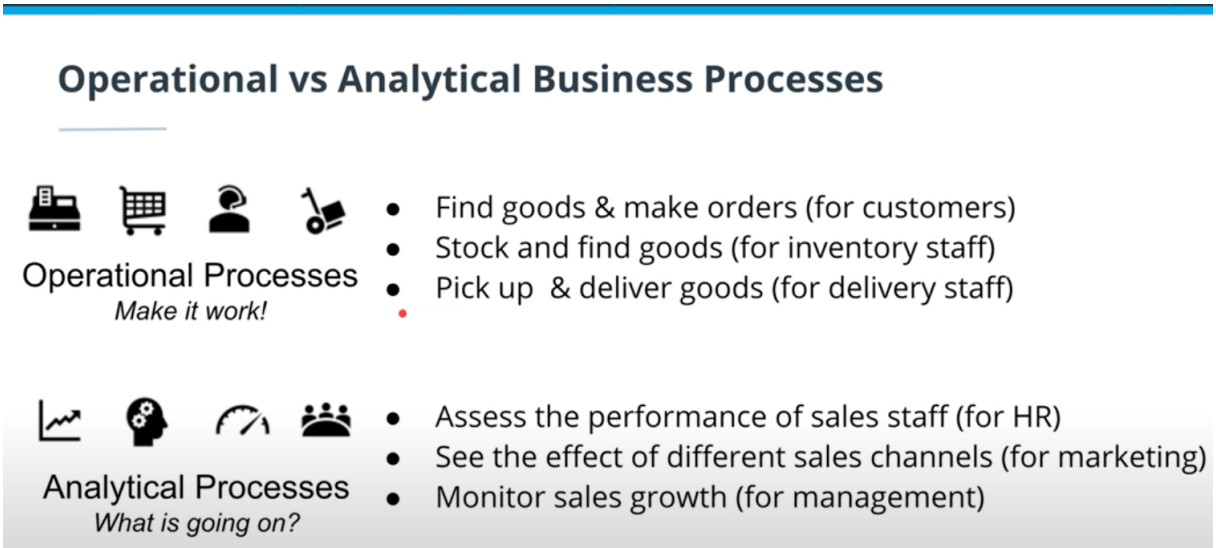
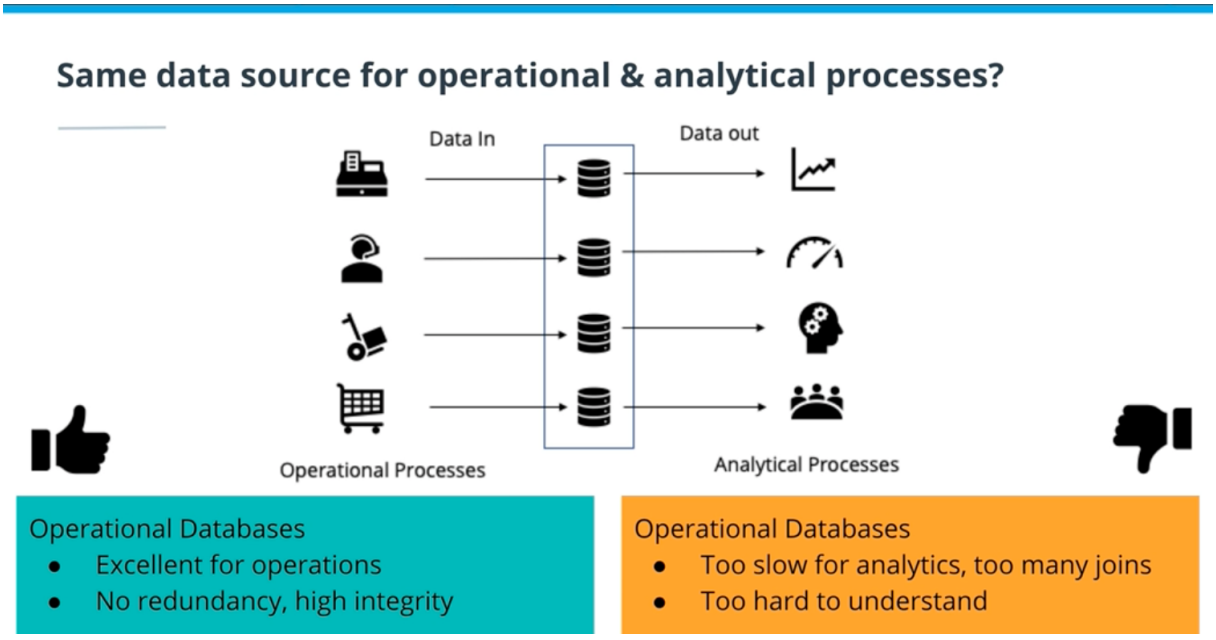
Cloud Data Warehouses

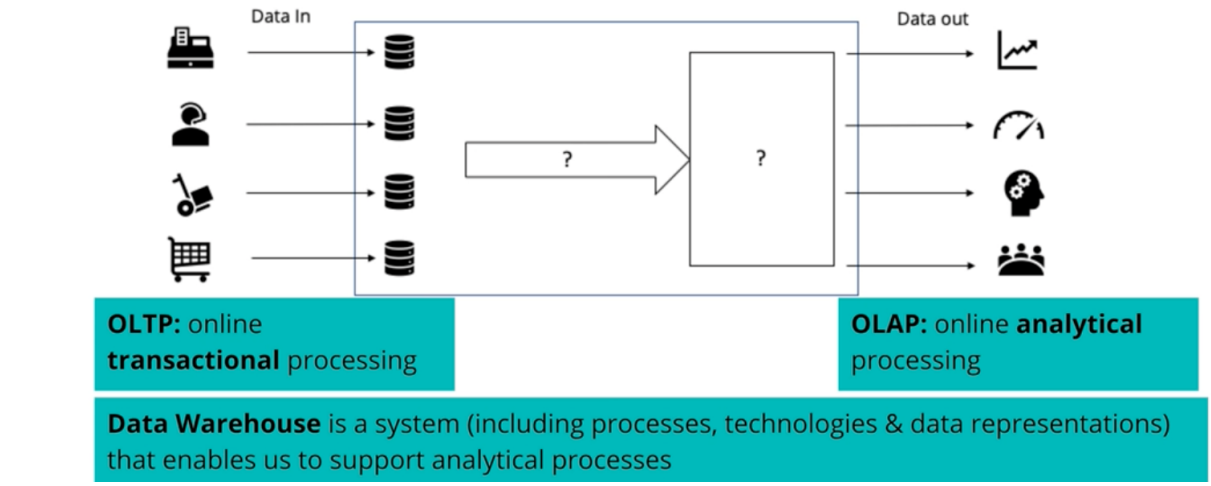
Course 2 | Cloud Data Warehouses

▼ **Introduction to DWH** (Business vs Technical Perspective, CUBE ROLAP, Columner storage vs Row)

Business vs Technical Perspective





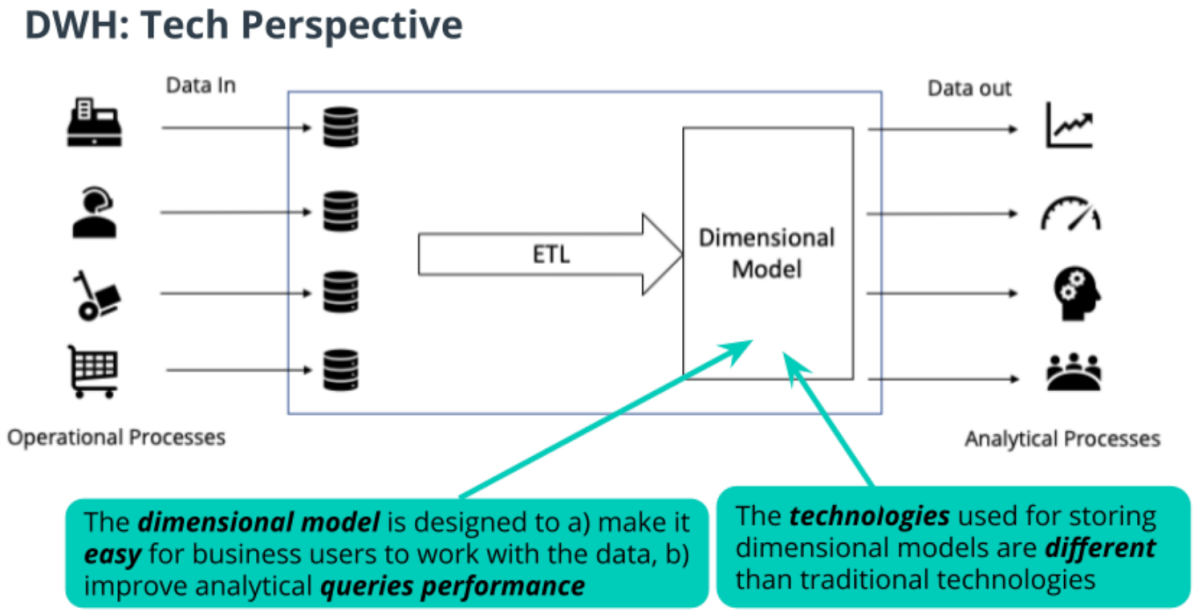


Data Warehouse Definitions

- A data warehouse is a copy of transaction data specifically structured for query and analysis. - *Kimball*
- A data warehouse is a **subject-oriented**, **integrated**, **nonvolatile**, and **time-variant** collection of data in support of management's decisions. - *Inmon*
- A data warehouse is a system that retrieves and consolidates data periodically from the source systems into a **dimensional** or **normalized** data store. It usually keeps years of history and is queried for business intelligence or other analytical activities. It is typically updated in batches, not every time a transaction happens in the source system. - *Rainard*

Data Warehouse: Technical Perspective

Extract the data from the source systems used for operations, transform the data, and load it into a dimensional model



Dimensional Model Review

Goals of the Star Schema

- Easy to understand
- Fast analytical query performance

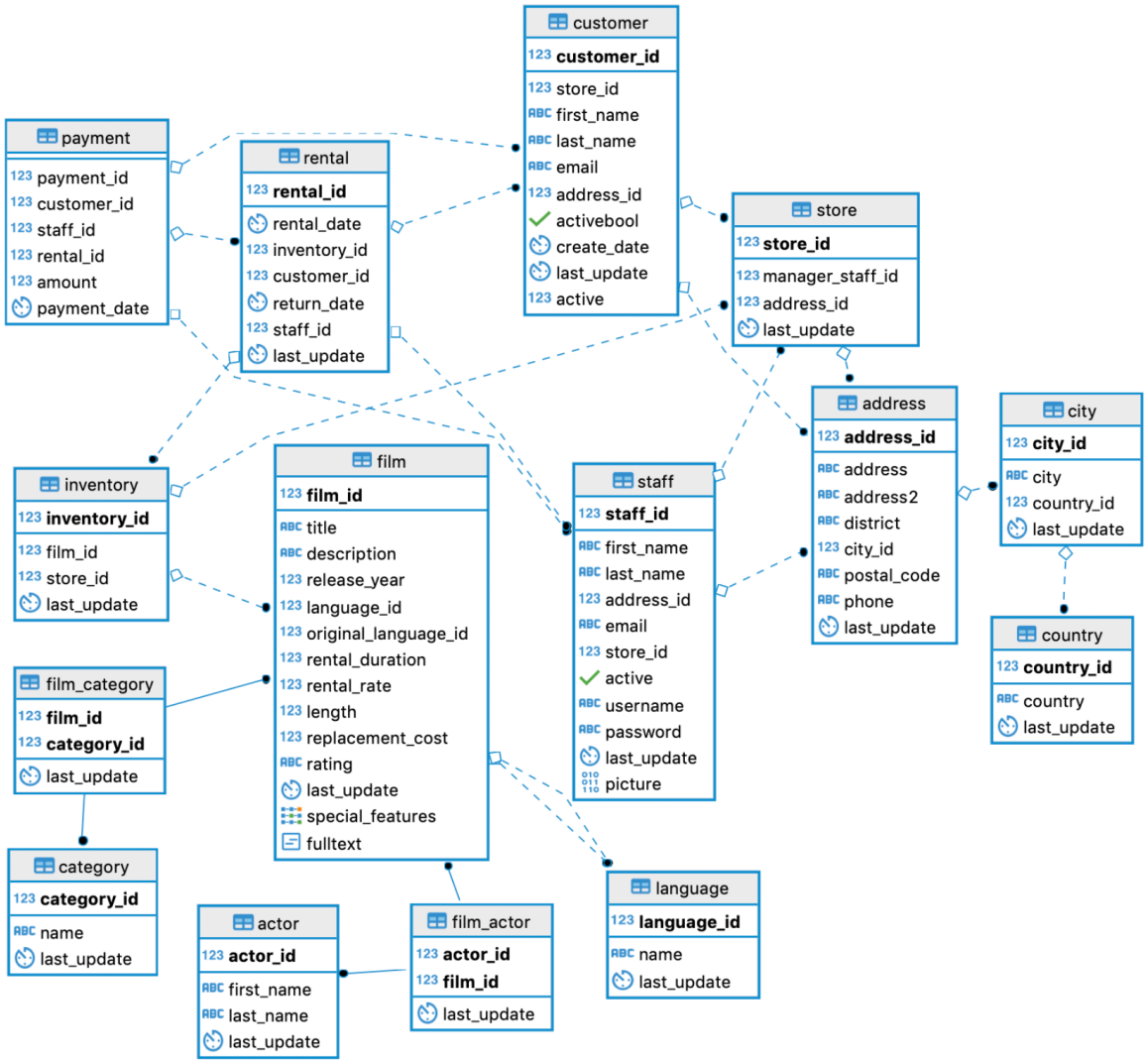
Fact Tables

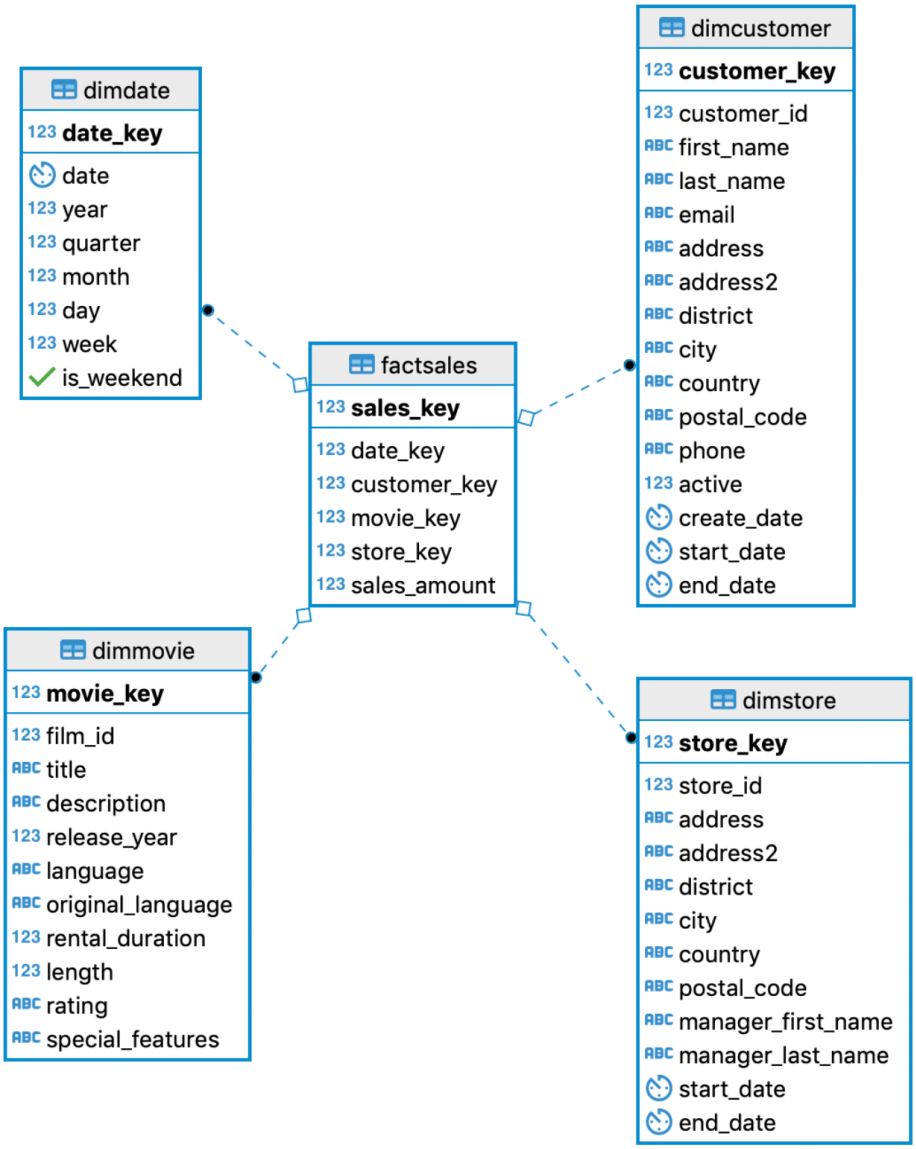
- Record business events, like an order, a phone call, a book review
- Fact tables columns record events recorded in quantifiable metrics like quantity of an item, duration of a call, a book rating

Dimension Tables

- Record the context of the business events, e.g. who, what, where, why, etc..
- Dimension tables columns contain attributes like the store at which an item is purchased or the customer who made the call, etc.

▼ ***DEMO Snowflake to Star (Fact & Dimension) Schema***






```
!PGPASSWORD=student createdb -h 127.0.0.1 -U student pagila
!PGPASSWORD=student psql -q -h 127.0.0.1 -U student -d pagila -f Data/pagila-schema.sql
!PGPASSWORD=student psql -q -h 127.0.0.1 -U student -d pagila -f Data/pagila-data.sql

%load_ext sql

DB_ENDPOINT = "127.0.0.1"
DB = 'pagila'
DB_USER = 'student'
DB_PASSWORD = 'student'
DB_PORT = '5432'

# postgresql://username:password@host:port/database
conn_string = "postgresql://{}:{}@{}:{}/{}" \
                        .format(DB_USER, DB_PASSWORD, DB_ENDPOINT, DB_PORT, DB)

print(conn_string)
%sql $conn_string

## Explore the (snowflake) 3NF Schema first
nStores = %sql select count(*) from store;
nFilms = %sql select count(*) from film;
nCustomers = %sql select count(*) from customer;
nRentals = %sql select count(*) from rental;
```

```
nPayment = %sql select count(*) from payment;
nStaff = %sql select count(*) from staff;
nCity = %sql select count(*) from city;
nCountry = %sql select count(*) from country;

print("nFilms\t\t=", nFilms[0][0])
print("nCustomers\t=", nCustomers[0][0])
print("nRentals\t=", nRentals[0][0])
print("nPayment\t=", nPayment[0][0])
print("nStaff\t\t=", nStaff[0][0])
print("nStores\t\t=", nStores[0][0])
print("nCities\t\t=", nCity[0][0])
print("nCountry\t\t=", nCountry[0][0])

## Build the Star Schema now
%%sql
CREATE TABLE dimDate
(
  date_key integer NOT NULL PRIMARY KEY,
  date date NOT NULL,
  year smallint NOT NULL,
  quarter smallint NOT NULL,
  month smallint NOT NULL,
  day smallint NOT NULL,
  week smallint NOT NULL,
  is_weekend boolean
);

CREATE TABLE dimCustomer
(
  customer_key SERIAL PRIMARY KEY,
  customer_id  smallint NOT NULL,
  first_name   varchar(45) NOT NULL,
  last_name    varchar(45) NOT NULL,
  email        varchar(50),
  address      varchar(50) NOT NULL,
  address2     varchar(50),
  district     varchar(20) NOT NULL,
  city         varchar(50) NOT NULL,
  country      varchar(50) NOT NULL,
  postal_code  varchar(10),
  phone        varchar(20) NOT NULL,
  active       smallint NOT NULL,
  create_date  timestamp NOT NULL,
  start_date   date NOT NULL,
  end_date     date NOT NULL
);

CREATE TABLE dimMovie
(
  movie_key          SERIAL PRIMARY KEY,
  film_id            smallint NOT NULL,
  title              varchar(255) NOT NULL,
  description        text,
  release_year       year,
  language           varchar(20) NOT NULL,
  original_language  varchar(20),
  rental_duration    smallint NOT NULL,
  length             smallint NOT NULL,
  rating             varchar(5) NOT NULL,
  special_features   varchar(60) NOT NULL
);
CREATE TABLE dimStore
(
  store_key           SERIAL PRIMARY KEY,
  store_id            smallint NOT NULL,
  address             varchar(50) NOT NULL,
  address2            varchar(50),
  district            varchar(20) NOT NULL,
  city                varchar(50) NOT NULL,
  country             varchar(50) NOT NULL,
  postal_code         varchar(10),
  manager_first_name  varchar(45) NOT NULL,
  manager_last_name   varchar(45) NOT NULL,
  start_date          date NOT NULL,
  end_date            date NOT NULL
);
CREATE TABLE factSales
(
  sales_key        SERIAL PRIMARY KEY,
  date_key         INT NOT NULL REFERENCES dimDate(date_key),
```

```
  customer_key     INT NOT NULL REFERENCES dimCustomer(customer_key),
  movie_key        INT NOT NULL REFERENCES dimMovie(movie_key),
  store_key        INT NOT NULL REFERENCES dimStore(store_key),
  sales_amount     decimal(5,2) NOT NULL
);

##ETL from the 3NF into Fact & Dimension tables
%%sql
INSERT INTO dimDate (date_key, date, year, quarter, month, day, week, is_weekend)
SELECT DISTINCT(TO_CHAR(payment_date :: DATE, 'yyyyMMDD')::integer) AS date_key,
       date(payment_date)                                           AS date,
       EXTRACT(year FROM payment_date)                              AS year,
       EXTRACT(quarter FROM payment_date)                           AS quarter,
       EXTRACT(month FROM payment_date)                             AS month,
       EXTRACT(day FROM payment_date)                               AS day,
       EXTRACT(week FROM payment_date)                              AS week,
       CASE WHEN EXTRACT(ISODOW FROM payment_date) IN (6, 7) THEN true ELSE false END AS is_weekend
FROM payment;


INSERT INTO dimCustomer (customer_key, customer_id, first_name, last_name, email, address, address2, district, city, country, posta
SELECT c.customer_id AS customer_key,
       c.customer_id,
       c.first_name,
       c.last_name,
       c.email,
       a.address,
       a.address2,
       a.district,
       ci.city,
       co.country,
       a.postal_code,
       a.phone,
       c.active,
       c.create_date,
       now()         AS start_date,
       now()         AS end_date
FROM customer c
JOIN address a  ON (c.address_id = a.address_id)
JOIN city ci    ON (a.city_id = ci.city_id)
JOIN country co ON (ci.country_id = co.country_id);

INSERT INTO dimMovie (movie_key, film_id, title, description, release_year, language, original_language, rental_duration, length, r
SELECT f.film_id      AS movie_key,
       f.film_id,
       f.title,
       f.description,
       f.release_year,
       l.name         AS language,
       orig_lang.name AS original_language,
       f.rental_duration,
       f.length,
       f.rating,
       f.special_features
FROM film f
JOIN language l              ON (f.language_id=l.language_id)
LEFT JOIN language orig_lang ON (f.original_language_id = orig_lang.language_id);

INSERT INTO dimStore (store_key, store_id, address, address2, district, city, country, postal_code, manager_first_name, manager_las
SELECT s.store_id    AS store_key,
       s.store_id,
       a.address,
       a.address2,
       a.district,
       c.city,
       co.country,
       a.postal_code,
       st.first_name AS manager_first_name,
       st.last_name  AS manager_last_name,
       now()         AS start_date,
       now()         AS end_date
FROM store s
JOIN staff st   ON (s.manager_staff_id = st.staff_id)
JOIN address a  ON (s.address_id = a.address_id)
JOIN city c     ON (a.city_id = c.city_id)
JOIN country co ON (c.country_id = co.country_id);

INSERT INTO factSales (date_key, customer_key, movie_key, store_key, sales_amount)
SELECT TO_CHAR(p.payment_date :: DATE, 'yyyyMMDD')::integer AS date_key ,
       p.customer_id                                        AS customer_key,
       i.film_id                                            AS movie_key,
```

```
       i.store_id                                           AS store_key,
       p.amount                                             AS sales_amount
FROM payment p
JOIN rental r    ON ( p.rental_id = r.rental_id )
JOIN inventory i ON ( r.inventory_id = i.inventory_id );

##queries are not much faster and easy to write
##the one below on the new schema
%%time
%%sql
SELECT dimMovie.title, dimDate.month, dimCustomer.city, sum(sales_amount) as revenue
FROM factSales
JOIN dimMovie    on (dimMovie.movie_key      = factSales.movie_key)
JOIN dimDate     on (dimDate.date_key         = factSales.date_key)
JOIN dimCustomer on (dimCustomer.customer_key = factSales.customer_key)
group by (dimMovie.title, dimDate.month, dimCustomer.city)
order by dimMovie.title, dimDate.month, dimCustomer.city, revenue desc;

##vs the old schema one
%%time
%%sql
SELECT f.title, EXTRACT(month FROM p.payment_date) as month, ci.city, sum(p.amount) as revenue
FROM payment p
JOIN rental r    ON ( p.rental_id = r.rental_id )
JOIN inventory i ON ( r.inventory_id = i.inventory_id )
JOIN film f ON ( i.film_id = f.film_id)
JOIN customer c  ON ( p.customer_id = c.customer_id )
JOIN address a ON ( c.address_id = a.address_id )
JOIN city ci ON ( a.city_id = ci.city_id )
group by (f.title, month, ci.city)
order by f.title, month, ci.city, revenue desc;

!PGPASSWORD=student pg_dump -h 127.0.0.1 -U student pagila > Data/pagila-star.sql
```

▼ DEMO Excercise 2 CUBE

```
## CUBE
## Group by CUBE (dim1, dim2, ..) , produces all combinations of different lenghts in one go.
## This view could be materialized in a view and queried which would save lots repetitive aggregations

##this cube below
SELECT dimDate.month,dimStore.country,sum(sales_amount) as revenue
FROM factSales
JOIN dimDate     on (dimDate.date_key         = factSales.date_key)
JOIN dimStore on (dimStore.store_key = factSales.store_key)
GROUP by cube(dimDate.month,  dimStore.country);

##is equivalent to the code below but runs it half the time
SELECT  NULL as month, NULL as country, sum(sales_amount) as revenue
FROM factSales
    UNION all
SELECT NULL, dimStore.country,sum(sales_amount) as revenue
FROM factSales
JOIN dimStore on (dimStore.store_key = factSales.store_key)
GROUP by  dimStore.country
    UNION all
SELECT cast(dimDate.month as text) , NULL, sum(sales_amount) as revenue
FROM factSales
JOIN dimDate on (dimDate.date_key = factSales.date_key)
GROUP by dimDate.month
    UNION all
SELECT cast(dimDate.month as text),dimStore.country,sum(sales_amount) as revenue
FROM factSales
JOIN dimDate     on (dimDate.date_key         = factSales.date_key)
JOIN dimStore on (dimStore.store_key = factSales.store_key)
GROUP by (dimDate.month, dimStore.country)
```

▼ Column Format in ROLAP

```
'''
ROLAP means doing the OLAP cubes on the fly from a
relational database instead of buying a specific OLAP database for handling these (MOLAP).

A feature of ROLAP is that you can retrieve data column-wise from the disk
instead of row-wise - so you don't have to load for the whole row to get maybe just one value.
```

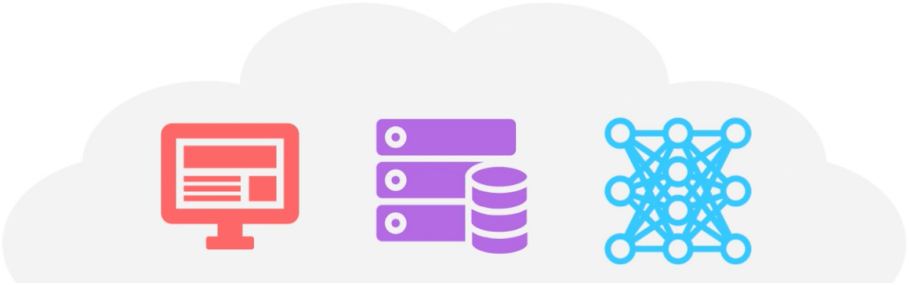
```
Performance increases a lot. Demo below
'''
%load_ext sql
##create database
!sudo -u postgres psql -c 'CREATE DATABASE reviews;'

!wget http://examples.citusdata.com/customer_reviews_1998.csv.gz
!wget http://examples.citusdata.com/customer_reviews_1999.csv.gz

!gzip -d customer_reviews_1998.csv.gz
!gzip -d customer_reviews_1999.csv.gz

!mv customer_reviews_1998.csv /tmp/customer_reviews_1998.csv
!mv customer_reviews_1999.csv /tmp/customer_reviews_1999.csv
##connest to db
DB_ENDPOINT = "127.0.0.1"
DB = 'reviews'
DB_USER = 'student'
DB_PASSWORD = 'student'
DB_PORT = '5432'

# postgresql://username:password@host:port/database
conn_string = "postgresql://{}:{}@{}:{}/{}" \
                        .format(DB_USER, DB_PASSWORD, DB_ENDPOINT, DB_PORT, DB)

print(conn_string)
%sql $conn_string

#create a table with normal row storage and copy data inside
%%sql
DROP TABLE IF EXISTS customer_reviews_row;
CREATE TABLE customer_reviews_row
(
    customer_id TEXT,
    review_date DATE,
    review_rating INTEGER,
    review_votes INTEGER,
    review_helpful_votes INTEGER,
    product_id CHAR(10),
    product_title TEXT,
    product_sales_rank BIGINT,
    product_group TEXT,
    product_category TEXT,
    product_subcategory TEXT,
    similar_product_ids CHAR(10)[]
)
%%sql
COPY customer_reviews_row FROM '/tmp/customer_reviews_1998.csv' WITH CSV;
COPY customer_reviews_row FROM '/tmp/customer_reviews_1999.csv' WITH CSV;

##create table with columner storage now
%%sql

-- load extension first time after install
CREATE EXTENSION cstore_fdw;

-- create server object
CREATE SERVER cstore_server FOREIGN DATA WRAPPER cstore_fdw;

%%sql
-- create foreign table
DROP FOREIGN TABLE IF EXISTS customer_reviews_col;

CREATE FOREIGN TABLE customer_reviews_col
(
    customer_id TEXT,
    review_date DATE,
    review_rating INTEGER,
    review_votes INTEGER,
    review_helpful_votes INTEGER,
    product_id CHAR(10),
    product_title TEXT,
    product_sales_rank BIGINT,
    product_group TEXT,
    product_category TEXT,
    product_subcategory TEXT,
    similar_product_ids CHAR(10)[]
)
SERVER cstore_server
OPTIONS(compression 'pglz');
```

```
%%sql
COPY customer_reviews_col FROM '/tmp/customer_reviews_1998.csv' WITH CSV;
COPY customer_reviews_col FROM '/tmp/customer_reviews_1999.csv' WITH CSV;

##compare performance
%%time
%%sql
SELECT
    customer_id, review_date, review_rating, product_id, product_title
FROM
    customer_reviews_row
WHERE
    customer_id ='A27T7HVDXA3K2A' AND
    product_title LIKE '%Dune%' AND
    review_date >= '1998-01-01' AND
    review_date <= '1998-12-31';

%%time
%%sql
SELECT
    customer_id, review_date, review_rating, product_id, product_title
FROM
    customer_reviews_col
WHERE
    customer_id ='A27T7HVDXA3K2A' AND
    product_title LIKE '%Dune%' AND
    review_date >= '1998-01-01' AND
    review_date <= '1998-12-31';

#another
%%time
%%sql
SELECT product_title, avg(review_rating)
FROM customer_reviews_col
WHERE review_date >= '1995-01-01'
    AND review_date <= '1998-12-31'
GROUP BY product_title
ORDER by product_title
LIMIT 20;

%%time
%%sql
SELECT product_title, avg(review_rating)
FROM customer_reviews_row
WHERE review_date >= '1995-01-01'
    AND review_date <= '1998-12-31'
GROUP BY product_title
ORDER by product_title
LIMIT 20;
```

▼ **Intro to Cloud Computing and AWS (**Creating IAM Roles / IAM Users / Security Groups, Launching/Deleting Redshift Clusters, Creating S3 buckets)

What is Cloud Computing?

Using a **network of remote servers** hosted on the internet to **store, manage, and process data**, rather than a local server or a personal computer.



Cloud computing:
the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer.

Amazon Web Services

Amazon Web Services is one of the largest providers in the cloud computing industry, with over 140 services in compute, storage, databases, networking, developer tools, security, and more. In this lesson, we'll learn about a few essential tools and services in AWS and practice using them. These services can be accessed in three different ways: the AWS Management Console, the Command Line Interface (CLI), or Software Development Kits (SDKs), which can be used in combination.

We'll start with the AWS Management Console, which is the web user interface. The AWS CLI is a useful way to control and automate your services with code, and SDKs allow you to easily integrate services with your applications through APIs built around specific languages and platforms.

Dimensional Model Storage on AWS

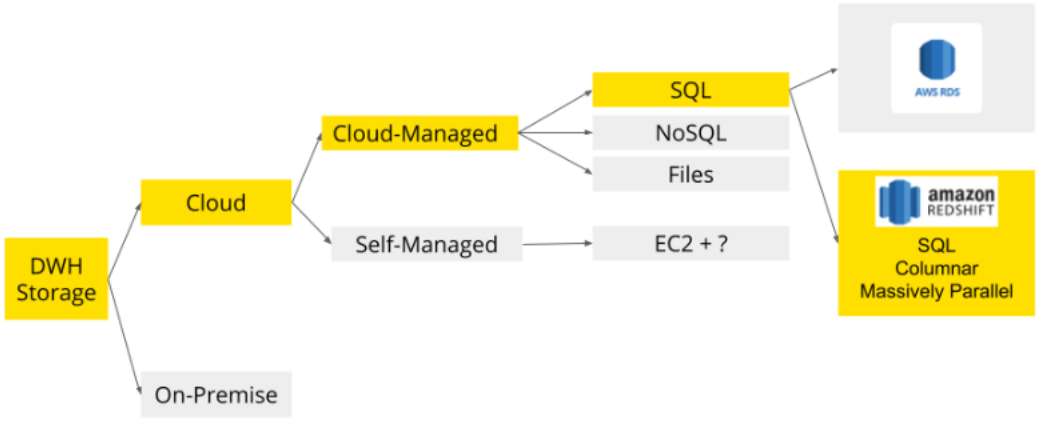
Cloud-Managed

- Amazon RDS, Amazon DynamoDB, Amazon S3
- Re-use of expertise; way less IT Staff for security, upgrades, etc. and way less OpEx
- Deal with complexity with techniques like: “Infrastructure as code”

Self-Managed

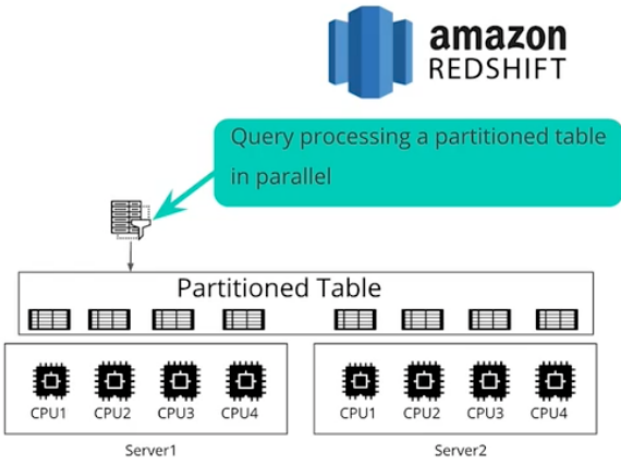
- EC2 + Postgresql, EC2 + Cassandra
- EC2 + Unix FS
- Always “catch-all” option if needed

DWH Dimensional Model *Storage* on AWS

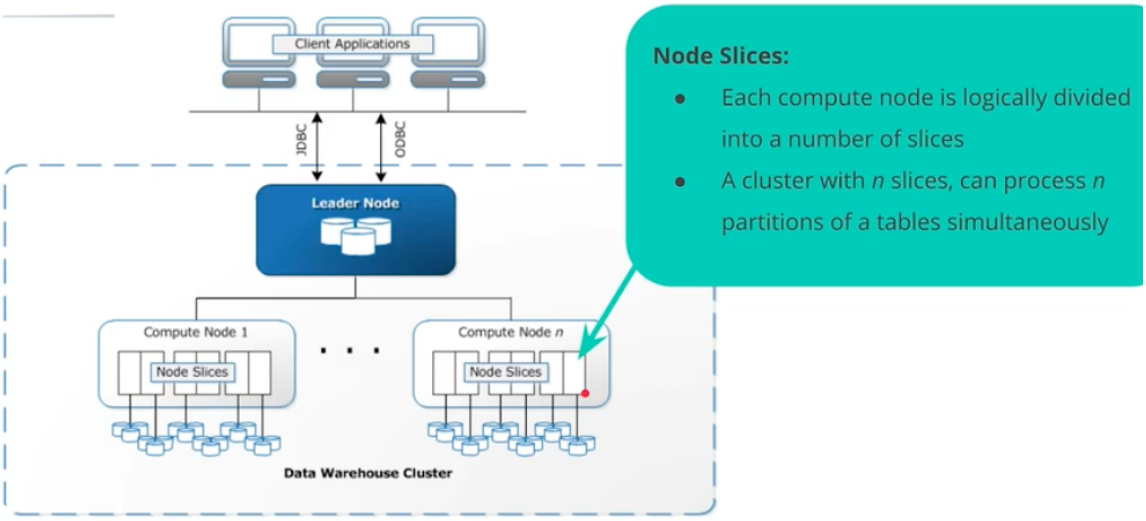


Amazon Redshift Technology

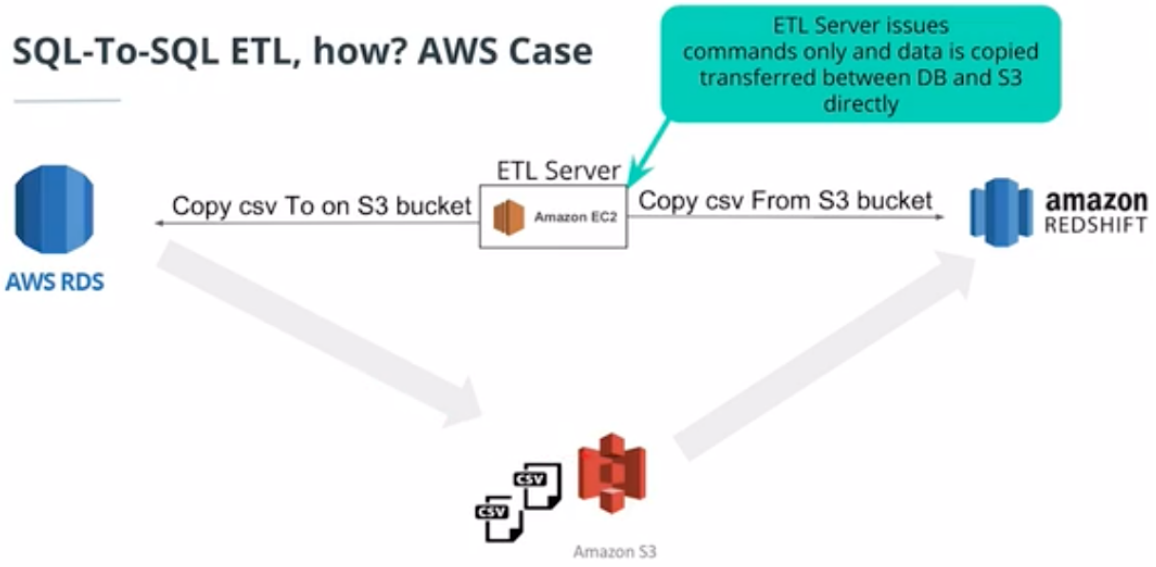
- Massively Parallel Processing (MPP) databases **parallelize the execution of one query on multiples CPUs/machines**
- **How? A table is partitioned and partitions are processed in parallel**
- Amazon Redshift is a *cloud-managed*, column- oriented, MPP database
- Other examples include Teradata Aster, Oracle ExaData and Azure SQL

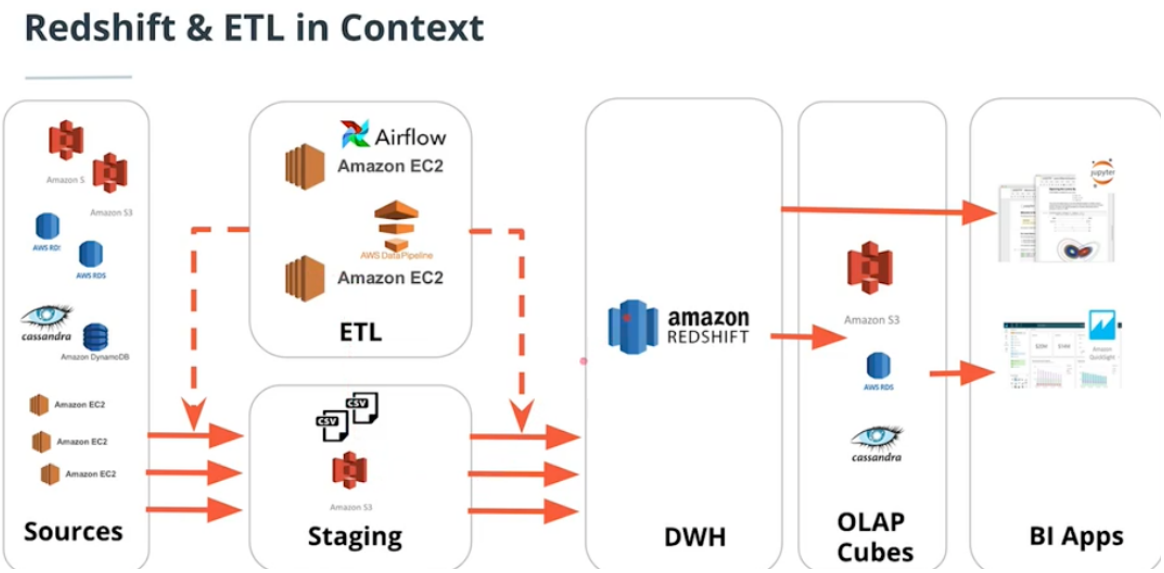


Redshift Architecture: Slices



SQL-To-SQL ETL, how? AWS Case





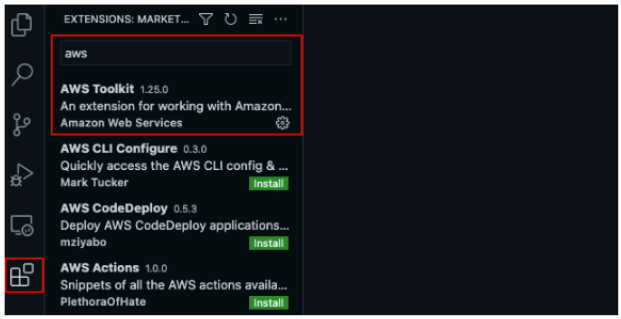
▼ **Creating AWS Resources**

▼ CONNECT VSCode with AWS

Connect VSCode with AWS

Install AWS Toolkit Extension in VS Code

- Open **Extensions** tab
- Search **AWS**
- Install **AWS Toolkit**



AWS Toolkit Extension Installation

Step 1: Create a new file called "credentials" with the following details:

```
[default]
aws_access_key_id=COPY_FROM_CLASSROOM
aws_secret_access_key=COPY_FROM_CLASSROOM
aws_session_token=COPY_FROM_CLASSROOM
```

Replace `COPY_FROM_CLASSROOM` with the values you see when you click on the "Launch AWS Gateway" button in the classroom as shown below.

OPEN AWS CONSOLE

Step 2: Create a new file called "config" with the following details:

```
[default]
region=us-west-2
output=json
```

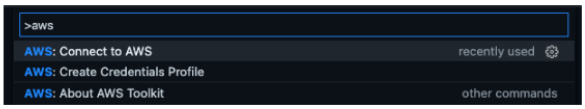
Step 3: Save the "credentials" and "config" file at the following location

Operating system	Location of files
Linux and macOS	`~/.aws/config` `~/.aws/credentials`
Windows	`%USERPROFILE%\.aws\config` `%USERPROFILE%\.aws\credentials`

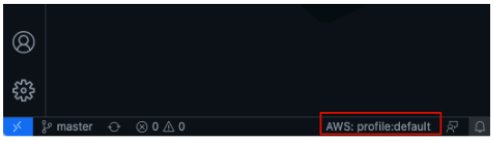
Note *- If the* `.aws` *directory is not present, please create it first, and then save the files at the location specified in the table above.*

Connect to AWS

- Once the credentials are saved, open the VS Code's command palette by pressing `Ctrl+Shift+P` for Windows/Linux OR `Cmd+Shift+P` for Mac, and select `AWS: Connect to AWS`
- On a successful connection `AWS: profile:default` at the bottom left of VS Code window.



AWS: Connect to AWS



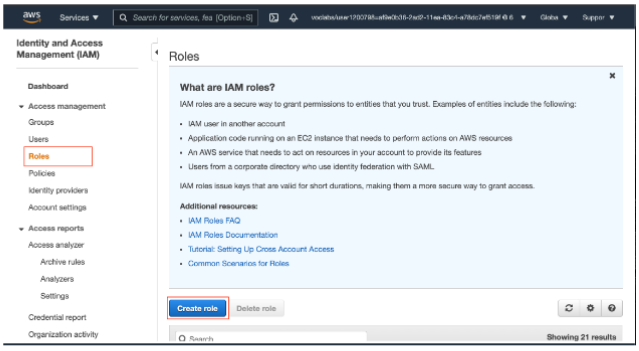
Successful AWS Connection Indicator

▼ CREATE IAM Role

Create an IAM Role

Here, you'll create an IAM role that you will later attach to your Redshift cluster to enable your cluster to load data from Amazon S3 buckets. Read more about IAM roles and Redshift here.

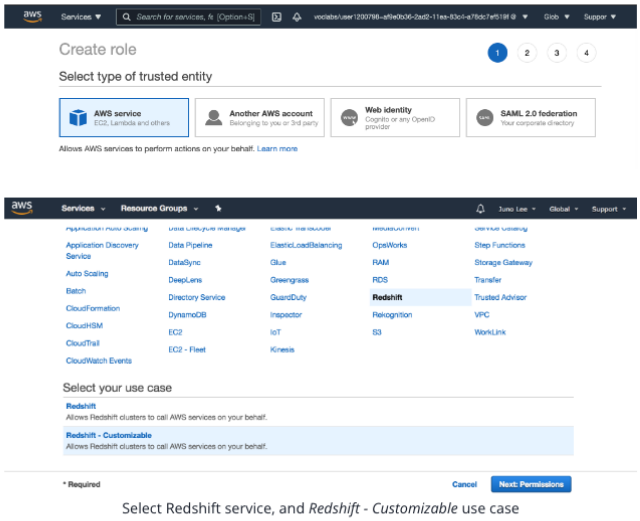
1. Once you have signed into the AWS management console, navigate to the IAM service dashboard.
2. In the left navigation pane, choose **Roles**.
3. Choose **Create role**.



IAM Roles dashbaord

4. In the **AWS Service** group as the trusted entity, and choose **Redshift** service.
5. Under **Select your use case**, choose **Redshift - Customizable**, and then **Next: Permissions**.

4. In the **AWS Service** group as the trusted entity, and choose **Redshift** service.
5. Under **Select your use case**, choose **Redshift - Customizable**, and then **Next: Permissions**.



Select Redshift service, and *Redshift - Customizable* use case

6. On the **Attach permissions policies** page, search for and select the **AmazonS3ReadOnlyAccess** policy, and then click on the **Next: Tags** button.
7. Tags are optional. Click on the **Next: Review** button.

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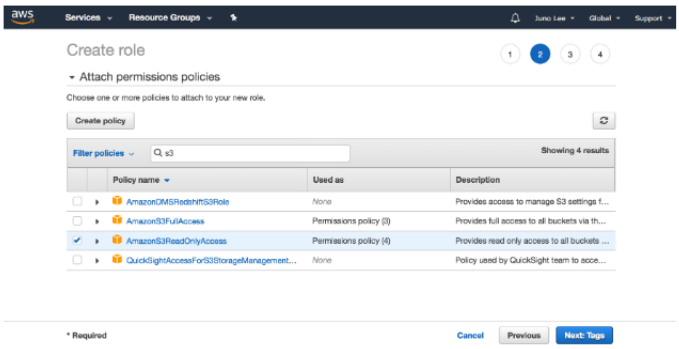
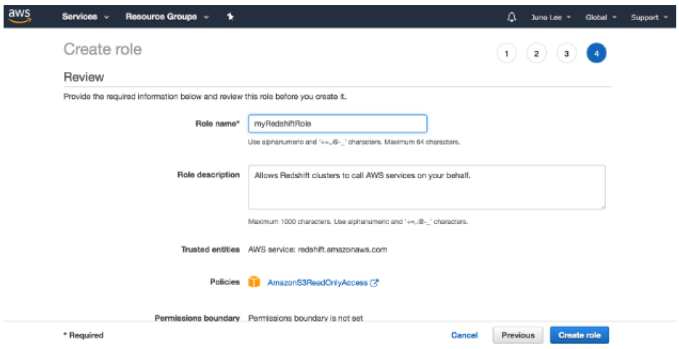


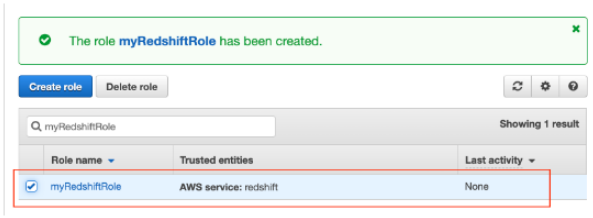
Select a policy to attach to the new role

8. For **Role name**, enter `myRedshiftRole`, and then choose **Create Role**.



Provide role name and description

9. You will see a success message when the new role will be created.



Role created successfully

> *That's great! On the next page, you'll learn to* ***attach this role to a new/existing cluster***

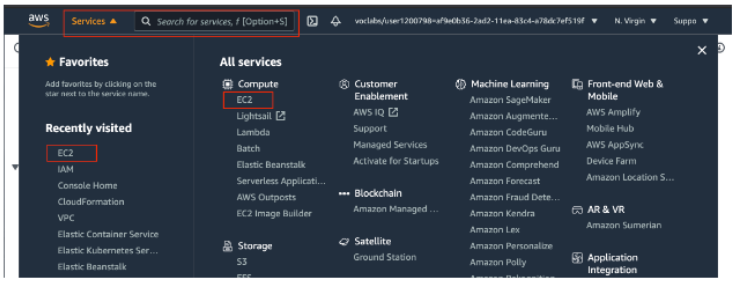
▼ CREAT Security Group EC2

Create Security Group

Here, you'll create a security group you will later use to authorize access to your Redshift cluster.

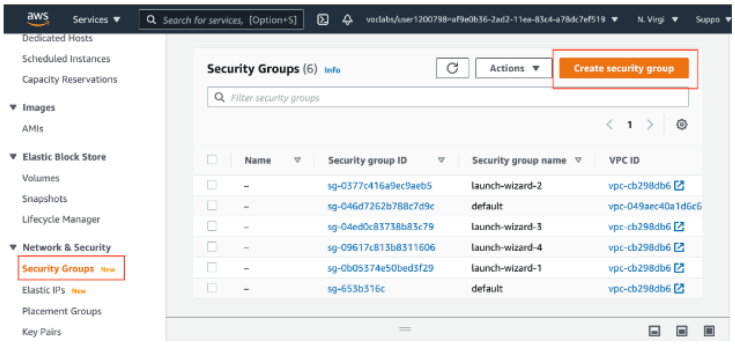
> *A security group will act as firewall rules for your Redshift cluster to control inbound and outbound traffic.*

1. Navigate to the EC2 service



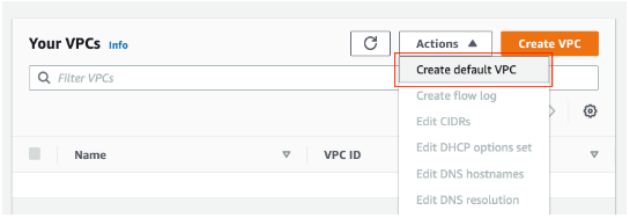
Navigate to any service

2. Under **Network and Security** in the left navigation pane, select **Security Groups**. Click the **Create Security Group** button to launch a wizard.

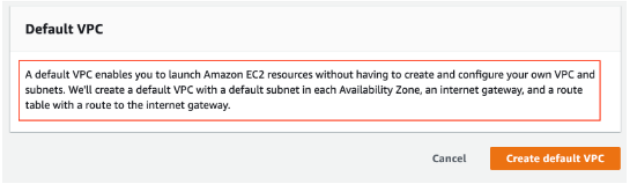


3. In the *Create security group* wizard, enter the basic details.

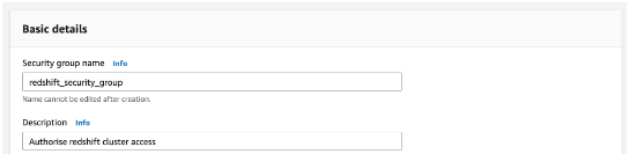
Section	Field	Value
Basic details	Security group name	`redshift_security_group`
	Description	`Authorise redshift cluster access`
	VPC	Choose the default VPC It is a VPC in a default region, and has a public subnet in each Availability Zone. If a default VPC doesn't show up, create a default VPC



Create a default VPC, if not available already



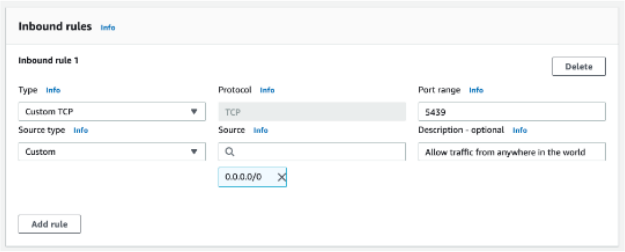
Info about a default VPC



4. In the *Inbound rules* section, click on **Add Rule** and enter the following values:

Section	Field	Value
Inbound rules	Type	Custom TCP Rule
	Protocol	TCP
	Port range	5439 The default port for Amazon Redshift is 5439, but your port might be different.
	Source type	Custom
	Source	`0.0.0.0/0` *(Anywhere in the world)*

Important: Using `0.0.0.0/0` is not recommended for anything other than demonstration purposes because it allows access from any computer on the internet. *In a real environment, you would create inbound rules based on your own network settings.*

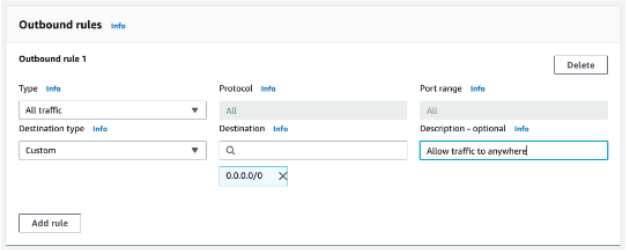


Inbound rules

5. Outbound rules allow traffic to anywhere by default.

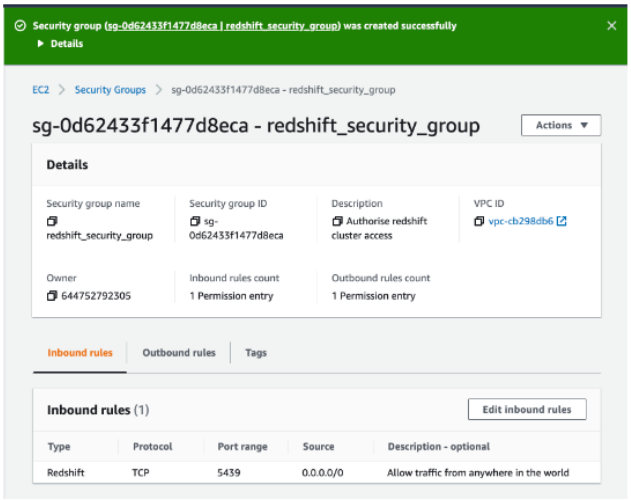
Inbound rules

5. Outbound rules allow traffic to anywhere by default.



Outbound rules

6. Click on the *Create security group* button at the bottom. You will see a success message.



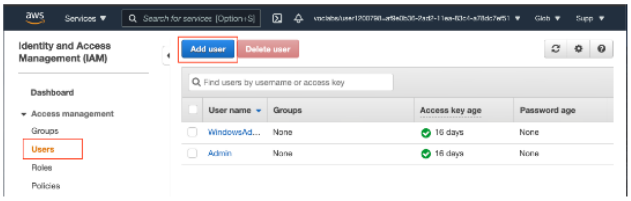
Details of a security group

▼ CREATE IAM User

Create an IAM User

Here, you'll create an IAM user that you will use to access your Redshift cluster.

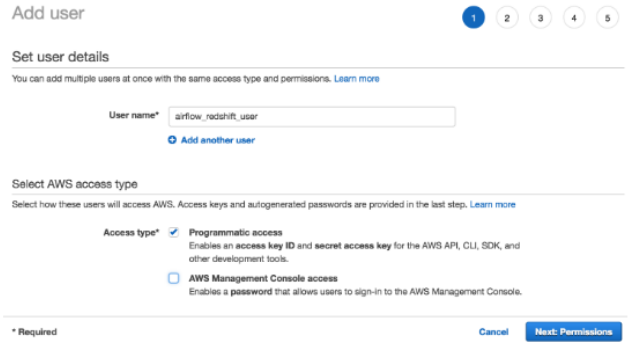
1. Navigate to the IAM console. In the left navigation pane, choose **Users**, and click on the **Add User** button. It will launch a new wizard.



IAM Users dashboard

2. **Set user details**

   Enter a name for your user , say *airflow_redshift_user*, and choose **Programmatic access**. Then click on the **Next: Permissions** button.



Create IAM users → Set user details

3. **Set permissions**

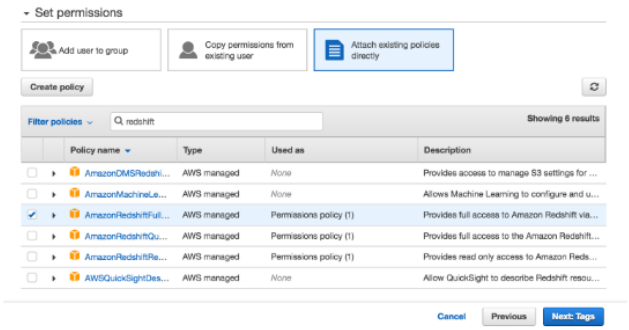
   Choose **Attach existing policies directly** option.

3. **Set permissions**

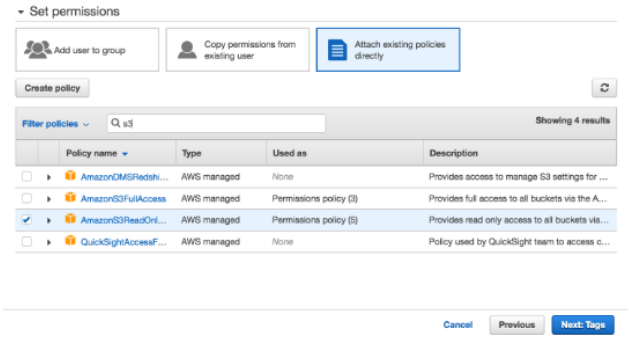
   Choose **Attach existing policies directly** option.

   - Search for redshift and select **AmazonRedshiftFullAccess**.
   - Then, search for S3 and select **AmazonS3ReadOnlyAccess**.

   After selecting both policies, choose **Next: Tags**. Skip this page and choose **Next: Review**.

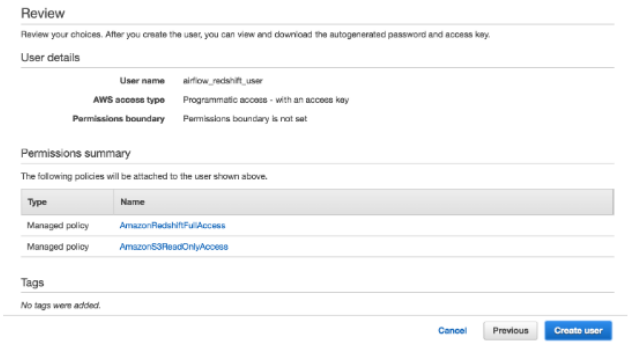


Create IAM user → Set permissions → Select *AmazonRedshiftFullAccess*



Create IAM user → Set permissions → Select *AmazonS3ReadOnlyAccess*

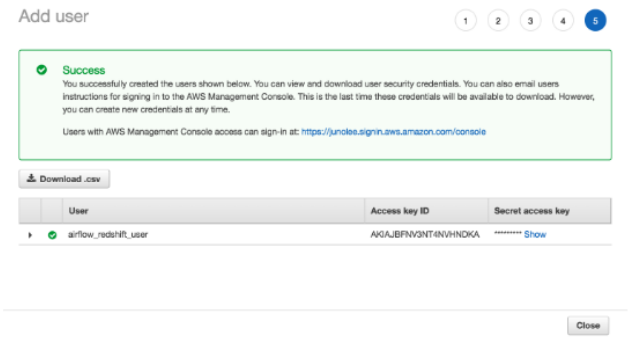
4. **Review** your choices and finally click on the **Create user** button.



Review the new IAM user details

5. **Save your credentials!**
   This is the only time you can view or download these credentials on AWS. Choose **Download .csv** to download these credentials and then save th need to copy and paste this **Access key ID** and **Secret access key** in the next step.

> *We **strongly advise** you to keep this **Access key ID** and **Secret access key** closely guarded, including not putting them in a GitHub public repo, etc.*

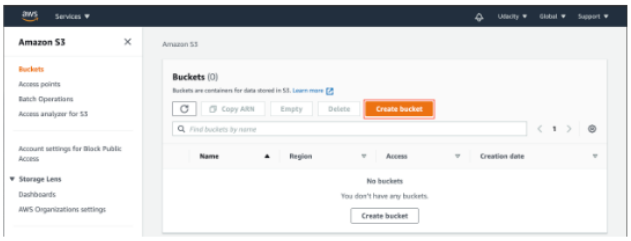


User created successfully.
Copy the Access key Is and Secret access key.

▼ CREATE A Bucket S3

Create a Bucket

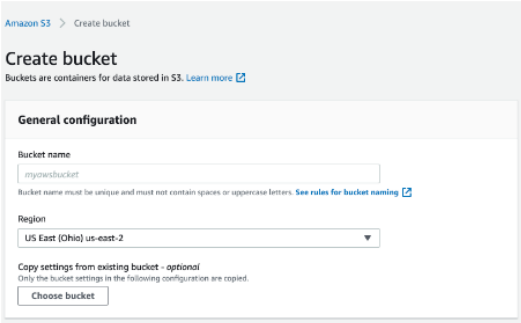
1. Navigate to the S3 dashboard, and click on the **Create bucket** button. It will launch a new wizard.



S3 service → Buckets dashboard.
View all of the S3 buckets in your account
(S3 is a global service, not a region-specific).

We create a bucket first, and later we upload files and folders to it.

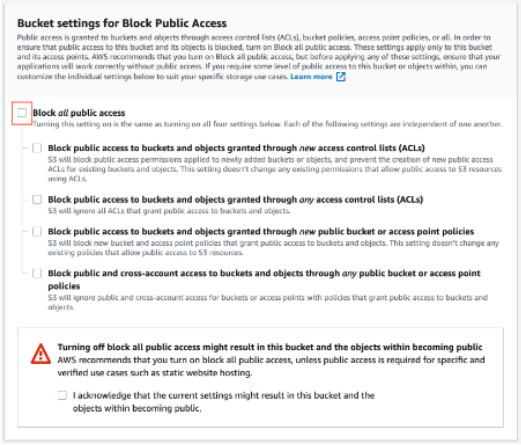
2. **General configuration**
   Provide the bucket-name and the region where you want to locate the bucket. The bucket name must be unique worldwide, and must not contair



Create a bucket - Provide general details

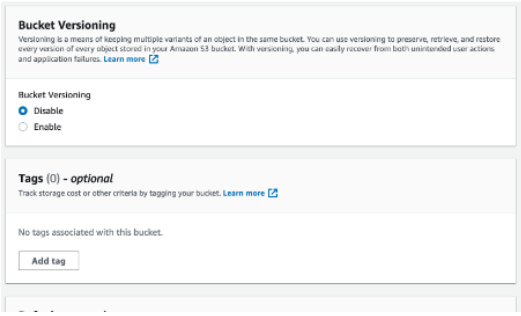
3. **Public Access settings**

You can choose public visibility. Let's uncheck the *Block all public access* option.



Create a bucket - Make it public

4. **Bucket Versioning and Encryption**
   - Bucket Versioning - Keep it disabled.
   - Encryption - If enabled, it will encrypt the files being stored in the bucket.
   - Object Lock - If enables, it will prevent the files in the bucket from being deleted or modified.

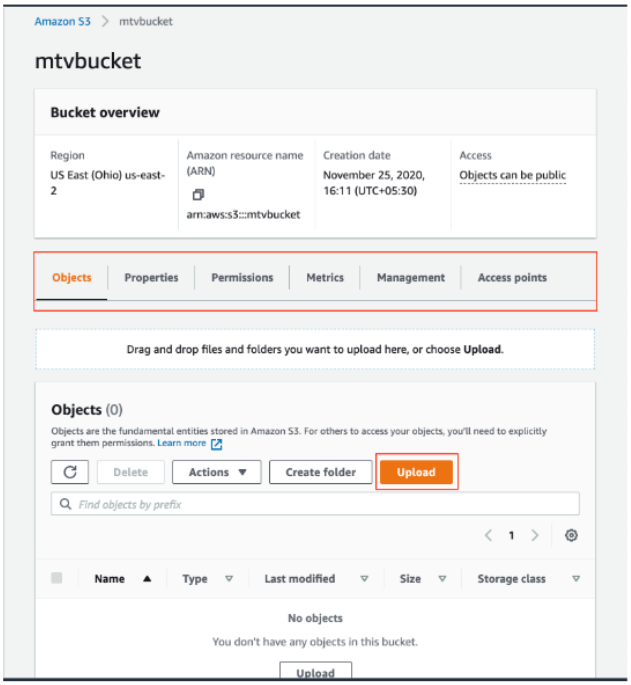


Create a bucket - Provide additional details

In the snapshots above, we have created a public bucket. Let's see **how to upload files and folders to the bucket**, and configure additional settings.

Upload File/Folders to the Bucket

From the S3 dashboard, click on the name of the bucket you have created in the step above.

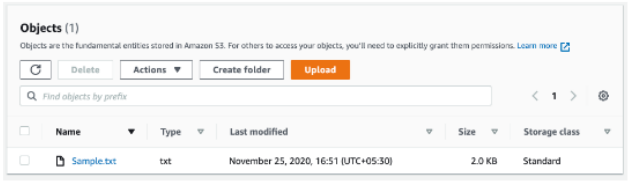


Details of an existing bucket. Upload files/folders to this bucket.

Details of an existing bucket. Upload files/folders to this bucket.

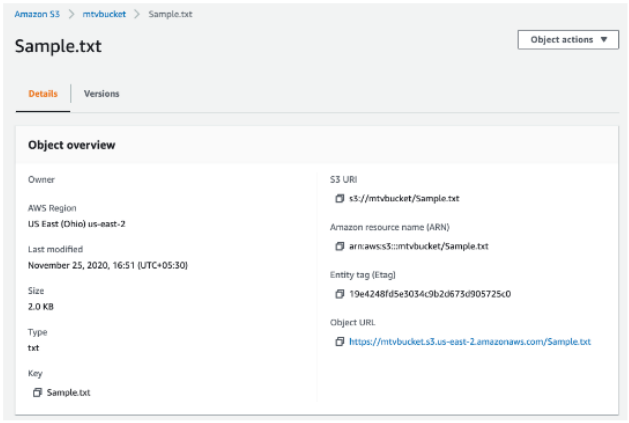
In the snapshot above, it shows that the bucket is in the Region: `US East (Ohio) us-east-2`, and it has a unique Amazon resource name (ARN): `a`
You can view more details of the bucket, in the tabs next to the bucket overview: **Objects, Properties, Permissions, Metrics, Management,** and **Acce**
sample file to the bucket:

1. Click on the **Upload** button to upload files and folders into the current bucket. In the snapshot below, we have uploaded a **Sample.txt** file.



A sample file in the bucket

2. Click on the file name to view the file-specific details, as shown below.



Details of an individual file (object)

Details of an Existing Bucket

1. Properties

There are several properties that you can set for S3 buckets, such as:

- Bucket Versioning - Allows you to keep multiple versions of an object in the same bucket.
- Static website hosting - Mark if the bucket is used to host a website. S3 is a very cost-effective and cheap solution for serving up static web content.
- Requester pays - Make the requester pays for requests and data transfer costs.
- Server access logging - Log requests for access to your bucket.
- **Permissions**

It shows who has access to the S3 bucket, and who has access to the data within the bucket. In the example snapshots above, the bucket is public, meaning anyone can access it. Here, we can write an access policy (in JSON format) to provides access to the objects stored in the bucket.

2. Metrics

View the metrics for usage, request, and data transfer activity within your bucket, such as, total bucket size, total number of objects, and storage class analysis.

3. Management

It allows you to create life cycle rules to help manage your objects. It includes rules such as transitioning objects to another storage class, archiving them, or deleting them after a specified period of time.

4. Access points

Here, you can create access endpoints for sharing the bucket at scale. Using an endpoint, you can perform all regular operations on the bucket.

▼ Launching Redshift Cluster

Launching a Redshift Cluster in the AWS Console

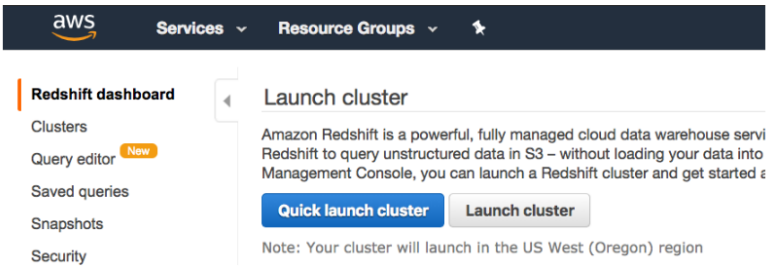
- Follow the instructions below to create a Redshift cluster
- Use the query editor to create a table and insert data
- Delete the cluster

Note: The steps below were introduced in lesson 2. You can use the IAM role and security group created in the last lesson.

Launch a Redshift Cluster

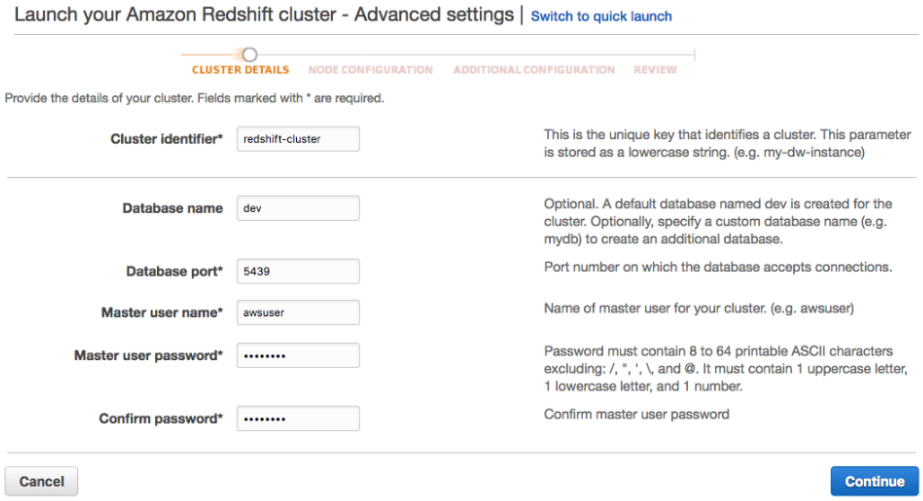
WARNING: The cluster that you are about to launch will be live, and you will be charged the standard Amazon Redshift usage fees for the cluster until you delete it. **Make sure to delete your cluster each time you're finished working to avoid large, unexpected costs.** Instructions on deleting your cluster are included on the last page. You can always launch a new cluster, so don't leave your Redshift cluster running overnight or throughout the week if you don't need to.

1. Open AWS Console by clicking on the `Launch AWS Gateway` button followed by `Open AWS Console`.
2. Search and select `Redshift` in the AWS Services search bar. This will open the Amazon Redshift Dashboard.
3. On the Amazon Redshift Dashboard, choose **Create cluster**.

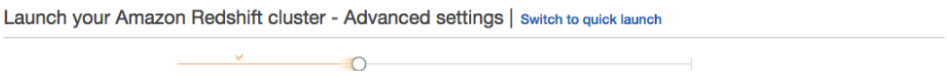


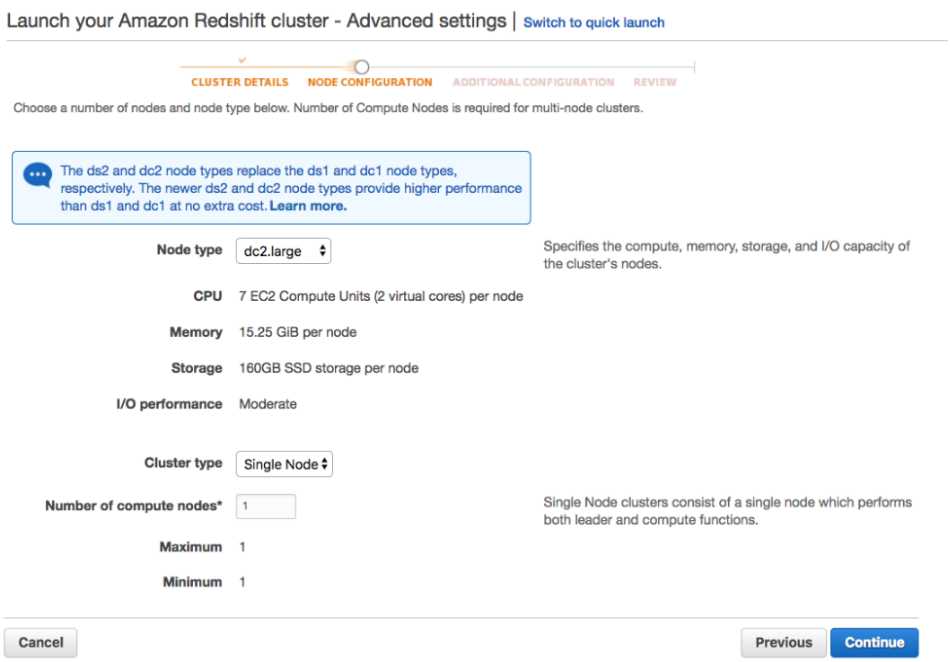
3. On the Cluster details page, enter the following values and then choose Continue:
   - **Cluster identifier**: Enter `redshift-cluster`.

3. On the Cluster details page, enter the following values and then choose Continue:
   - **Cluster identifier**: Enter `redshift-cluster`.
   - **Database name**: Enter `dev`.
   - **Database port**: Enter `5439`.
   - **Master user name**: Enter `awsuser`.
   - **Master user password** and **Confirm password**: Enter a password for the master user account.



4. On the Node Configuration page, accept the default values and choose **Continue**.

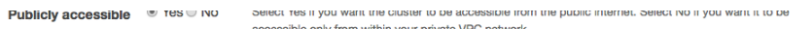




5. On the Additional Configuration page, enter the following values:

   - **VPC security groups**: redshift_security_group
   - **Available IAM roles**: myRedshiftRole

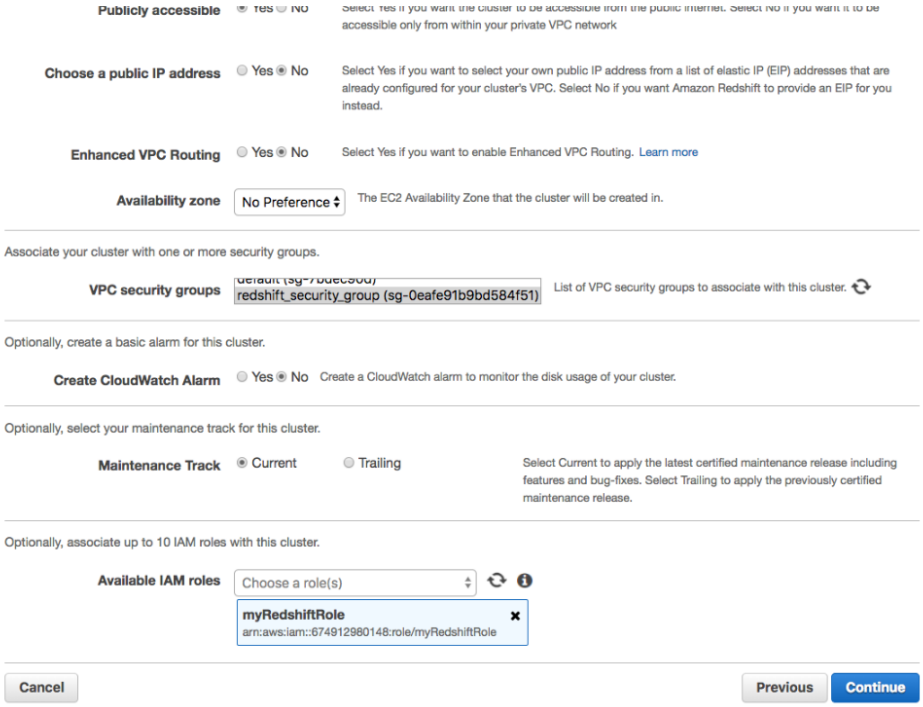
   Choose **Continue**.



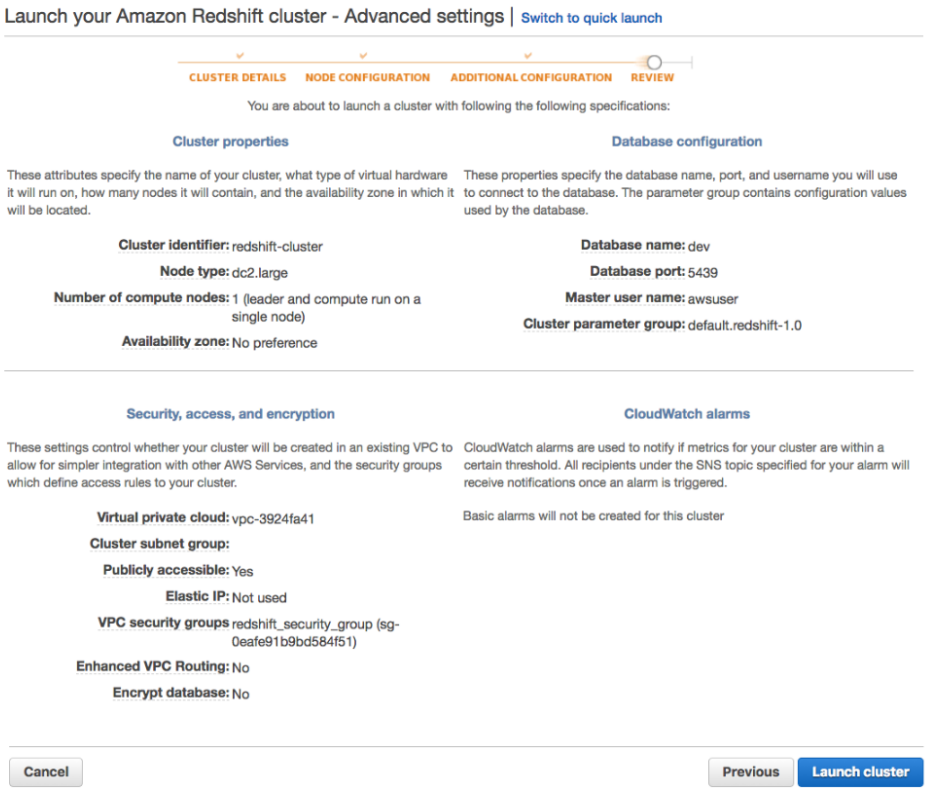
5. On the Additional Configuration page, enter the following values:

- **VPC security groups**: redshift_security_group
- **Available IAM roles**: myRedshiftRole

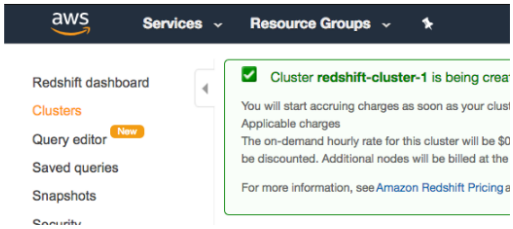
Choose **Continue**.



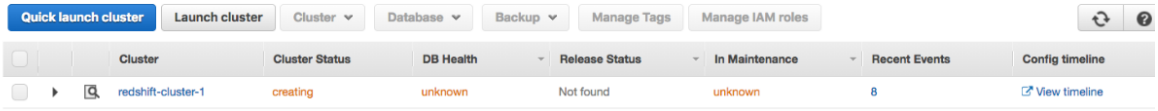
6. Review your Cluster configuration and choose **Launch cluster**.

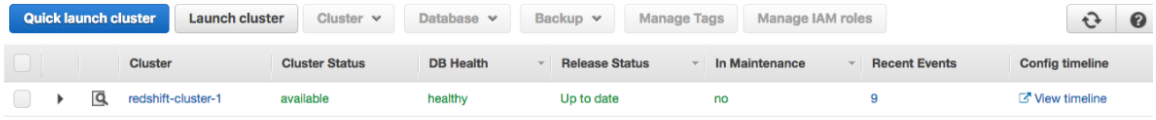


7. A confirmation page will appear and the cluster will take a few minutes to finish. Choose **Clusters** in the left navigation pane to return to the list of clusters.



8. On the Clusters page, look at the cluster that you just launched and review the **Cluster Status** information. Make sure that the **Cluster Status** is **available** and the **Databas Health** is **healthy** before you try to connect to the database later. You can expect this to take 5-10 minutes.



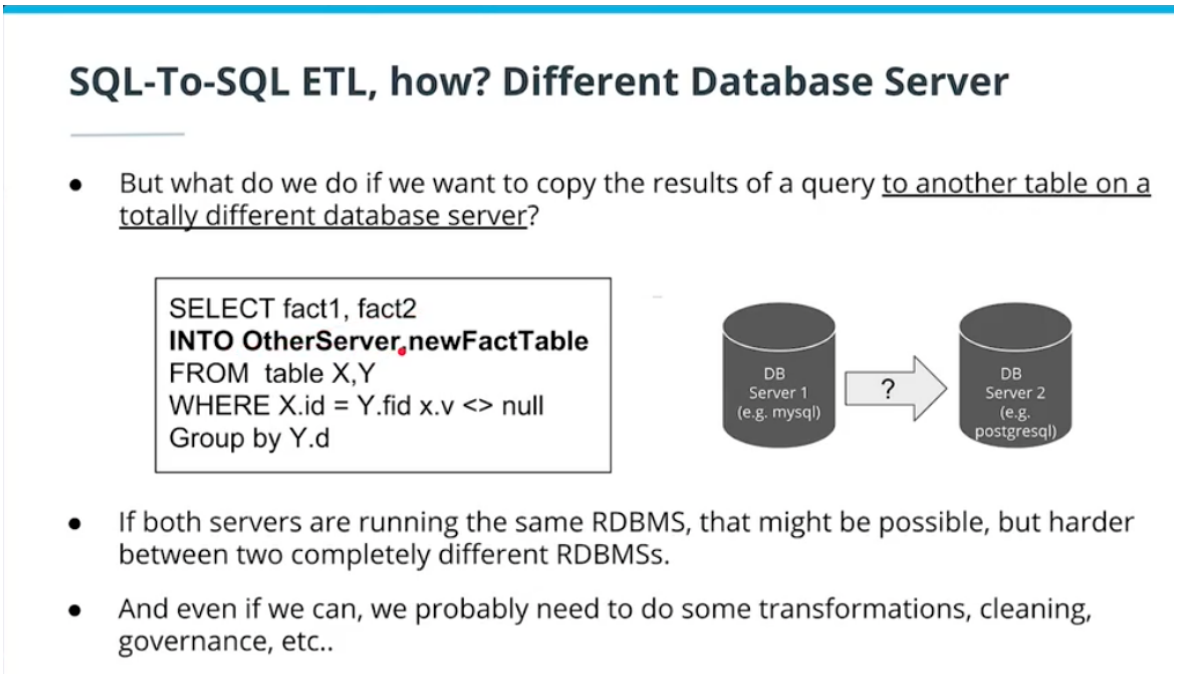


Delete a Redshift Cluster

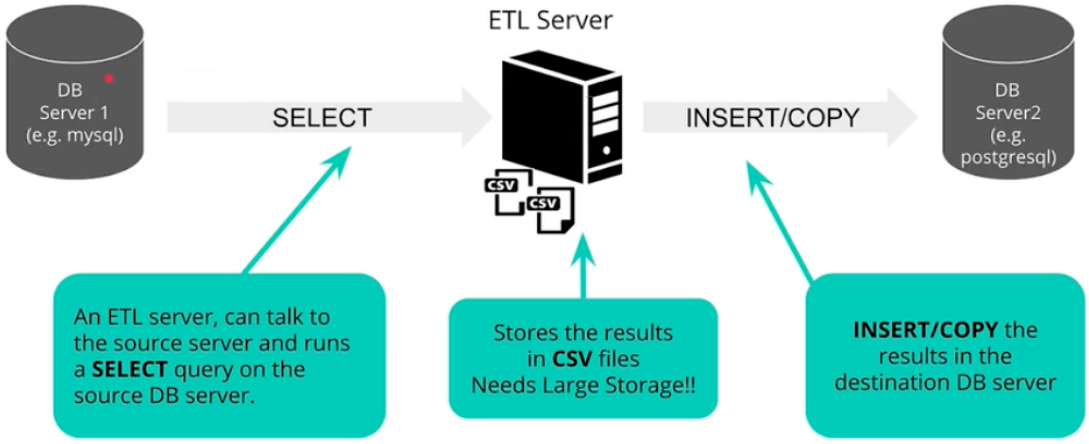
Make sure to delete your cluster each time you're finished working to avoid large, unexpected costs. You can always launch a new cluster, so don't leave it running overnight or

▼ Implementing Data Warehouses on AWS

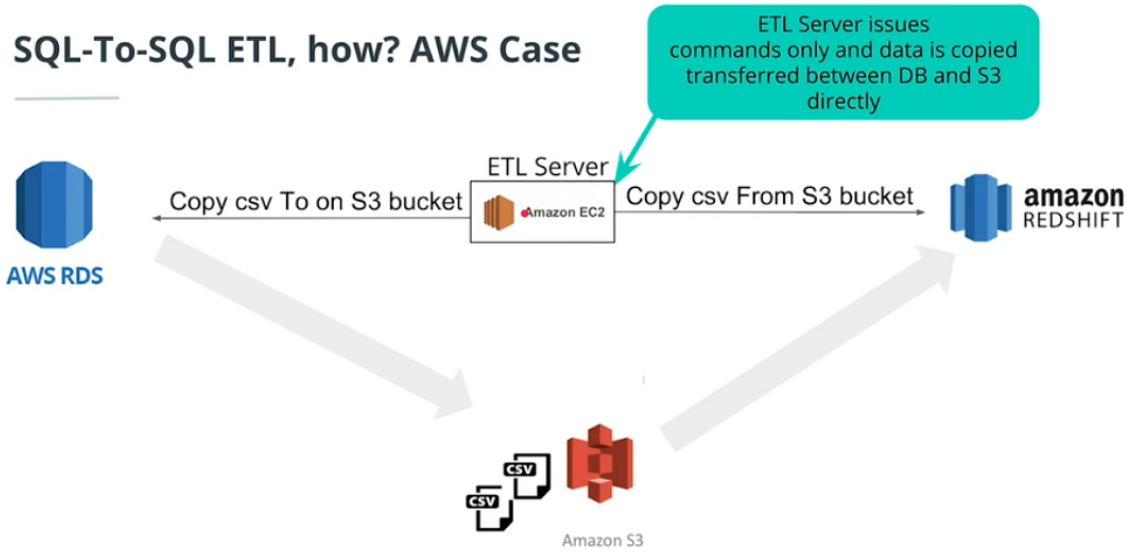
▼ Theory



SQL-To-SQL ETL, how? A more general solution



SQL-To-SQL ETL, how? AWS Case



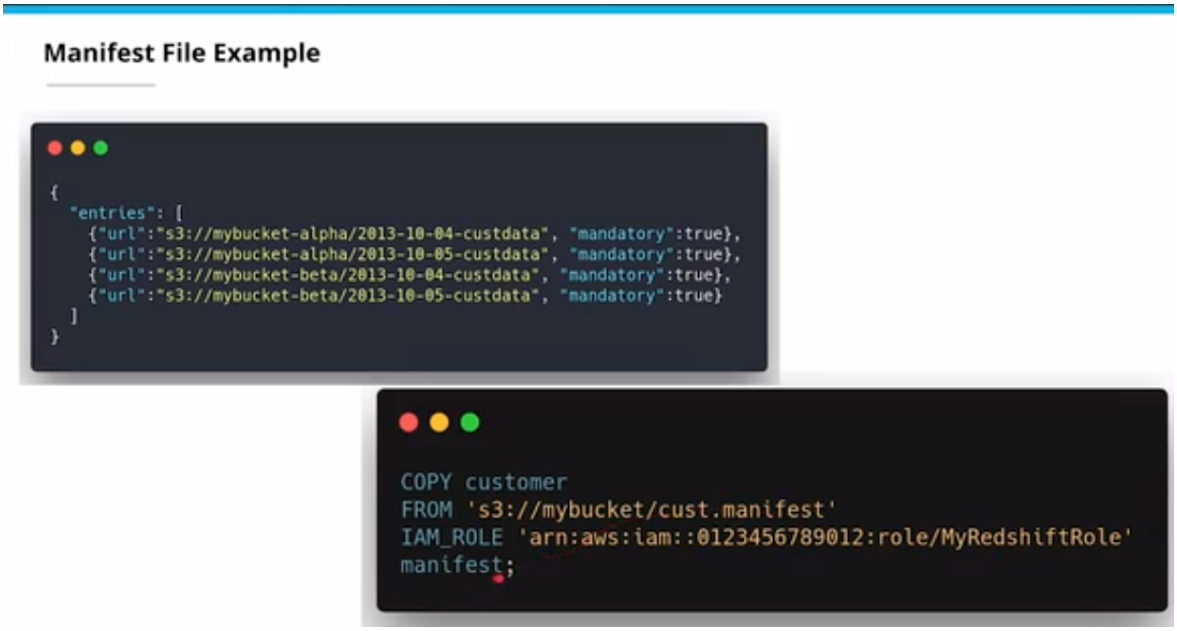
Ingesting at Scale: Use COPY

- To transfer data from an S3 staging area to redshift use the **COPY** command
- Inserting data row by using **INSERT** will be very slow
- If the file is large:
  - It is better to break it up to **multiple files**
  - Ingest in **Parallel**
    - Either using a **common prefix**
    - Or a **manifest file**
- Other considerations:
  - Better to ingest from the same AWS region
  - Better to compress the all the csv files
- One can also specify the delimiter to be used

Common Prefix Example

```
COPY sporting_event_ticket FROM 's3://udacity-labs/tickets/split/part'
CREDENTIALS 'aws_iam_role=arn:aws:iam::464956546:role/dwhRole'
gzip DELIMITER ';' REGION 'us-west-2';
```

```
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00000.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00001.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00002.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00003.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00004.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00005.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00006.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00007.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00008.csv.gz')
s3.ObjectSummary(bucket_name='udacity-labs', key='tickets/split/part-00009.csv.gz')
```



▼ **Infrastructure as a Code (IaC)** Exercise

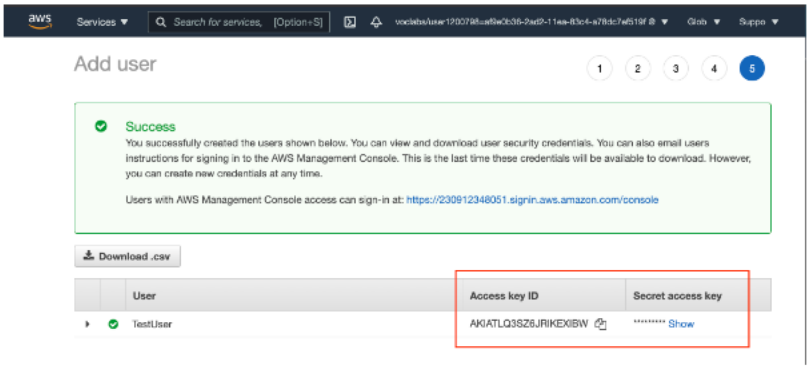
```
import pandas as pd
import boto3
import json
```

STEP 0: (Prerequisite) Save the AWS Access key

1. Create a new IAM user

IAM service is a global service, meaning newly created IAM users are not restricted to a specific region by default.

- Go to AWS IAM service and click on the "**Add user**" button to create a new IAM user in your AWS account.
- Choose a name of your choice.
- Select "*Programmatic access*" as the access type. Click Next.
- Choose the *Attach existing policies directly* tab, and select the "**AdministratorAccess**". Click Next.
- Skip adding any tags. Click Next.
- Review and create the user. It will show you a pair of access key ID and secret.
- Take note of the pair of access key ID and secret. This pair is collectively known as **Access key**.



Snapshot of a pair of an Access key

2. Save the access key and secret

Edit the file `dwh.cfg` in the same folder as this notebook and save the access key and secret against the following variables:

```
KEY= <YOUR_AWS_KEY>
SECRET= <YOUR_AWS_SECRET>
```

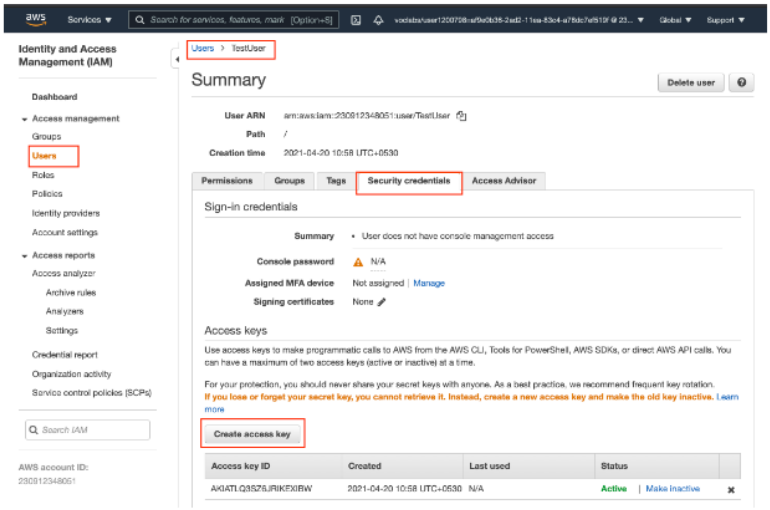
For example:

```
KEY=6JW3ATLQ34PH3AKI
SECRET=wnoBHA+qUBFgwCRHJqgqrLU0i
```

3. Troubleshoot

If your keys are not working, such as getting an `InvalidAccessKeyId` error, then you cannot retrieve them again. You have either of the following two options:

1. **Option 1 - Create a new pair of access keys for the existing user**
    - Go to the IAM dashboard and view the details of the existing (Admin) user.
    - Select on the **Security credentials** tab, and click the **Create access key** button. It will generate a new pair of access key ID and secret.
    - Save the new access key ID and secret in your `dwh.cfg` file



Snapshot of creating a new Access keys for the existing user

2. **Option 2 - Create a new IAM user with Admin access** - Refer to the instructions at the top.

```
### LOAD DWH PARAMs from a file

import configparser
config = configparser.ConfigParser()
config.read_file(open('dwh.cfg'))

KEY                    = config.get('AWS','KEY')
SECRET                 = config.get('AWS','SECRET')

DWH_CLUSTER_TYPE       = config.get("DWH","DWH_CLUSTER_TYPE")
DWH_NUM_NODES          = config.get("DWH","DWH_NUM_NODES")
DWH_NODE_TYPE          = config.get("DWH","DWH_NODE_TYPE")

DWH_CLUSTER_IDENTIFIER = config.get("DWH","DWH_CLUSTER_IDENTIFIER")
DWH_DB                 = config.get("DWH","DWH_DB")
DWH_DB_USER            = config.get("DWH","DWH_DB_USER")
DWH_DB_PASSWORD        = config.get("DWH","DWH_DB_PASSWORD")
DWH_PORT               = config.get("DWH","DWH_PORT")

DWH_IAM_ROLE_NAME      = config.get("DWH", "DWH_IAM_ROLE_NAME")

(DWH_DB_USER, DWH_DB_PASSWORD, DWH_DB)

pd.DataFrame({"Param":
                  ["DWH_CLUSTER_TYPE", "DWH_NUM_NODES", "DWH_NODE_TYPE", "DWH_CLUSTER_IDENTIFIER", "DWH_DB", "DWH_DB_USER", "DWH_DB
              "Value":
                  [DWH_CLUSTER_TYPE, DWH_NUM_NODES, DWH_NODE_TYPE, DWH_CLUSTER_IDENTIFIER, DWH_DB, DWH_DB_USER, DWH_DB_PASSWORD, DW
             })
```

Create clients for IAM, EC2, S3 and Redshift

Note: We are creating these resources in the the **us-west-2** region. Choose the same region in the your AWS web console to the see these resources.

```
import boto3

ec2 = boto3.resource('ec2',
                       region_name="us-west-2",
                       aws_access_key_id=KEY,
                       aws_secret_access_key=SECRET
                    )

s3 = boto3.resource('s3',
                       region_name="us-west-2",
                       aws_access_key_id=KEY,
                       aws_secret_access_key=SECRET
                    )

iam = boto3.client('iam',aws_access_key_id=KEY,
                     aws_secret_access_key=SECRET,
                     region_name='us-west-2'
                   )

redshift = boto3.client('redshift',
                       region_name="us-west-2",
                       aws_access_key_id=KEY,
                       aws_secret_access_key=SECRET
                       )
```

Check out the sample data sources on S3

```
sampleDbBucket =  s3.Bucket("awssampledbuswest2")
for obj in sampleDbBucket.objects.filter(Prefix="ssbgz"):
    print(obj)
# for obj in sampleDbBucket.objects.all():
#     print(obj)
```

STEP 1: IAM ROLE

- Create an IAM Role that makes Redshift able to access S3 bucket (ReadOnly)

```
from botocore.exceptions import ClientError

#1.1 Create the role,
try:
    print("1.1 Creating a new IAM Role")
    dwhRole = iam.create_role(
        Path='/',
        RoleName=DWH_IAM_ROLE_NAME,
        Description = "Allows Redshift clusters to call AWS services on your behalf.",
        AssumeRolePolicyDocument=json.dumps(
            {'Statement': [{'Action': 'sts:AssumeRole',
               'Effect': 'Allow',
               'Principal': {'Service': 'redshift.amazonaws.com'}}],
             'Version': '2012-10-17'})
    )
except Exception as e:
    print(e)


print("1.2 Attaching Policy")

iam.attach_role_policy(RoleName=DWH_IAM_ROLE_NAME,
                       PolicyArn="arn:aws:iam::aws:policy/AmazonS3ReadOnlyAccess"
                      )['ResponseMetadata']['HTTPStatusCode']

print("1.3 Get the IAM role ARN")
roleArn = iam.get_role(RoleName=DWH_IAM_ROLE_NAME)['Role']['Arn']

print(roleArn)
```

STEP 2: Redshift Cluster

- Create a RedShift Cluster
- For complete arguments to `create_cluster`, see docs

```
try:
    response = redshift.create_cluster(
        #HW
        ClusterType=DWH_CLUSTER_TYPE,
        NodeType=DWH_NODE_TYPE,
        NumberOfNodes=int(DWH_NUM_NODES),

        #Identifiers & Credentials
        DBName=DWH_DB,
        ClusterIdentifier=DWH_CLUSTER_IDENTIFIER,
        MasterUsername=DWH_DB_USER,
        MasterUserPassword=DWH_DB_PASSWORD,

        #Roles (for s3 access)
        IamRoles=[roleArn]
    )
except Exception as e:
    print(e)
```

2.1 *Describe* the cluster to see its status

- run this block several times until the cluster status becomes `Available`

```
def prettyRedshiftProps(props):
    pd.set_option('display.max_colwidth', -1)
    keysToShow = ["ClusterIdentifier", "NodeType", "ClusterStatus", "MasterUsername", "DBName", "Endpoint", "NumberOfNodes", 'VpcId
    x = [(k, v) for k,v in props.items() if k in keysToShow]
    return pd.DataFrame(data=x, columns=["Key", "Value"])

myClusterProps = redshift.describe_clusters(ClusterIdentifier=DWH_CLUSTER_IDENTIFIER)['Clusters'][0]
prettyRedshiftProps(myClusterProps)
```

2.2 Take note of the cluster endpoint and role ARN

DO NOT RUN THIS unless the cluster status becomes "Available". Make ure you are checking your Amazon Redshift cluster in the **us-west-2** region.

```
DWH_ENDPOINT = myClusterProps['Endpoint']['Address']
DWH_ROLE_ARN = myClusterProps['IamRoles'][0]['IamRoleArn']
print("DWH_ENDPOINT :: ", DWH_ENDPOINT)
print("DWH_ROLE_ARN :: ", DWH_ROLE_ARN)
```

STEP 3: Open an incoming TCP port to access the cluster ednpoint

```
try:
    vpc = ec2.Vpc(id=myClusterProps['VpcId'])
    defaultSg = list(vpc.security_groups.all())[0]
    print(defaultSg)
    defaultSg.authorize_ingress(
        GroupName=defaultSg.group_name,
        CidrIp='0.0.0.0/0',
        IpProtocol='TCP',
        FromPort=int(DWH_PORT),
        ToPort=int(DWH_PORT)
    )
except Exception as e:
    print(e)
```

STEP 4: Make sure you can connect to the cluster

```
%load_ext sql

conn_string="postgresql://{}:{}@{}:{}/{}".format(DWH_DB_USER, DWH_DB_PASSWORD, DWH_ENDPOINT, DWH_PORT,DWH_DB)
print(conn_string)
%sql $conn_string
```

STEP 5: Clean up your resources

DO NOT RUN THIS UNLESS YOU ARE SUREWe will be using these resources in the next exercises

```
#### CAREFUL!!
#-- Uncomment & run to delete the created resources
redshift.delete_cluster( ClusterIdentifier=DWH_CLUSTER_IDENTIFIER,  SkipFinalClusterSnapshot=True)
#### CAREFUL!!

myClusterProps = redshift.describe_clusters(ClusterIdentifier=DWH_CLUSTER_IDENTIFIER)['Clusters'][0]
prettyRedshiftProps(myClusterProps)

#### CAREFUL!!
#-- Uncomment & run to delete the created resources
iam.detach_role_policy(RoleName=DWH_IAM_ROLE_NAME, PolicyArn="arn:aws:iam::aws:policy/AmazonS3ReadOnlyAccess")
iam.delete_role(RoleName=DWH_IAM_ROLE_NAME)
#### CAREFUL!!
```

▼ **Parallel ETL exercise**

The scope here is to show that parallel copying is faster than uploading the whole csv

```
%load_ext sql
from time import time
import configparser
import matplotlib.pyplot as plt
import pandas as pd
```

STEP 1: Get the params of the created redshift cluster

- We need:
  - The redshift cluster

    endpoint
  - The that give access to Redshift to read from S3

    IAM role ARN

```
config = configparser.ConfigParser()
config.read_file(open('dwh.cfg'))
KEY=config.get('AWS','key')
SECRET= config.get('AWS','secret')

DWH_DB= config.get("DWH","DWH_DB")
DWH_DB_USER= config.get("DWH","DWH_DB_USER")
DWH_DB_PASSWORD= config.get("DWH","DWH_DB_PASSWORD")
DWH_PORT = config.get("DWH","DWH_PORT")

# FILL IN THE REDSHIFT ENPOINT HERE
# e.g. DWH_ENDPOINT="redshift-cluster-1.csmamz5zxmle.us-west-2.redshift.amazonaws.com"
DWH_ENDPOINT="dwhcluster.cslugxhlivog.us-east-2.redshift.amazonaws.com"

#FILL IN THE IAM ROLE ARN you got in step 2.2 of the previous exercise
#e.g DWH_ROLE_ARN="arn:aws:iam::988332130976:role/dwhRole"
DWH_ROLE_ARN="arn:aws:iam::149551910519:role/dwhRole"
```

STEP 2: Connect to the Redshift Cluster

```
conn_string="postgresql://{}:{}@{}:{}/{}".format(DWH_DB_USER, DWH_DB_PASSWORD, DWH_ENDPOINT, DWH_PORT,DWH_DB)
print(conn_string)
%sql $conn_string

import boto3

s3 = boto3.resource('s3',
                       region_name="us-west-2",
                       aws_access_key_id=KEY,
                       aws_secret_access_key=SECRET
```

```
                    )

sampleDbBucket =  s3.Bucket("udacity-labs")

for obj in sampleDbBucket.objects.filter(Prefix="tickets"):
    print(obj)
```

STEP 3: Create Tables

```
%%sql
DROP TABLE IF EXISTS "sporting_event_ticket";
CREATE TABLE "sporting_event_ticket" (
    "id" double precision DEFAULT nextval('sporting_event_ticket_seq') NOT NULL,
    "sporting_event_id" double precision NOT NULL,
    "sport_location_id" double precision NOT NULL,
    "seat_level" numeric(1,0) NOT NULL,
    "seat_section" character varying(15) NOT NULL,
    "seat_row" character varying(10) NOT NULL,
    "seat" character varying(10) NOT NULL,
    "ticketholder_id" double precision,
    "ticket_price" numeric(8,2) NOT NULL
);
```

STEP 4: Load Partitioned data into the cluster

```
%%time
qry = """
    copy sporting_event_ticket from 's3://udacity-labs/tickets/split/part'
    credentials 'aws_iam_role={}'
    gzip delimiter ';' compupdate off region 'us-west-2';
""".format(DWH_ROLE_ARN)

%sql $qry
```

STEP 4: Create Tables for the non-partitioned data

```
%%sql
DROP TABLE IF EXISTS "sporting_event_ticket_full";
CREATE TABLE "sporting_event_ticket_full" (
    "id" double precision DEFAULT nextval('sporting_event_ticket_seq') NOT NULL,
    "sporting_event_id" double precision NOT NULL,
    "sport_location_id" double precision NOT NULL,
    "seat_level" numeric(1,0) NOT NULL,
    "seat_section" character varying(15) NOT NULL,
    "seat_row" character varying(10) NOT NULL,
    "seat" character varying(10) NOT NULL,
    "ticketholder_id" double precision,
    "ticket_price" numeric(8,2) NOT NULL
);
```

STEP 5: Load non-partitioned data into the cluster

Note how it's slower than loading partitioned data

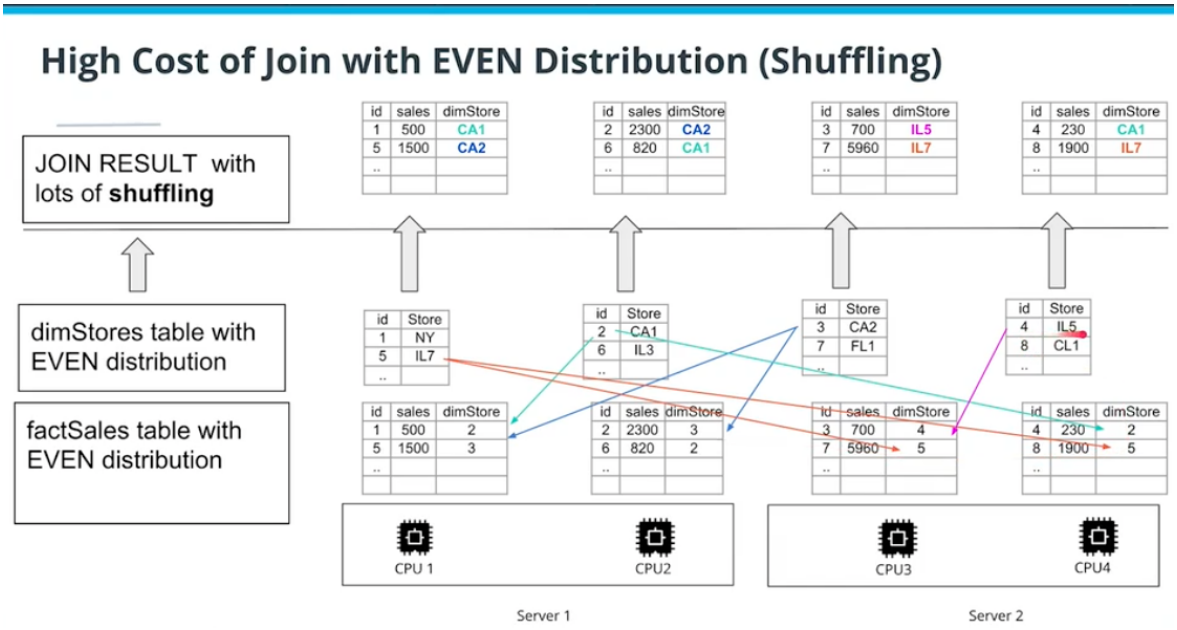
```
%%time

qry = """
    copy sporting_event_ticket_full from 's3://udacity-labs/tickets/full/full.csv.gz'
    credentials 'aws_iam_role={}'
    gzip delimiter ';' compupdate off region 'us-west-2';
""".format(DWH_ROLE_ARN)

%sql $qry
```

▼ **Distributions Styles**

Distribution Styles

- EVEN distribution
- ALL distribution
- AUTO distribution
- KEY distribution

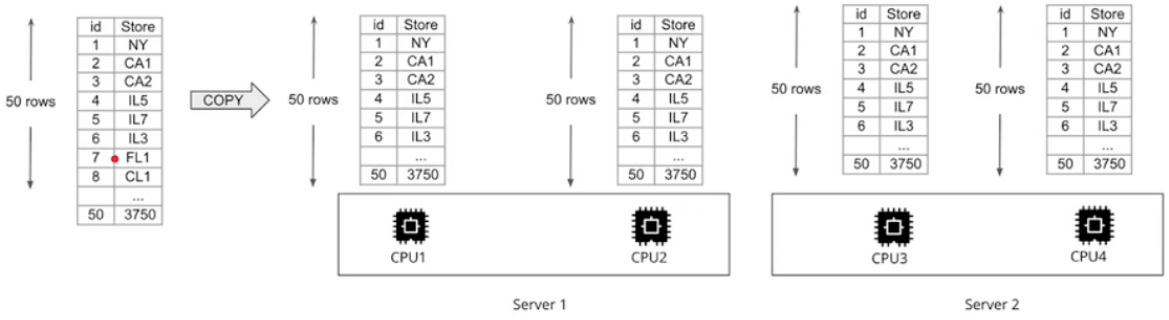
EVEN Distribution can be fast as it split the tables equally between CPU. But it has a high cost of join because different CPUs need to talk as in the picture below.



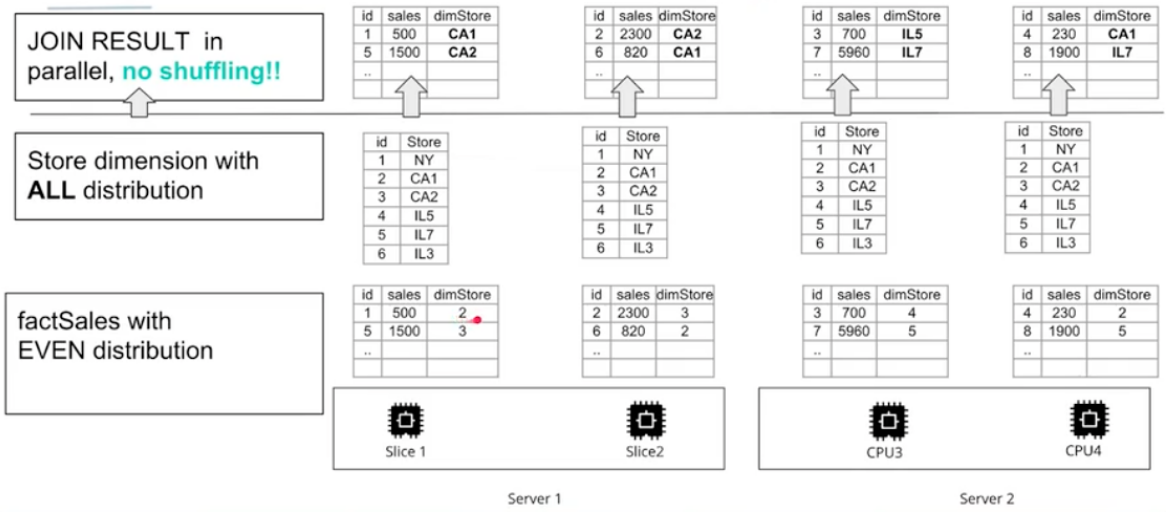
ALL Distribution

Distribution Style: ALL

- Small tables could be replicated on all slices to speed up joins
- Used frequently for dimension tables
- AKA "broadcasting"



Distribution Style: Distributing facts with EVEN and Dimensions with ALL eliminates shuffling



AUTO Distribution

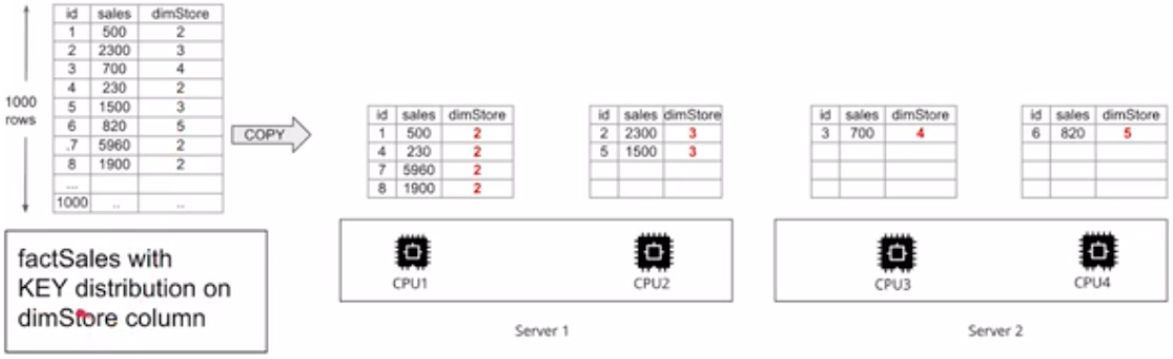
Distribution Style : AUTO

- Leave decision to Redshift
- "Small enough" tables are distributed with an ALL strategy
- Large tables are distributed with EVEN strategy

KEY Distribution

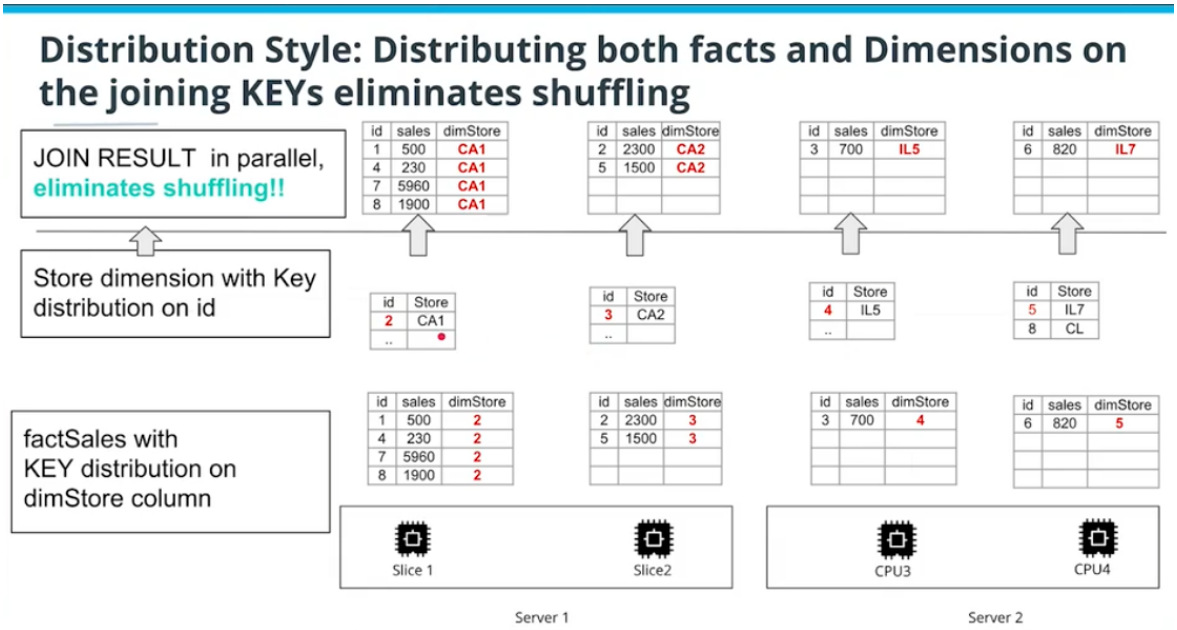
Distribution Style: KEY

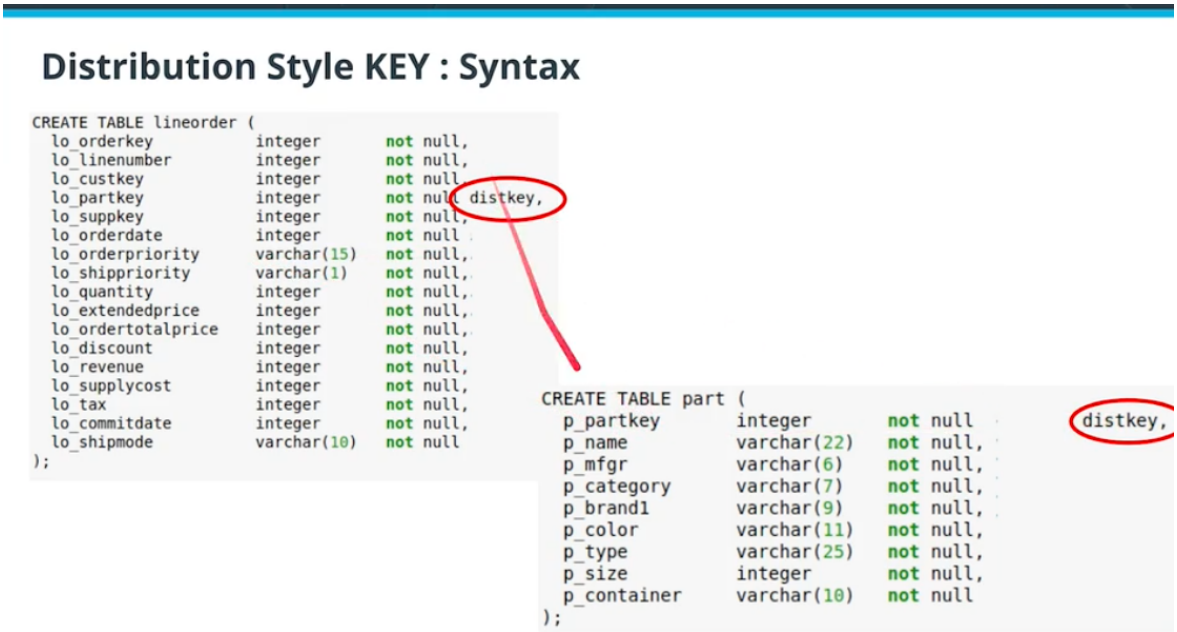
- Rows having similar values are placed in the same slice



Distribution Style : KEY - cont'd

- Rows having similar values are placed in the same slice
- This can lead to a skewed distribution if some values of the dist key are more frequent than others
- However, very useful when a dimension table is too big to be distributed with ALL strategy. In that case, we distribute both the a fact table and the dimension table using the same dist key.
- If two tables are distributed on the joining keys, redshift collocates the rows from both tables on the same slices





▼ **Table Design**

```
%load_ext sql

from time import time
import configparser
import matplotlib.pyplot as plt
import pandas as pd

config = configparser.ConfigParser()
config.read_file(open('dwh.cfg'))
KEY=config.get('AWS','key')
SECRET= config.get('AWS','secret')

DWH_DB= config.get("DWH","DWH_DB")
```

```
DWH_DB_USER= config.get("DWH","DWH_DB_USER")
DWH_DB_PASSWORD= config.get("DWH","DWH_DB_PASSWORD")
DWH_PORT = config.get("DWH","DWH_PORT")
```

STEP 1: Get the params of the created redshift cluster

We need:

- The redshift cluster

  endpoint

- The that give access to Redshift to read from S3

  IAM role ARN

```
# FILL IN THE REDSHIFT ENDPOINT HERE
# e.g. DWH_ENDPOINT="redshift-cluster-1.csmamz5zxmle.us-west-2.redshift.amazonaws.com"
DWH_ENDPOINT="dwhcluster.cslugxhlivog.us-east-2.redshift.amazonaws.com"

#FILL IN THE IAM ROLE ARN you got in step 2.2 of the previous exercise
#e.g DWH_ROLE_ARN="arn:aws:iam::988332130976:role/dwhRole"
DWH_ROLE_ARN="arn:aws:iam::149551910519:role/dwhRole"
```

STEP 2: Connect to the Redshift Cluster

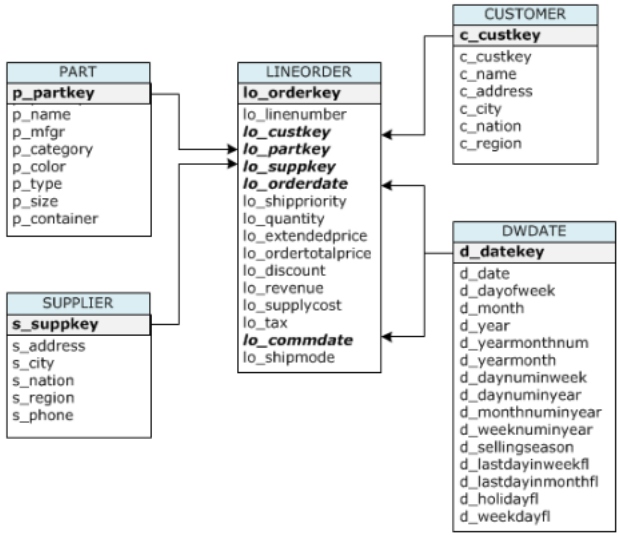
```
import os
conn_string="postgresql://{}:{}@{}:{}/{}".format(DWH_DB_USER, DWH_DB_PASSWORD, DWH_ENDPOINT, DWH_PORT,DWH_DB)
print(conn_string)
%sql $conn_string
```

STEP 3: Create Tables

We are going to use a benchmarking data set common for benchmarking star schemas in data warehouses.

The data is pre-loaded in a public bucket on the `us-west-2` region

Our examples will be based on the Amazon Redshfit tutorial but in a scripted environment in our workspace



3.1 Create tables (no distribution strategy) in the `nodist` schema

```
%%sql
CREATE SCHEMA IF NOT EXISTS nodist;
SET search_path TO nodist;
```

```
DROP TABLE IF EXISTS part cascade;
DROP TABLE IF EXISTS supplier;
DROP TABLE IF EXISTS supplier;
DROP TABLE IF EXISTS customer;
DROP TABLE IF EXISTS dwdate;
DROP TABLE IF EXISTS lineorder;

CREATE TABLE part
(
  p_partkey     INTEGER NOT NULL,
  p_name        VARCHAR(22) NOT NULL,
  p_mfgr        VARCHAR(6) NOT NULL,
  p_category    VARCHAR(7) NOT NULL,
  p_brand1      VARCHAR(9) NOT NULL,
  p_color       VARCHAR(11) NOT NULL,
  p_type        VARCHAR(25) NOT NULL,
  p_size        INTEGER NOT NULL,
  p_container   VARCHAR(10) NOT NULL
);

CREATE TABLE supplier
(
  s_suppkey   INTEGER NOT NULL,
  s_name      VARCHAR(25) NOT NULL,
  s_address   VARCHAR(25) NOT NULL,
  s_city      VARCHAR(10) NOT NULL,
  s_nation    VARCHAR(15) NOT NULL,
  s_region    VARCHAR(12) NOT NULL,
  s_phone     VARCHAR(15) NOT NULL
);

CREATE TABLE customer
(
  c_custkey      INTEGER NOT NULL,
  c_name         VARCHAR(25) NOT NULL,
  c_address      VARCHAR(25) NOT NULL,
  c_city         VARCHAR(10) NOT NULL,
  c_nation       VARCHAR(15) NOT NULL,
  c_region       VARCHAR(12) NOT NULL,
  c_phone        VARCHAR(15) NOT NULL,
  c_mktsegment   VARCHAR(10) NOT NULL
);

CREATE TABLE dwdate
(
  d_datekey            INTEGER NOT NULL,
  d_date               VARCHAR(19) NOT NULL,
  d_dayofweek          VARCHAR(10) NOT NULL,
  d_month              VARCHAR(10) NOT NULL,
  d_year               INTEGER NOT NULL,
  d_yearmonthnum       INTEGER NOT NULL,
  d_yearmonth          VARCHAR(8) NOT NULL,
  d_daynuminweek       INTEGER NOT NULL,
  d_daynuminmonth      INTEGER NOT NULL,
  d_daynuminyear       INTEGER NOT NULL,
  d_monthnuminyear     INTEGER NOT NULL,
  d_weeknuminyear      INTEGER NOT NULL,
  d_sellingseason      VARCHAR(13) NOT NULL,
  d_lastdayinweekfl    VARCHAR(1) NOT NULL,
  d_lastdayinmonthfl   VARCHAR(1) NOT NULL,
  d_holidayfl          VARCHAR(1) NOT NULL,
  d_weekdayfl          VARCHAR(1) NOT NULL
);
CREATE TABLE lineorder
(
  lo_orderkey          INTEGER NOT NULL,
  lo_linenumber        INTEGER NOT NULL,
  lo_custkey           INTEGER NOT NULL,
  lo_partkey           INTEGER NOT NULL,
  lo_suppkey           INTEGER NOT NULL,
  lo_orderdate         INTEGER NOT NULL,
  lo_orderpriority     VARCHAR(15) NOT NULL,
  lo_shippriority      VARCHAR(1) NOT NULL,
  lo_quantity          INTEGER NOT NULL,
  lo_extendedprice     INTEGER NOT NULL,
  lo_ordertotalprice   INTEGER NOT NULL,
  lo_discount          INTEGER NOT NULL,
  lo_revenue           INTEGER NOT NULL,
  lo_supplycost        INTEGER NOT NULL,
  lo_tax               INTEGER NOT NULL,
```

```
  lo_commitdate        INTEGER NOT NULL,
  lo_shipmode          VARCHAR(10) NOT NULL
);
```

3.1 Create tables (with a distribution strategy) in the `dist` schema

```
%%sql

CREATE SCHEMA IF NOT EXISTS dist;
SET search_path TO dist;

DROP TABLE IF EXISTS part cascade;
DROP TABLE IF EXISTS supplier;
DROP TABLE IF EXISTS supplier;
DROP TABLE IF EXISTS customer;
DROP TABLE IF EXISTS dwdate;
DROP TABLE IF EXISTS lineorder;

CREATE TABLE part (
  p_partkey       integer       not null  sortkey distkey,
  p_name          varchar(22)   not null,
  p_mfgr          varchar(6)      not null,
  p_category      varchar(7)      not null,
  p_brand1        varchar(9)      not null,
  p_color         varchar(11)   not null,
  p_type          varchar(25)   not null,
  p_size          integer       not null,
  p_container     varchar(10)     not null
);

CREATE TABLE supplier (
  s_suppkey       integer        not null sortkey,
  s_name          varchar(25)    not null,
  s_address       varchar(25)    not null,
  s_city          varchar(10)    not null,
  s_nation        varchar(15)    not null,
  s_region        varchar(12)    not null,
  s_phone         varchar(15)    not null)
diststyle all;

CREATE TABLE customer (
  c_custkey       integer        not null sortkey,
  c_name          varchar(25)    not null,
  c_address       varchar(25)    not null,
  c_city          varchar(10)    not null,
  c_nation        varchar(15)    not null,
  c_region        varchar(12)    not null,
  c_phone         varchar(15)    not null,
  c_mktsegment      varchar(10)    not null)
diststyle all;

CREATE TABLE dwdate (
  d_datekey            integer       not null sortkey,
  d_date               varchar(19)   not null,
  d_dayofweek       varchar(10)   not null,
  d_month           varchar(10)   not null,
  d_year               integer       not null,
  d_yearmonthnum       integer     not null,
  d_yearmonth          varchar(8) not null,
  d_daynuminweek       integer       not null,
  d_daynuminmonth      integer       not null,
  d_daynuminyear       integer       not null,
  d_monthnuminyear     integer       not null,
  d_weeknuminyear      integer       not null,
  d_sellingseason      varchar(13)    not null,
  d_lastdayinweekfl    varchar(1)    not null,
  d_lastdayinmonthfl   varchar(1)    not null,
  d_holidayfl          varchar(1)    not null,
  d_weekdayfl          varchar(1)    not null)
diststyle all;

CREATE TABLE lineorder (
  lo_orderkey           integer       not null,
  lo_linenumber         integer       not null,
  lo_custkey            integer       not null,
  lo_partkey            integer       not null distkey,
  lo_suppkey            integer       not null,
  lo_orderdate          integer       not null sortkey,
```

```
  lo_orderpriority      varchar(15)     not null,
  lo_shippriority       varchar(1)      not null,
  lo_quantity           integer       not null,
  lo_extendedprice      integer       not null,
  lo_ordertotalprice    integer       not null,
  lo_discount           integer       not null,
  lo_revenue            integer       not null,
  lo_supplycost         integer       not null,
  lo_tax                integer       not null,
  lo_commitdate         integer         not null,
  lo_shipmode           varchar(10)     not null
);
```

STEP 4: Copying tables

Our intent here is to run 5 COPY operations for the 5 tables respectively as show below.

However, we want to do accomplish the following:

- Make sure that the `DWH_ROLE_ARN` is substituted with the correct value in each query
- Perform the data loading twice once for each schema (dist and nodist)
- Collect timing statistics to compare the insertion times Thus, we have scripted the insertion as found below in the function `loadTables` which returns a pandas dataframe containing timing statistics for the copy operations

```
copy customerfrom 's3://awssampledbuswest2/ssbgz/customer'
credentials 'aws_iam_role=<DWH_ROLE_ARN>'
gzip region 'us-west-2';

copy dwdatefrom 's3://awssampledbuswest2/ssbgz/dwdate'
credentials 'aws_iam_role=<DWH_ROLE_ARN>'
gzip region 'us-west-2';

copy lineorderfrom 's3://awssampledbuswest2/ssbgz/lineorder'
credentials 'aws_iam_role=<DWH_ROLE_ARN>'
gzip region 'us-west-2';

copy partfrom 's3://awssampledbuswest2/ssbgz/part'
credentials 'aws_iam_role=<DWH_ROLE_ARN>'
gzip region 'us-west-2';

copy supplierfrom 's3://awssampledbuswest2/ssbgz/supplier'
credentials 'aws_iam_role=<DWH_ROLE_ARN>'
gzip region 'us-west-2';
```

4.1 Automate the copying

```
def loadTables(schema, tables):
    loadTimes = []
    SQL_SET_SCEMA = "SET search_path TO {};".format(schema)
    %sql $SQL_SET_SCEMA

    for table in tables:
        SQL_COPY = """
copy {} from 's3://awssampledbuswest2/ssbgz/{}'
credentials 'aws_iam_role={}'
gzip region 'us-west-2';
        """.format(table,table, DWH_ROLE_ARN)

        print("======= LOADING TABLE: ** {} ** IN SCHEMA ==> {} =======".format(table, schema))
        print(SQL_COPY)

        t0 = time()
        %sql $SQL_COPY
        loadTime = time()-t0
        loadTimes.append(loadTime)

        print("=== DONE IN: {0:.2f} sec\n".format(loadTime))
    return pd.DataFrame({"table":tables, "loadtime_"+schema:loadTimes}).set_index('table')
```

```
#-- List of the tables to be loaded
tables = ["customer","dwdate","supplier", "part", "lineorder"]

#-- Insertion twice for each schema (WARNING!! EACH CAN TAKE MORE THAN 10 MINUTES!!!)
nodistStats = loadTables("nodist", tables)
distStats = loadTables("dist", tables)
```

4.1 Compare the load performance results

```
#-- Plotting of the timing results
stats = distStats.join(nodistStats)
stats.plot.bar()
plt.show()
```

STEP 5: Compare Query Performance

```
oneDim_SQL ="""
set enable_result_cache_for_session to off;
SET search_path TO {};

select sum(lo_extendedprice*lo_discount) as revenue
from lineorder, dwdate
where lo_orderdate = d_datekey
and d_year = 1997
and lo_discount between 1 and 3
and lo_quantity < 24;
"""

twoDim_SQL="""
set enable_result_cache_for_session to off;
SET search_path TO {};

select sum(lo_revenue), d_year, p_brand1
from lineorder, dwdate, part, supplier
where lo_orderdate = d_datekey
and lo_partkey = p_partkey
and lo_suppkey = s_suppkey
and p_category = 'MFGR#12'
and s_region = 'AMERICA'
group by d_year, p_brand1
"""

drill_SQL = """
set enable_result_cache_for_session to off;
SET search_path TO {};

select c_city, s_city, d_year, sum(lo_revenue) as revenue
from customer, lineorder, supplier, dwdate
where lo_custkey = c_custkey
and lo_suppkey = s_suppkey
and lo_orderdate = d_datekey
and (c_city='UNITED KI1' or
c_city='UNITED KI5')
and (s_city='UNITED KI1' or
s_city='UNITED KI5')
and d_yearmonth = 'Dec1997'
group by c_city, s_city, d_year
order by d_year asc, revenue desc;
"""


oneDimSameDist_SQL ="""
set enable_result_cache_for_session to off;
SET search_path TO {};

select lo_orderdate, sum(lo_extendedprice*lo_discount) as revenue
from lineorder, part
where lo_partkey  = p_partkey
group by lo_orderdate
order by lo_orderdate
"""

def compareQueryTimes(schema):
    queryTimes  =[]
```

```
    for i,query in enumerate([oneDim_SQL, twoDim_SQL, drill_SQL, oneDimSameDist_SQL]):
        t0 = time()
        q = query.format(schema)
        %sql $q
        queryTime = time()-t0
        queryTimes.append(queryTime)
    return pd.DataFrame({"query":["oneDim","twoDim", "drill", "oneDimSameDist"], "queryTime_"+schema:queryTimes}).set_index
```

```
noDistQueryTimes = compareQueryTimes("nodist")
distQueryTimes   = compareQueryTimes("dist")
```

```
queryTimeDF =noDistQueryTimes.join(distQueryTimes)
queryTimeDF.plot.bar()
plt.show()
```

```
improvementDF = queryTimeDF["distImprovement"] =100.0*(queryTimeDF['queryTime_nodist']-queryTimeDF['queryTime_dist'])/query
improvementDF.plot.bar(title="% dist Improvement by query")
plt.show()
```