the cluster (using the AWS S3 CLI).
3. Use the following commands to stop and start Zeppelin for the notebook authorization to take effect (after the copy operation):

```
sudo stop zeppelin  
sudo start zeppelin
```


Conclusion

In this document, we explored design considerations and associated deployment models that can be used to teach big data skills in a university setting using Amazon EMR. There are various tradeoffs to analyze in terms of resource control and protecting student data in exchange for administrative overhead. In any of the discussed scenarios, the Amazon EMR service provides a simplified way to manage the underlying compute infrastructure such that resources are only billed as they are used. These deployment models combined with proper preparation and course design, can enable your organization to quickly deploy EMR clusters in an educational setting to enable hands-on access with a pay-as-you-go-model.

Contributors

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Document revisions

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| Change | Description | Date |
|-------------------------------------|--|-----------------|
| Minor update | Updated commands in <i>Step 3</i> — <i>Restarting Zeppelin service</i> . | August 4, 2021 |
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