TCSS 462/562: (Software Engineering for) Cloud Computing
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School of Engineering and Technology
University of Washington – Tacoma

Tutorial 6 – Introduction to Lambda III: Serverless Databases

Disclaimer: Subject to updates as corrections are found
Version 0.11
Scoring: 20 pts maximum

The purpose of this tutorial is to introduce the use of relational databases from AWS Lambda. This tutorial will demonstrate the use of SQLite, an in-memory file-based database that runs inside a Lambda function to provide a "temporary" relational database that lives for the lifetime of the Lambda container. Secondly, the tutorial demonstrates the use of the Amazon Relational Database Service (RDS) to create a persistent relational database using Serverless Aurora MySQL 5.6 for data storage and query support for Lambda functions.

Goals of this tutorial include:

1. Introduce the Sqlite database using the command line "sqlite3" tool.
2. Deploy a Lambda Function that uses a file-based SQLite3 database in the "/tmp" directory of the Lambda container that persists between client function invocations
3. Compare the difference between using file-based and in-memory SQLite DBs on Lambda.
4. Create an Amazon RDS Aurora MySQL Serverless database
5. Launch an EC2 instance and install the mysql command line client to interface with the Aurora serverless database.
6. Deploy an AWS Lambda function that uses the MySQL Serverless database.

1. Using the SQLite Command Line

To begin, create a directory called "saaf_sqlite".
Then clone the git repository under the new directory:

```
git clone https://github.com/wlloyduw/saaf_sqlite3.git
```

If using Windows or Mac, download the "Precompiled binaries" as a zip file from:
https://www.sqlite.org/download.html

On Windows/Mac, unzip the zip file, and then run the **sqlite3** program.

On Ubuntu Linux, the package sqlite3 can be installed which is version ~3.31.1 on Ubuntu 20.04 LTS. Then launch the sqlite3 database client:

```
sudo apt update
sudo apt install sqlite3
# navigate to your java project directory first
cd {base directory where project was cloned}/saaf_sqlite3/java_template/
sqlite3
```

Check out the version of the db using ".version".

Check out available commands using ".help".

```
sqlite> .version
SQLite 3.31.1 2020-01-27 19:55:54
zlib version 1.2.11
gcc-9.3.0
sqlite> .quit
```

Start by saving a new database file, and then exit the tool:

```
sqlite> .save new.db
sqlite> .quit
```

Then, check the size of an empty sqlite db file:

```
$ ls -l new.db
total 3848
-rw-r--r-- 1 wlloyd wlloyd    4096 Nov  1 19:05 new.db
```

It is only 4096 bytes, very small!

Next, work with data in the database:

```
$ sqlite3 new.db
SQLite version 3.31.1 2020-01-27 19:55:54
Enter ".help" for usage hints.
sqlite> .databases
main: /home/wlloyd/git/tutorial6/saaf_sqlite3/new.db
sqlite> .tables
```

There are initially no tables.
Create a table and insert some data:

```
sqlite> create table newtable (name text, city text, state text);
sqlite> .tables
newtable
sqlite> insert into newtable values('Susan Smith','Tacoma','Washington');
sqlite> insert into newtable values('Bill Gates','Redmond','Washington');
sqlite> select * from newtable;
Susan Smith|Tacoma|Washington
Bill Gates|Redmond|Washington
```

Now check how the database file has grown after adding a table and a few rows:

sqlite> .quit
$ ls -l new.db

Question 1. After creating the table 'newtable' and loading data to sqlite, what is the size of the new.db database file?

The sqlite3 command line tool can be used to perform common **C**reate **R**ead **U**pdate and **D**elete queries on a sqlite database. This allows the database to be preloaded with data and bundled with a Lambda function for deployment to the cloud as needed.

If you're unfamiliar with SQL, and writing SQL queries, please consider completing the online tutorial:

SQLite Tutorial:
http://www.sqlitetutorial.net/

Follow the steps for "Getting started with SQLite" (1, 2, and 3), and then complete the Basic SQLite tutorial to review performing different types of queries using the sample Chinook database with 11 tables downloaded from step 3.

2. Combining SQLite with AWS Lambda

SQLite can be leveraged directly from programming languages such as Java, Python, and Node.JS. SQLite provides an alternative to basic CSV and text file storage with a SQL-compatible query-able file format. SQLite does not replace a full-fledged enterprise relational database management system (dbms) in terms of scalability, etc. But given the small footprint of SQLite, it provides an excellent database alternative for serverless environments and Internet of Things devices.

Next, explore the saaf_sqlite project in Netbeans or another Java IDE.

"saaf_sqlite" provides a Java-based Lambda "Hello" function based on SAAF from Tutorial #4. Look at the code inside: **saaf_sqlite/java_template/src/main/java/ lambda/HelloSqlite.java**.

```
setCurrentDirectory("/tmp");
try
{
      // Connection string an in-memory SQLite DB
      //Connection con = DriverManager.getConnection("jdbc:sqlite:");

      // Connection string for a file-based SQlite DB
      Connection con = DriverManager.getConnection("jdbc:sqlite:mytest.db");

```

The first line of code (LOC) calls a helper function to set the working directory to "/tmp" inside the Lambda function.

"/tmp" provides a read/write 512MB filesystem on Lambda.
As a security precaution, code deployed to Lambda has only limited permission to write to the filesystem, as /tmp is enabled for read/write.

SQLite can work with databases entirely in memory, or on disk. The first database connection string is commented out, but could be used if wanting to work with a database only in memory.

The advantage of creating the database on disk is that data persists beyond the runtime of the Java code. On Lambda, this means as long as the original runtime container is preserved, the data is preserved. If containers are kept WARM, they can last up to 6 to 8 hours. After 6-8 hours, it will be necessary to save any SQLite databases to S3 to persist the data for longer.

Perform a clean build of the saaf_sqlite project to create a jar file.
Following instructions from tutorial #4, deploy a new lambda function called "helloSqlite".
Be sure to set the function's handler in the AWS Lambda GUI.
Choose one method (AWS CLI or CURL) for invoking "helloSqlite" from **callservice.sh**.
If wanting to use a HTTP/REST URL, configure the API Gateway to provide a URL for access via Curl. Otherwise use the "helloSqlite" Lambda function name and the AWS Lambda CLI.

Under your new project, modify the callservice.sh script to invoke your newly deployed Sqlite Lambda function:
saaf_sqlite/java_template/test/callservice.sh

Then run the script. Below the API Gateway invocation code in BASH has been commented out using a "#" in front of each line.

```
$ ./callservice.sh
Invoking Lambda function using AWS CLI
real 0m11.985s
user 0m0.288s
sys 0m0.064s

AWS CLI RESULT:
{
  ….. // some attributes removed from brevity...
  "uuid": "8c321d18-d16e-4cd8-acac-cbc8d65fe138",
  "error": "",
  "vmuptime": 1541129227,
  "newcontainer": 1,
  "value": "Hello Fred Smith",
  "names": [
    "Fred Smith"
  ]
}
```

Using a file, each time the service is called and the same runtime container is used, a name is appended to the temporary file-based SQLite database. We see the "names" array in the JSON grow with each subsequent call.

Try running the ./callservice.sh script now several times (10x) to watch the names array grow.

Now, try out what happens when two clients call the Lambda function at the same time.

Inspect the simple calltwice.sh script:

```
cat calltwice.sh
```

Now, try running calltwice.sh:

```
./calltwice.sh
```

If you do not see the command prompt after awhile, press [ENTER].

Invoking a Lambda with two clients in parallel forces Lambda to create additional server infrastructure.

Question 2. When the second client calls the helloSqlite Lambda function, how is the data different in the second container environment compared to the initial/first container?

Now, try out a memory-only SQLite database. Modify your Lambda code to swap out the type of database. Comment out the file-based database in favor of memory only:

```
setCurrentDirectory("/tmp");
try
{

  // Connection string an in-memory SQLite DB
  Connection con = DriverManager.getConnection("jdbc:sqlite:");

  // Connection string for a file-based SQlite DB
  // Connection con = DriverManager.getConnection("jdbc:sqlite:/tmp/mytest.db");
```

Build a new JAR file, and redeploy it to Lambda for the helloSqlite Lambda function.

Using callservice.sh, try calling the Lambda several times in succession.

Question 3. For Lambda calls that execute in the same runtime container identified by the UUID returned in JSON, does the data persist between client Lambda calls with an in-memory DB? (YES or NO)

Next, let's modify the code for helloSqlite to add a static int counter that tracks the total number of calls to the container.

Define a static int at the start of public class HelloSqlite:

```
public class HelloSqlite implements RequestHandler<Request, HashMap<String, Object>>
{
    static String CONTAINER_ID = "/tmp/container-id";
    static Charset CHARSET = Charset.forName("US-ASCII");

    static int uses = 0;
```

Then modify the definition of String hello near the bottom of the Lambda function to report the uses count:

```
        // **********************************************************************
        // Set hello message here
        // **********************************************************************
        uses = uses + 1;
        String hello = "Hello " + request.getName() + " calls=" + uses;
```

Build a new JAR file, and redeploy it to Lambda for the helloSqlite Lambda function.

Using callservice.sh, try calling the Lambda with the static uses counter several times in succession:

```
./callservice.sh
./callservice.sh
./callservice.sh
```

Question 4. Does the value of the static int persist for Lambda calls that execute in the same runtime container identified by the UUID returned in JSON? (YES or NO)

Now, try running with calltwice.sh.

Question 5. How is the value of the static int different across different runtime containers identified by the UUID returned in JSON?

Next, inspect the SQL code for the helloSqlite Lambda function:

```
// Detect if the table 'mytable' exists in the database
PreparedStatement ps = con.prepareStatement("SELECT name FROM sqlite_master WHERE
type='table' AND name='mytable'");
ResultSet rs = ps.executeQuery();
if (!rs.next())
{
	// 'mytable' does not exist, and should be created
	logger.log("trying to create table 'mytable'");
	ps = con.prepareStatement("CREATE TABLE mytable ( name text, col2 text, col3
text);");
	ps.execute();
}
rs.close();

// Insert row into mytable
ps = con.prepareStatement("insert into mytable values('" + request.getName() +
"','b','c');");
ps.execute();

// Query mytable to obtain full resultset
ps = con.prepareStatement("select * from mytable;");
rs = ps.executeQuery();
```

The approach of our helloSqlite Lambda is to create a new file (or memory) database each time.

Question 6. Before inserting rows into 'mytable', what has to be done and why in the Java code above?

Consider how an in-memory SQLite DB could be preserved between calls. The Lambda function could use a static Connection object that is initialized similar to how the "uses" variable is initialized above. The connection would stay open as long as the Lambda function remains "warm".

3. Optional Exercise: Persisting SQLite database files to S3

Leveraging concepts from tutorial #5, modify the file-based version of helloSqlite to always save the database file in /tmp to S3 at the end of the function. Add a key to the request.java to allow the user to specify a database filename.

At the beginning of the function handler, using the user provided database filename from the request, check if the specified file exists in /tmp. If it does not exist, then download the file from S3. Then change the SQLite connection string to open the user provided database name. This way a user could request a specific database from S3 for their Lambda function call. As an added feature, if the file does not exist in S3, then create an initial version in /tmp and upload this to S3.

4. Create an Amazon Aurora MySQL Serverless Database v2

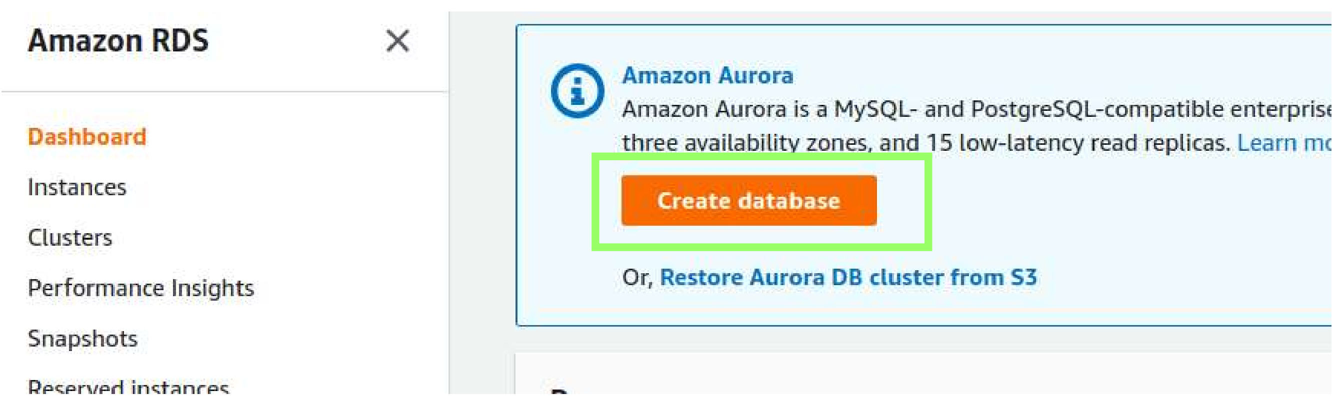
The AWS Relational Database Service now offers the Amazon Aurora *"serverless"* MySQL database. Note that serverless is in quotes. With version 2, the database is unfortunately no longer serverless. With version 2 the database can scale down to 0.5 Aurora Compute Units when not actively used. 0.5 Amazon Compute Units provides approximately 1 GB of memory and a fraction of a vCPU to host an always-on database at the prices of 6c/hour, $1.44/day, or $10.08/month plus storage charges are additional. Serverless Aurora supports automatic horizontal scaling up of database servers from 0.5 ACUs to as many as 128 ACUs, where 1 ACU provides 2 GB of memory and relative number of vCPUs that may scale like the r6 family of ec2 instances. The exact value is not published, but we expect 1 ACU provides 0.25 r6.large-style vCPUs. (recent 10-nm Intel Xeon 8375C). Aurora additionally provides automatic database backups and replicas.

**** TO STOP CHARGES FROM THE "SERVERLESS" DATABASE IT IS NECESSARY TO PAUSE THE DB CLUSTER ! ****

To get started, create a serverless database!

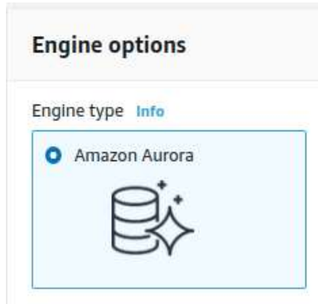
**** This portion of the tutorial requires AWS credits to complete. ****
Aurora serverless does not run in the FREE tier.

Under Services, search for and go to "RDS". Click "Create database" to launch the wizard:



First use the "**Standard create"** database creation method.

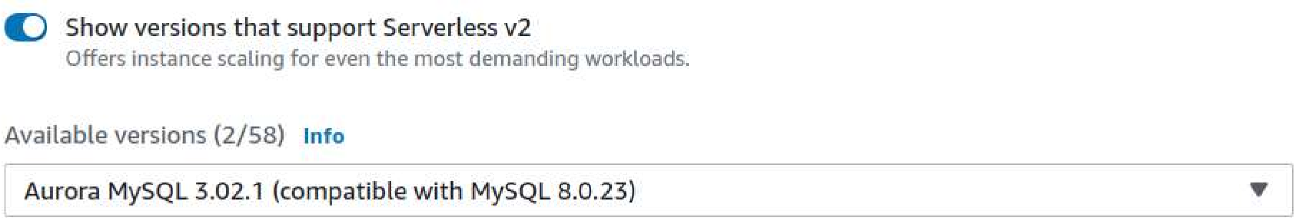
Then specify the "Amazon Aurora" engine



Then choose the following option:
Edition: Amazon Aurora MySQL-Compatible Edition

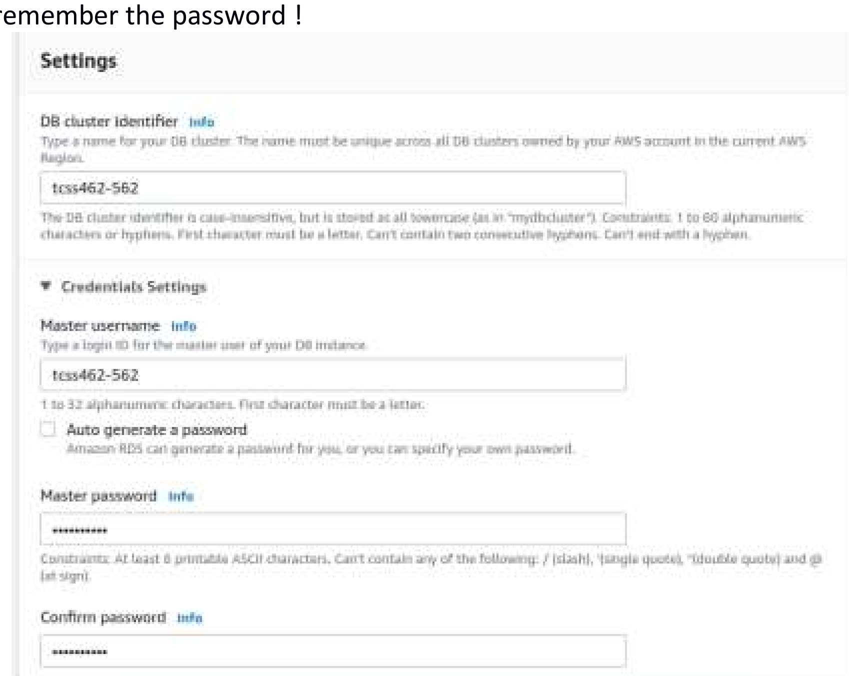
Expand the “Show filters” option.
Then select “**Show versions that support Serverless v2”**:

For the **Available versions** select the latest version:



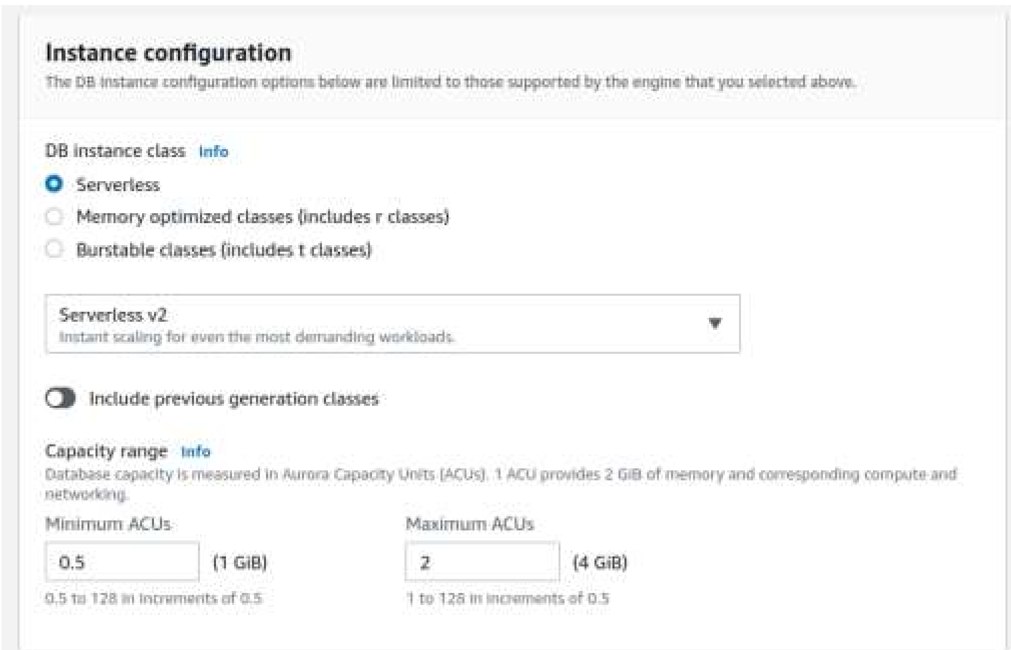
For **Templates**, select “**Dev/Test”.**

For **Settings**, specify a value for the ‘**DB cluster identifier**’, ‘**Master username**’, as well as the **Master password**.
Be sure to set and remember the password !



Use the following values:
DB cluster identifier: tcss462-562
Master username: tcss462562 **(DO NOT USE A DASH – this is not an accepted character)**
Master password: <provide a password, 8-char minimum>
Confirm password: <repeat the password>

Next, provide an '**Instance configuration'** scaling specifications. To save cost, specify a very low range of Aurora Compute Units:



Note that running the server for 1 hour with 0.5 Aurora Capacity Unit and 1GB of memory costs 6¢. Aurora Serverless costs 12¢/per ACU/per hour billed to the nearest second. Databases are always-on. Databases scale up instantly to the maximum ACUs, and take approximately 3-minutes to scale to the minimum ACUs after a period of inactivity. To limit charges, set the minimum Aurora Capacity Units to the minimum setting of **0.5**. Set the maximum to a small number for development/test purposes. If there are performance issues the maximum can be increased later.

For **Connectivity** specify:
Virtual Private Cloud (VPC):
Default VPC (vpc-xxxxxx) note: *the vpc-id will be visible*

Then open "Additional connectivity configuration":

DB Subnet group:
Select an existing DB subnet group if available. This is typically the default-vpc subnet group matching the default-vpc ID.

VPC security group (firewall):
Select "Choose existing", and then select "default" from the dropdown list.

For the remaining settings, the defaults can be used.
The press:

The RDS databases list will appear.
The state of creation can be monitored. Database creation takes a couple minutes.

5. Launch a t2.micro EC2 VM to connect to the Aurora DB MySQL database

It is not possible to directly connect to the Aurora MySQL Serverless database. This is because the database lives on a Virtual Private Cloud (VPC) that does not allow inbound traffic from the internet. This provides network isolation and security. Accessing the database requires launching an EC2 instance in the same VPC as the RDS database and associating a Public IP address with this EC2 instance. The RDS database itself does not have a public IP that is accessible from the outside. Providing direct connectivity to the RDS database requires: (1) setting up either a NAT Gateway (4.5¢/hour), (2) configuring a VM to act as a router/gateway which requires special network configuration, or (3) installing a proxy server such as haproxy on the publicly accessible VM to proxy inbound traffic for MySQL to the RDS database. A database client could then connect to the VM, not RDS, and the traffic is redirected. Fortunately, if deploying AWS Lambda functions in the same VPC as the RDS database, no special networking appliance (e.g. NAT gateway instance or router) is required to access the database. This saves cost and complexity.

Launch an EC2 as described in Tutorial 3. Refer to tutorial 3 to refresh how to do this.
Select the latest version of Ubuntu.

Specify a t2.micro, a free-tier instance.
The VM is being used as a database client.
A powerful VM is not required.
The t2.micro can also be launched as a spot-instance by specifying a spot request.
New AWS accounts receive 750 hours of free t2.micro time/month for the first year.

Provide the following settings:
Network: vpc (default)   - select your default VPC -
Subnet: no preference **or match the Region and Availability Zone (AZ) of the database instance (better)**
Use an auto-assigned Public IP
For the security group, select a existing security group, such as default, where you have already provided SSH permission to your client computer (laptop/desktop).
Review settings and Launch

Choose an existing keypair from a prior tutorial if available.
Otherwise, create a new keypair.

In the EC2 console, select the VM. If you have not enabled SSH access from your network, select the new VM, and click on "default" for Security groups. Click the "Inbound" Tab, and hit the [Edit] button. Click [Add Rule] and add a "SSH" "TCP" "22" rule for "My IP". This should allow SSH access to the t2.micro instance.
Refer to tutorial 3 to review the procedure.

Next in the EC2 console copy the public IP:
Use the COPY icon on the left-hand side to copy the IP address:

Now, using the command line, navigate to the folder where the keypair is stored, and ssh into the newly created t2.micro VM. Paste the address and SSH:

```
$ ssh -i <your key file name> ubuntu@<Public IPv4 address of VM>
```

Now from the Ubuntu t2.micro instance launched in the same VPC as the RDS database, optionally, install the AWSCLI if wanting to work with AWS directly from the VM. ***It is not required.***

```
# installing the AWSCLI is optional
sudo apt update
sudo apt install awscli
aws configure
# provide ACCESS_KEY and SECRET_KEY
# Find your credentials on your existing VM with: "cat ~/.aws/credentials"
```

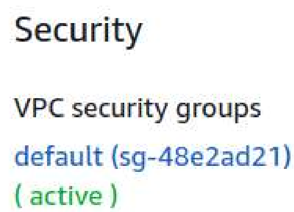
Next, install the mysql client to support connecting to the new RDS database:

```
# Install mysql client

sudo apt update

# sudo apt install mysql-client-core-5.7   # For old-versions of Ubuntu < 20.04
sudo apt install mysql-client-core-8.0     # for Ubuntu >= 20.04
```

Now customize the following command to point at your RDS database.

Navigate back into RDS in the AWS management console.
On the left hand-side select "Databases", then select "tcss462-562-instance-1".

It is necessary to configure the security group to allow the t2.micro to connect to the database. In the Connectivity & security tab, look under "Security" on the right:

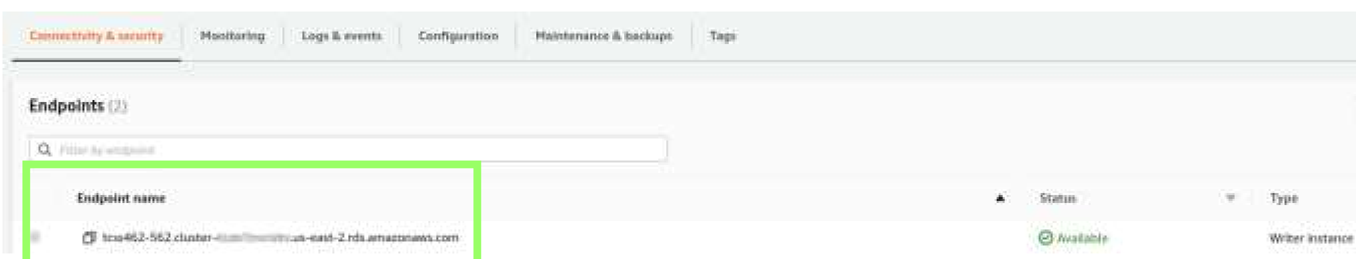


Click on the blue security group label to jump to the EC2 dashboard to edit network security settings.

In the Security editor, click the [Inbound rules] tab.
Click [Edit Inbound rules].
Click [Add Rule].
Select “MYSQL/Aurora”.
For the source, select “Anywhere-IPv4” to obtain the address range of “0.0.0.0/0”.
This enables any VM within the private VPC network to be able to connect to the database.
Hit [Save].

Now copy the database endpoint name which can be found by browsing the Aurora database in the Amazon RDS GUI.

Now navigate back to the **RDS service**.
On the left hand-side select “Databases”, then select the “tcss462-562” DB.
Look under the “Connectivity & security” tab,
Copy and paste the Endpoint name of the “Writer Instance” using the copy icon:



Now customize the mysql command to connect to your RDS database.
Replace <Database endpoint> and <your database password>.

```
mysql --host=<Database endpoint> --port=3306 --enable-cleartext-plugin --
user=tcss562 --password=<your database password>
```

Your Mysql client program should connect to the backend database.
The client program provides a command-line interface for working with the database server.

```
mysql: [Warning] Using a password on the command line interface can be insecure.
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 31
Server version: 8.0.23 Source distribution
```

```
Copyright (c) 2000, 2022, Oracle and/or its affiliates.

Oracle is a registered trademark of Oracle Corporation and/or its
affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql>
```

Try out the following commands.
MySQL can support multiple databases within a single server.
Display the databases on your RDS database:

```
show databases;
```

Now, create a new database:

```
create database TEST;
```

And check the list again:

```
show databases;
```

It is necessary to issue a "use" command for mysql to direct SQL queries to the database:

```
use TEST;
```

Next, create "mytable" to store data:

```
CREATE TABLE mytable (name VARCHAR(40), col2 VARCHAR(40), col3 VARCHAR(40));
```

Then display the list of known tables in the database:

```
show tables;
```

And describe the structure of the table:

```
describe mytable;
```

Now, try adding some data:

```
insert into mytable values ('fred','testcol2','testcol3');
```

And then check if it was inserted:

```
select * from mytable;
```

Help is available with the "help" command:

```
help
```

Exit mysql with:

```
\q
```

It may be useful to "stop" and "start" your t2.micro ec2 instance that has command-line access to the Amazon RDS database to support working with mysql. If no longer planning to use the ec2instance, **terminate it completely**. Note that "stopped" instances incur storage charges. New AWS accounts receive 30GB of EBS GP2 volume disk space for 1 year for free. After 1 year, the charge is 10¢/GB/month (gp2). The Ubuntu t2.micro requires 8GB of storage. The annual storage cost after the free introductory year goes to $9.60/year for a stopped instance with 1 x 8GB EBS volume. After 1 year, the t2.micro instance is no longer FREE, but the cost rises to 1.16¢/hour, ~27.8¢/day, ~$8.35/month, or ~$101.62/year for GP2, and slightly less for GP3.

6. Accessing Aurora Serverless Database from AWS Lambda

Next, on your development computer, create a directory called "saaf_rds".
Then under the new directory, clone the git repository:

```
git clone https://github.com/wlloyduw/saaf_rds_serverless.git
```

This project, provides a Lambda function that will interact with your Amazon RDS database. It requires "mytable" to have been created under the "TEST" database.
Optionally, it should be possible to create the database and table programmatically from Java if necessary.

Note the version of the SAAF framework in this project may not be up-to-date. For the term project, it is recommended to use this project only for reference purposes, and then to create a new project with the proper dependencies by cloning SAAF directly.

Once acquiring the project files, it is necessary to create a file called "db.properties".
There is a template provided. Copy this template to be named "db.properties" and edit this file to specify how to connect to your RDS database:

Find and edit this file:

```
cd saaf_rds_serverless/java_template/src/main/resources/
cp db.properties.empty db.properties
gedit db.properties
```

The **URL** should be specified as follows:

```
jdbc:mysql://<your database endpoint>:3306/TEST
```

Replace “<your database endpoint>” with the RDS database endpoint used to connect with mysql above. Be sure to add values for **password**, and **username** as well based on how your RDS database was initially configured.

Next, using NetBeans, perform a Clean Build of the Maven project to create the function’s jar file for deployment.

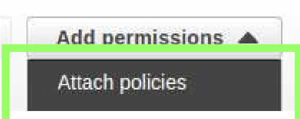
Now, create a new Lambda function. Refer to tutorial 4 for detailed instructions of creating Lambda functions. In the Create a Function Wizard, for **Permissions**, initially create the function using default permission settings.

Be sure to upload the **code source** under the **Code** tab as the newly created jar file.
Be sure to specify the **handler** under the **Code** tab and under **Runtime settings**.
The handler should be set to use the HelloMySQL class:
lambda.HelloMySQL::handleRequest

Next, adjust the security permissions.
Under the function’s **Configuration** tab, select **Permissions** from the left.

Click on the blue **Role name** link.
This will open the function’s security role in the IAM role editor.

On the right, select **Attach Policies** under the **Add permissions** button:



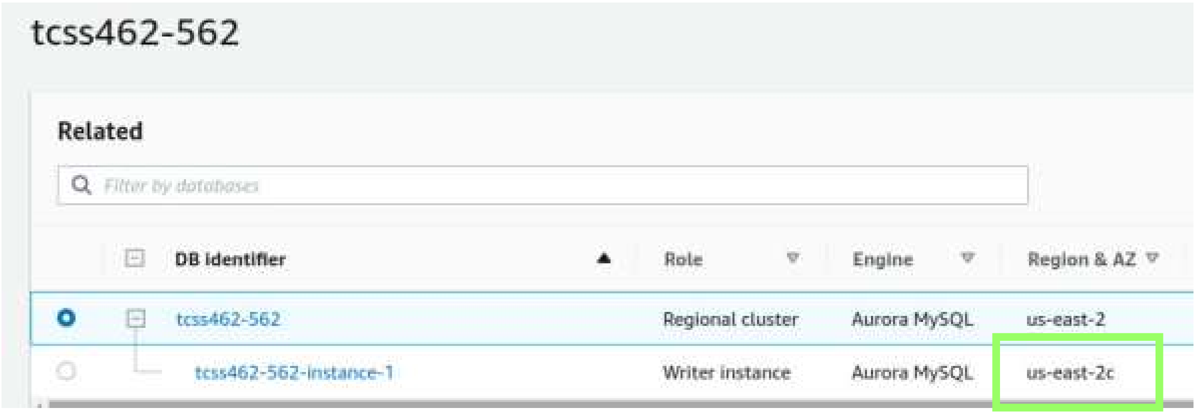
Then and attach the following policies one at a time:
AmazonRDSFullAccess
AWSLambdaVPCAccessExecutionRole

Then close the IAM role editor and go back to the AWS Lambda GUI.

Next, configure this Lambda function to run inside the same VPC and subnet as your RDS database. If not, there will be no connectivity between Lambda and the RDS database.

Under the “**Configuration**” tab, select **VPC** on the left. Now, click **Edit** to change the VPC configuration.
From the dropdown list, select the VPC that is labeled as “Default”. Next, specify the function’s subnet(s).
Every subnet has an availability zone listed on the far right.
Match the availability zone of your database with your serverless function.
For example, here the database is in us-east-2c, so the subnet should match us-east-2c.

To check which subnet (availability zone) your RDS serverless database is using, navigate to RDS.
On the left hand-side select “Databases”, then select your database “tcss462-562”.
The availability zone (AZ) of the database instance is shown clearly:



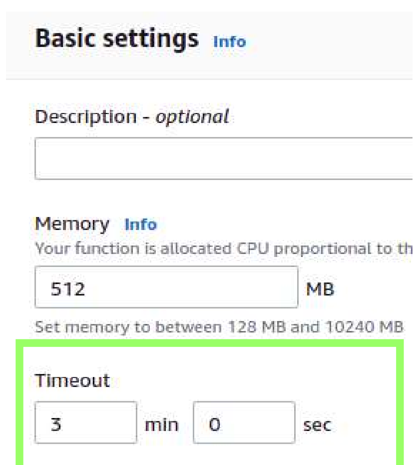
<u>IMPORTANT:</u> BE sure the subnet for your Lambda function matches the database instance. Select **<u>at least one subnet</u>** for your function that is shared with the RDS database. If using the Ohio region, expect subnets to be us-east-2a, us-east-2b, or us-east-2c.

Do not worry about this message if you receive it:

⚠ We recommend that you choose at least 2 subnets for Lambda to run your functions in high availability mode.

Select the default security group for the VPC settings and then SAVE the VPC settings.

Next, under the "**Configuration**" tab, under "**General configuration**" on the left: Set the Timeout to be greater than 3 minutes. Working with RDS for the term project, some queries may take several minutes. For tutorial 6, a long timeout is not required.



Your Lambda function should be ready to use.

Next configure callservice.sh to use the name of your newly deployed Lambda function. Use the AWS CLI to invoke the function directly. **Using the AWS CLI to invoke Lambda directly is recommended because of the potential for long timeouts when executing long queries with RDS Aurora Serverless.**

Now modify callservice.sh under java_template/test to invoke your new Lambda function to write names to your specified in the db.properties file: database=TEST table=mytable

7. After modifying callservice.sh, test your function with the time command as follows:

```
time ./callservice.sh
```

a) What is the "real" time reported for your Lambda function **in seconds** for the first call?
b) What is the value of the newcontainer attribute?
Does this indicate your Lambda function is warm? (YES/NO)
A "1" indicates a **COLD** container.

Run your function again with the time command.
c) How long does a second call take **in seconds**?

Now rerun the script several more times (3x-5x).

Each call to HelloMySQL will append a row to the table with the provided name.
The function queries the names stored in the table using a select SQL query.
The names are output in JSON using the "names" array.
Check how this is done in the HelloMySQL.java class in the handleRequest() method.

It may be necessary to troubleshoot your Lambda function's connectivity to RDS.
From the Monitoring tab of Lambda, use the [View logs in CloudWatch] button:

8. For question #8, modify the Lambda service to return the MySQL version as a response object parameter. Add a getter/setter to Response.java for "mysqlversion". Then, add an additional SQL query to obtain the version of MySQL. Use the following SQL query:

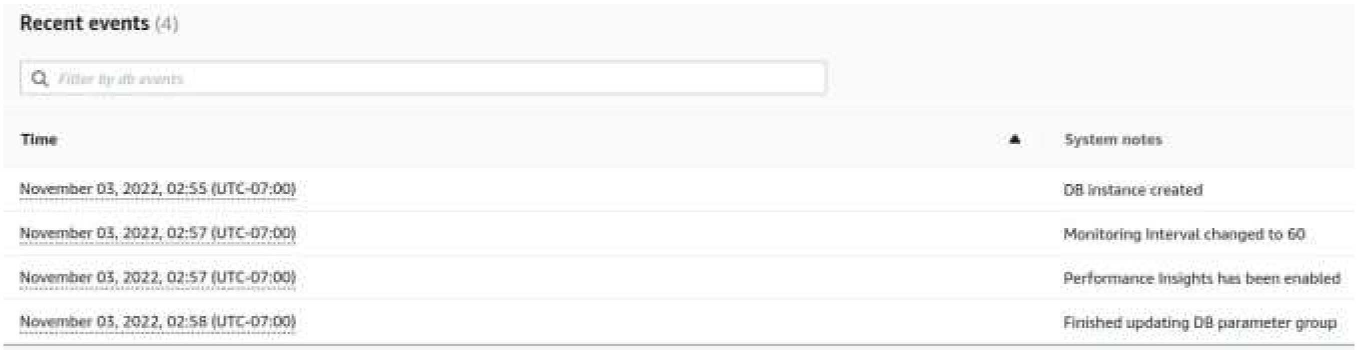
```
select version() as version;
```

With a result set, read the value from the column, and add it to the Response object.

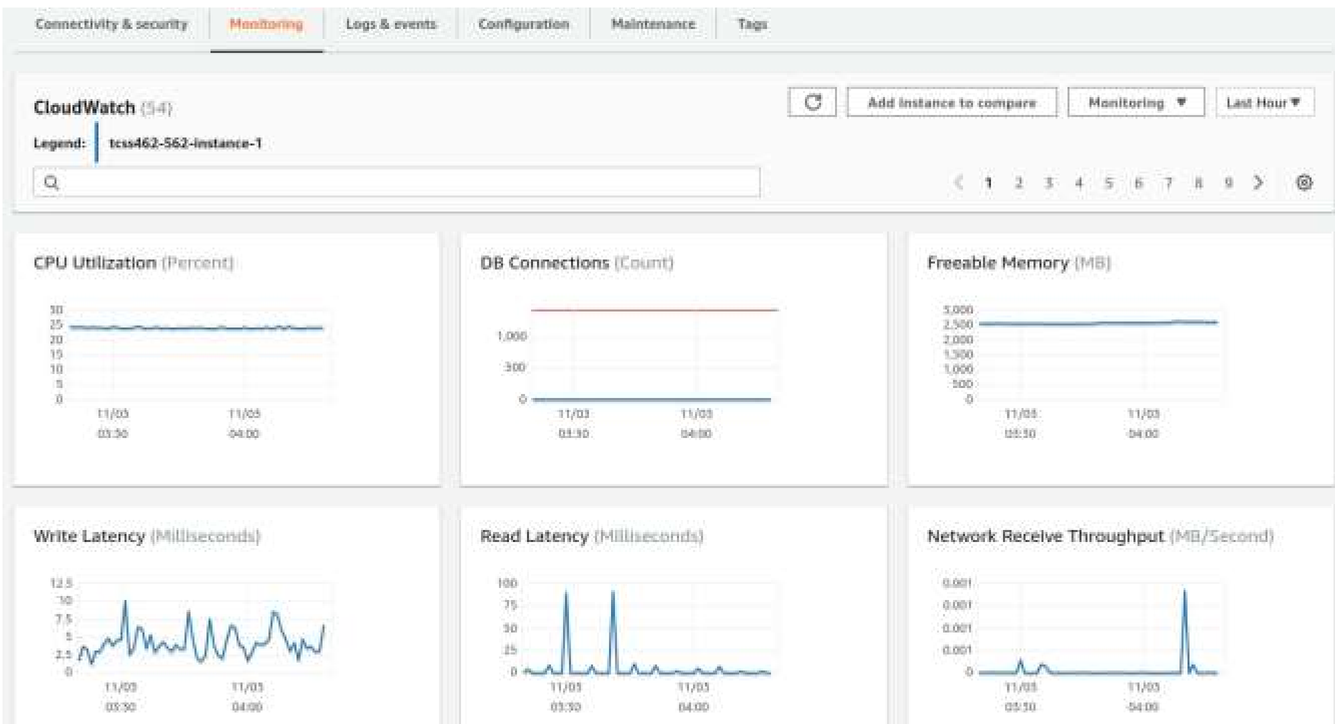
Now, using callservice.sh, run the service. Capture the complete output from the terminal as the answer for #8.

Aurora Serverless scales down to the minimum number of ACUs specified for the database after ~3 minutes of inactivity.

Database events are reported under the “Logs & events” tab on the RDS database page. From the log state changes can be monitored:



In RDS, under monitoring, CloudWatch graphs show RDS database resource utilization:



7. Stopping the database for up to 7 days

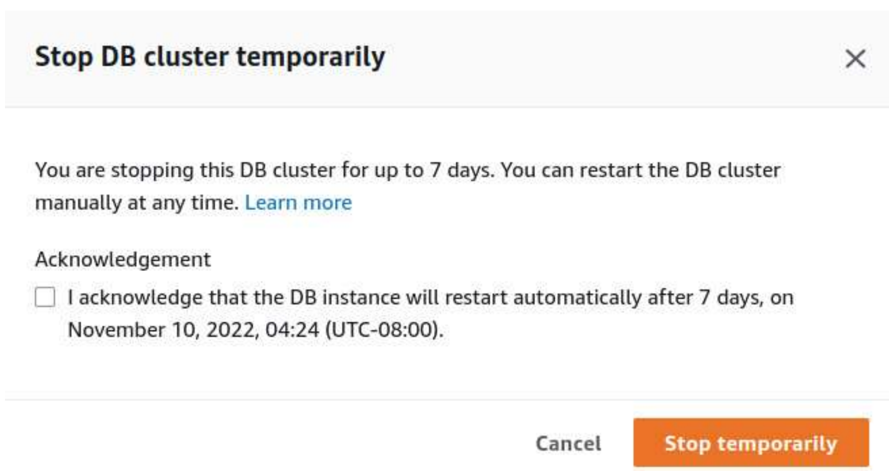
Amazon RDS Aurora Serverless v2 databases have always on charges.
Databases configured to have 0.5 ACUs will cost 6c/hour, $1.44/day, $10.08/week, or $43.80/month if kept running with 0.5 ACUs. ** **THIS IS VERY EXPENSIVE AND WILL DRAIN YOUR CREDITS FAST ** !!!**

“Serverless” databases can be paused for up to 7 days to suspect always-on charges.
This allows the database to remain inactive in the account where only data charges will apply.
WARNING !!! ** After 7 days, the database will automatically restart and continue to incur charges !!!

Now, practice temporarily stopping the database cluster.
From, RDS, select your database cluster, not the instance, but the whole cluster.

Then, select “Stop temporarily” from the Actions button drop-down.

A dialog box will now warn you how the database can only be suspended for 7 days.
It will then resume and start charging your account:



If needing to stop the database for more than a week, it will be necessary to re-stop it.
The recommended best practice, however, is to **DELETE THE DATABASE,** and recreate the database later after a week. It should be possible to use database backups to restore data and schemas.

Please review the documentation for more information on database backup and recovery:
https://docs.aws.amazon.com/AmazonRDS/latest/AuroraUserGuide/BackupRestoreAurora.html

9. Question 9
a. How long can an Amazon Aurora serverless database be temporarily stopped before it automatically restarts and starts charging the user up to $43.80/month at 0.5 ACUs ?

b. What is the best practice if an Amazon Aurora serverless database must be stopped for a very long time greater than Amazon's allowed temporary stop duration?

Submitting Tutorial #6

Create a PDF file using Google Docs, MS Word, or OpenOffice. Capture answers to questions 1-8 and submit the PDF on Canvas.

Be sure to terminate EC2 instances, and **DELETE** your Aurora RDS database once completing the tutorial.

DON'T JUST STOP THE DATABASE - - - DELETE IT ENTIRELY.
USE THE "DELETE" ACTION TO DO SO.

Related Articles providing additional background:

Article describing use cases for when to use the SQLite database:
https://www.sqlite.org/whentouse.html

Using Aurora Severless v2 database:
https://docs.aws.amazon.com/AmazonRDS/latest/AuroraUserGuide/aurora-serverless-v2.html

Blog Article: No, AWS, Aurora Serverless v2 Is Not Serverless:
https://www.lastweekinaws.com/blog/no-aws-aurora-serverless-v2-is-not-serverless/

Research paper on AWS Aurora – Cloud Native relational database with built in read replication up to 15-nodes:
https://media.amazonwebservices.com/blog/2017/aurora-design-considerations-paper.pdf

Key Aurora Serverless v2 limitation from:
https://docs.aws.amazon.com/AmazonRDS/latest/AuroraUserGuide/aurora-serverless-v2.how-it-works.html#aurora-serverless-v2.how-it-works.scaling

> **Note**
> Currently, Aurora Serverless v2 writers and readers don't scale all the way down to zero ACUs. Idle Aurora Serverless v2 writers and readers can scale down to the minimum ACU value that you specified for the cluster.
>
> That behavior is different than Aurora Serverless v1, which can pause after a period of idleness, but then takes some time to resume when you open a new connection. When your DB cluster with Aurora Serverless v2 capacity isn't needed for some time, you can stop and start clusters as with provisioned DB clusters. For details about stopping and starting clusters, see Stopping and starting an Amazon Aurora DB cluster.