DynamoDB Practical Workshop

January 11, 2018 Version

Overview

This lab document is meant to provide some practical exercises of implementing design patters using Amazon DynamoDB. Here's some of what you'll find:

List of exercises:

Who is it for?

- Developers looking for recommendations
- Database professionals looking for NoSQL and DynamoDB details

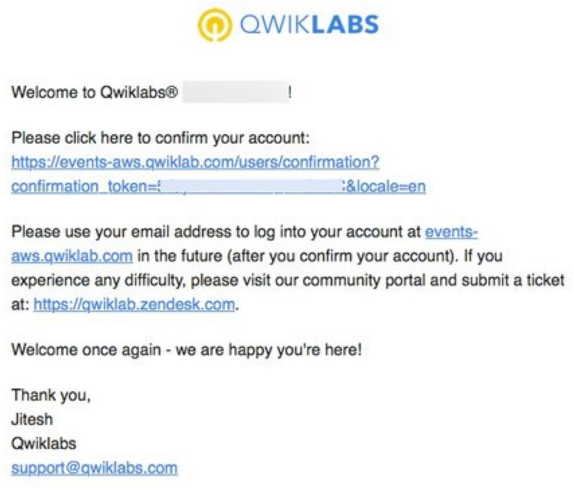
Requirements

- Basic experience with AWS
- Basic knowledge on DynamoDB
- Some experience with Python

Preparation

Step 1 - Starting the Qwiklab environment

1. Open a new Tab and open https://events-aws.qwiklab.com/
2. Create your user account using your email address registered for the re:Invent
3. You will receive an email from qwiklab.com to confirm your new account:



QWIKLABS

Welcome to Qwiklabs® [redacted] !

Please click here to confirm your account:
https://events-aws.qwiklab.com/users/confirmation?confirmation_token=[redacted]&locale=en

Please use your email address to log into your account at events-aws.qwiklab.com in the future (after you confirm your account). If you experience any difficulty, please visit our community portal and submit a ticket at: https://qwiklab.zendesk.com.

Welcome once again - we are happy you're here!

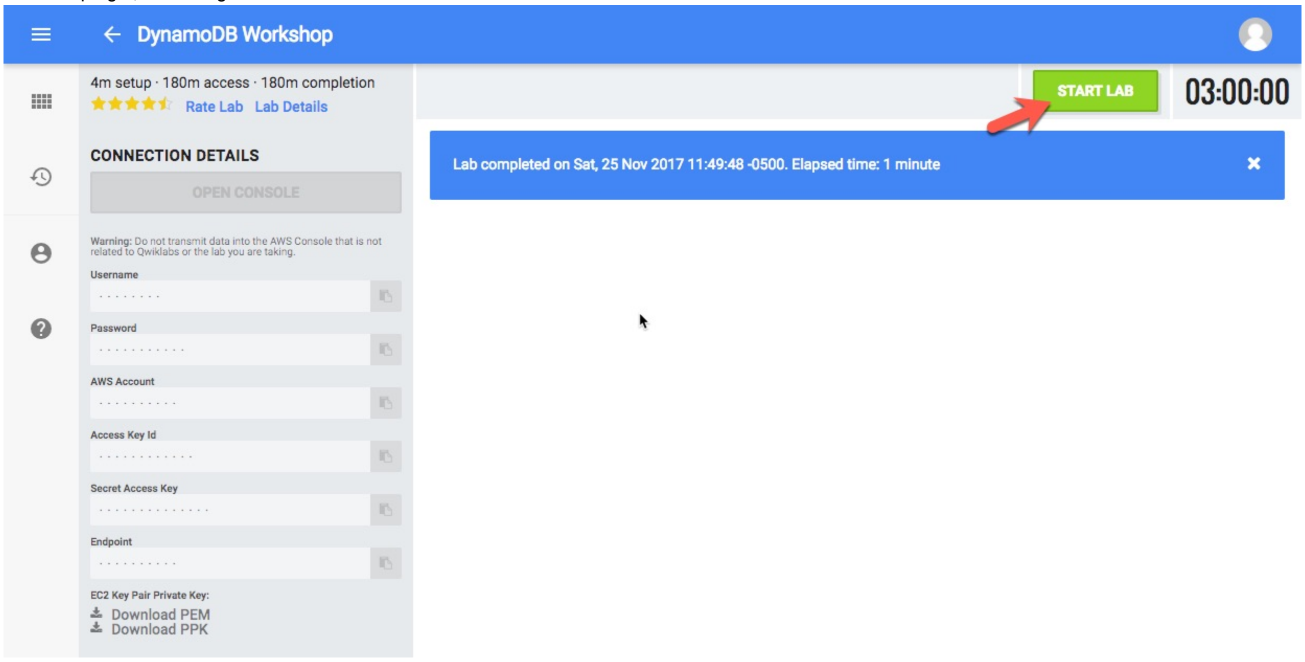
Thank you,
Jitesh
Qwiklabs
support@qwiklabs.com

Figure 1 - Qwiklabs confirmation email

4. Login to Qwiklabs using your email address and password

5. After login, you will see the classes "In Session"
6. Click on "DynamoDB Workshop Class"
7. In the new page, select the "DynamoDB Workshop"

8. On the top right, click the green button "Start Lab"



Lab completed on Sat, 25 Nov 2017 11:49:48 -0500. Elapsed time: 1 minute

Warning: Do not transmit data into the AWS Console that is not related to Qwiklabs or the lab you are taking.

Username

Password

AWS Account

Access Key Id

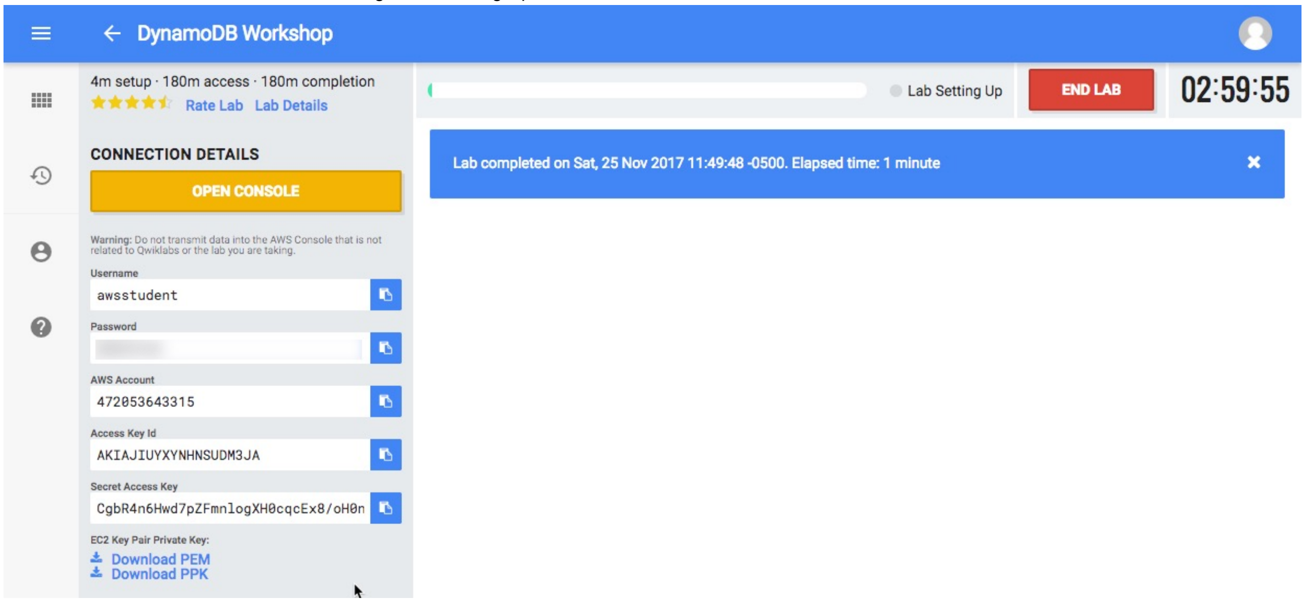
Secret Access Key

Endpoint

EC2 Key Pair Private Key:
Download PEM
Download PPK

Figure 2 - Start Lab

9. The Qwiklab will start. It will show the message "Lab Setting Up"



Lab completed on Sat, 25 Nov 2017 11:49:48 -0500. Elapsed time: 1 minute

Warning: Do not transmit data into the AWS Console that is not related to Qwiklabs or the lab you are taking.

Username
awsstudent

Password

AWS Account
472053643315

Access Key Id
AKIAJIUYXYNHNSUDM3JA

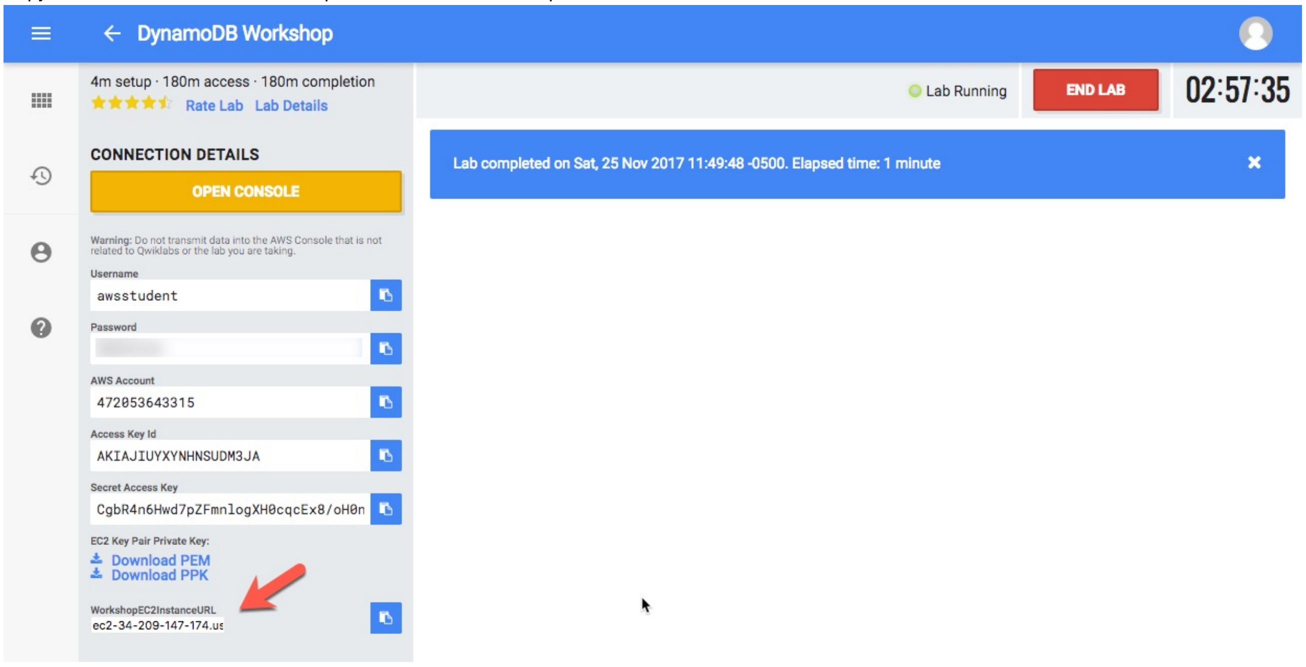
Secret Access Key
CgbR4n6Hwd7pZFmnlogXH0cqcEx8/oH0n

EC2 Key Pair Private Key:
Download PEM
Download PPK

Figure 3 - Lab Setting Up

10. Click "Download PEM" or "Download PPK". If you are using a MacOS you can choose the PEM file, if you are using Windows you are going to use the PPK file.

11. Copy the EC2 instance URL "WorkshopEC2InstanceURL" to setup the connection later


DynamoDB Workshop

4m setup · 180m access · 180m completion
Rate Lab Lab Details

Lab Running END LAB 02:57:35

Lab completed on Sat, 25 Nov 2017 11:49:48 -0500. Elapsed time: 1 minute

CONNECTION DETAILS

OPEN CONSOLE

Warning: Do not transmit data into the AWS Console that is not related to Qwiklabs or the lab you are taking.

Username
awsstudent

Password
[redacted]

AWS Account
472053643315

Access Key Id
AKIAJIUYXYNHNSUDM3JA

Secret Access Key
CgbR4n6Hwd7pZFmnlogXH0cqcEx8/oH0n

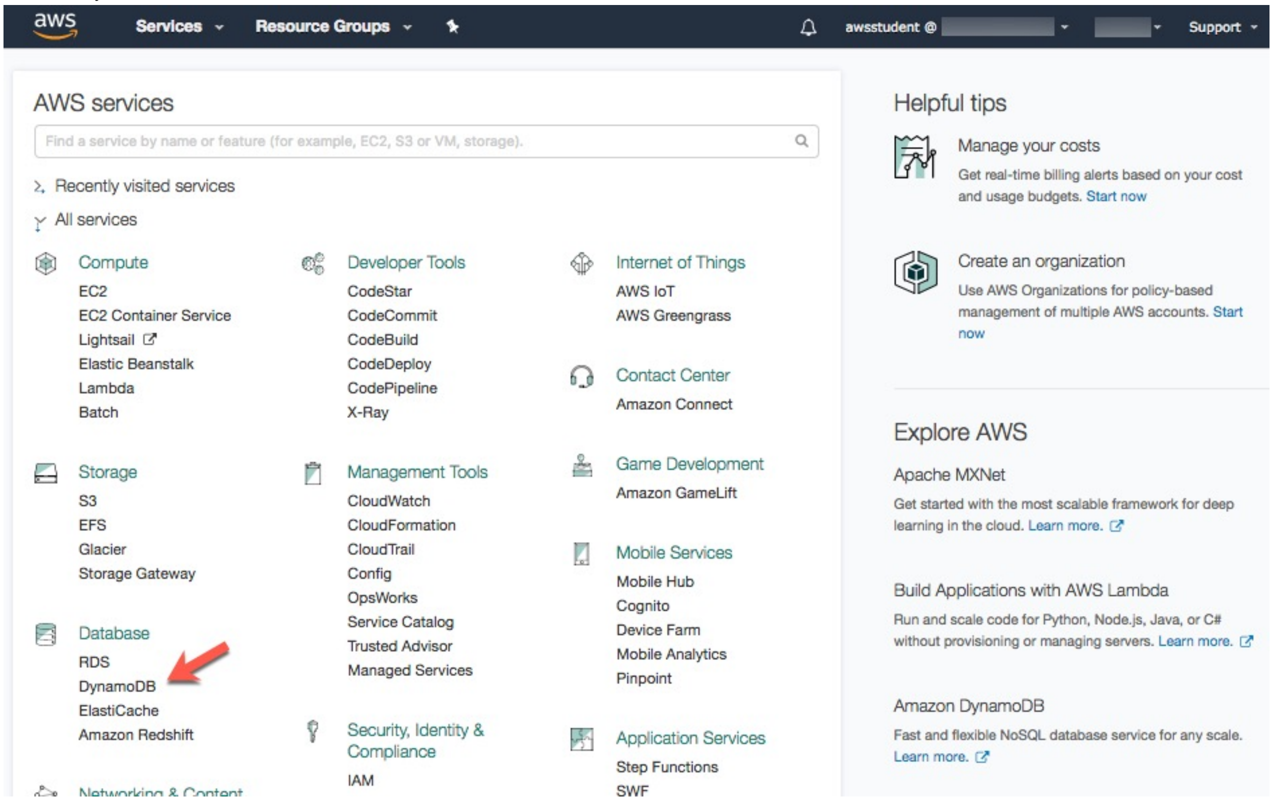
EC2 Key Pair Private Key:
Download PEM
Download PPK

WorkshopEC2InstanceURL
ec2-34-209-147-174.us

Figure 4 - Copy WorkshopEC2InstanceURL

Step 2 - Open the AWS console

1. On the left bar, click the orange button "Open Console".
2. Login to the AWS Console using the Username (awsstudent) and Password from the Qwiklabs page.
3. Verify the AWS region is set to "N Virginia" on the top right corner.
4. Click the DynamoDB service


aws Services Resource Groups awsstudent @ [redacted] [redacted] Support

AWS services

Find a service by name or feature (for example, EC2, S3 or VM, storage).

Recently visited services

All services

Compute
EC2
EC2 Container Service
Lightsail
Elastic Beanstalk
Lambda
Batch

Developer Tools
CodeStar
CodeCommit
CodeBuild
CodeDeploy
CodePipeline
X-Ray

Internet of Things
AWS IoT
AWS Greengrass

Contact Center
Amazon Connect

Storage
S3
EFS
Glacier
Storage Gateway

Management Tools
CloudWatch
CloudFormation
CloudTrail
Config
OpsWorks
Service Catalog
Trusted Advisor
Managed Services

Game Development
Amazon GameLift

Mobile Services
Mobile Hub
Cognito
Device Farm
Mobile Analytics
Pinpoint

Database
RDS
DynamoDB
ElastiCache
Amazon Redshift

Security, Identity & Compliance
IAM

Application Services
Step Functions
SWF

Networking & Content

Helpful tips

Manage your costs
Get real-time billing alerts based on your cost and usage budgets. Start now

Create an organization
Use AWS Organizations for policy-based management of multiple AWS accounts. Start now

Explore AWS

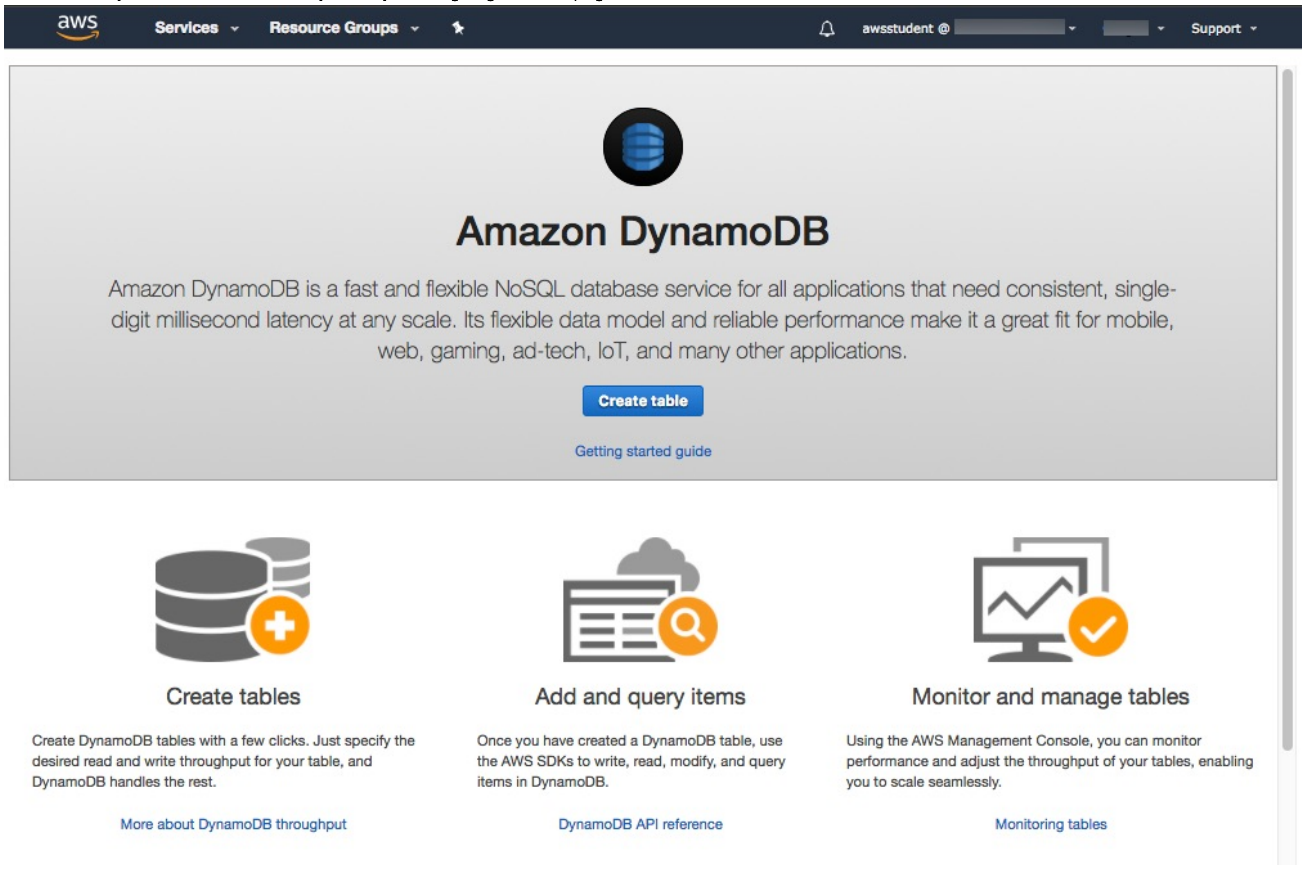
Apache MXNet
Get started with the most scalable framework for deep learning in the cloud. Learn more.

Build Applications with AWS Lambda
Run and scale code for Python, Node.js, Java, or C# without provisioning or managing servers. Learn more.

Amazon DynamoDB
Fast and flexible NoSQL database service for any scale. Learn more.

Figure 5 - AWS Console

5. There is no DynamoDB table created yet. So you are going to see a page like below.



Amazon DynamoDB is a fast and flexible NoSQL database service for all applications that need consistent, single-digit millisecond latency at any scale. Its flexible data model and reliable performance make it a great fit for mobile, web, gaming, ad-tech, IoT, and many other applications.

Create DynamoDB tables with a few clicks. Just specify the desired read and write throughput for your table, and DynamoDB handles the rest.

Once you have created a DynamoDB table, use the AWS SDKs to write, read, modify, and query items in DynamoDB.

Using the AWS Management Console, you can monitor performance and adjust the throughput of your tables, enabling you to scale seamlessly.

Figure 6 - DynamoDB

Step 3 - Connect to the EC2 instance

Using MacOS:

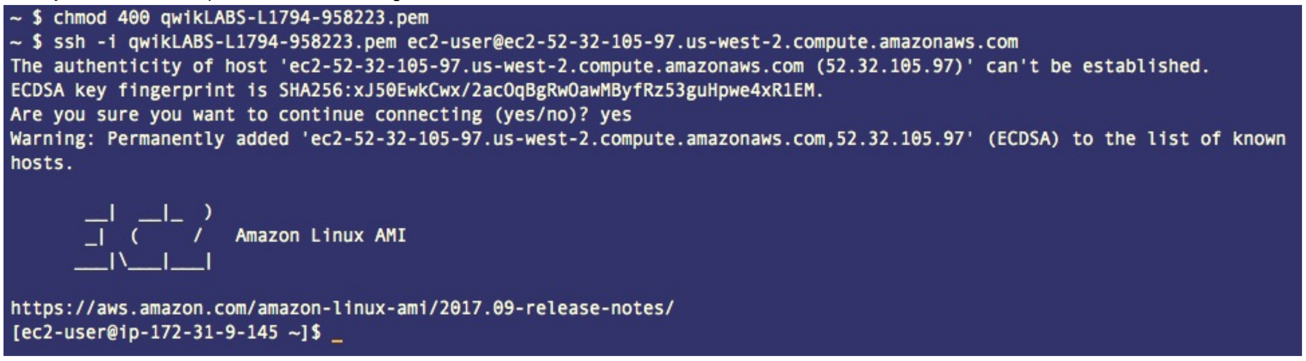
1. Go to the folder where you download the PEM file.
2. Use the chmod command to make sure that your private key file isn't publicly viewable. For example, if the name of your private key file is my-key-pair.pem, use the following command:

```
chmod 400 /path/my-key-pair.pem
```

3. Use the ssh command to connect to the instance. You specify the private key (.pem) file and ec2-user@public_dns_name. The user name is ec2-user. The public_dns_name is the EC2 URL you copied from the Qwiklab console.

```
ssh -i /path/my-key-pair.pem ec2-user@[public_dns_name]
```

4. Enter yes. You see a response like the following.

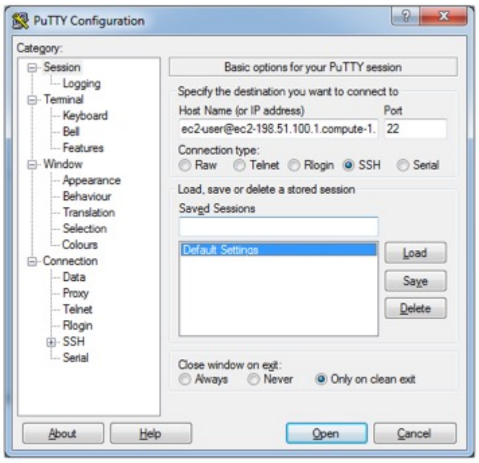


```
~ $ chmod 400 qwikLABS-L1794-958223.pem
~ $ ssh -i qwikLABS-L1794-958223.pem ec2-user@ec2-52-32-105-97.us-west-2.compute.amazonaws.com
The authenticity of host 'ec2-52-32-105-97.us-west-2.compute.amazonaws.com (52.32.105.97)' can't be established.
ECDSA key fingerprint is SHA256:xJ50EwkCwx/2acOqBgRwOawMByfRz53guHpwe4xR1EM.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'ec2-52-32-105-97.us-west-2.compute.amazonaws.com,52.32.105.97' (ECDSA) to the list of known
hosts.

       __|  __|_  )
       _|  (     /   Amazon Linux AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-ami/2017.09-release-notes/
[ec2-user@ip-172-31-9-145 ~]$ _
```

Figure 7 - Connecting to EC2 instance using SSH

Using Windows OS:

1. Download and install putty - http://www.chiark.greenend.org.uk/~sgtatham/putty/
2. Start PuTTY (from the Start menu, choose All Programs > PuTTY > PuTTY)
3. In the Category pane, choose Session and complete the following fields:
   a. In the **Host Name** box, enter ec2-user@public_dns_name. The public_dns_name is the EC2 URL you copied from the Qwiklab console.
   b. Ensure Port is 22.
   c. Under Connection type, select **SSH**.



Basic options for your PuTTY session

Specify the destination you want to connect to

Host Name (or IP address): ec2-user@ec2-198.51.100.1.compute-1.
Port: 22

Connection type: Raw Telnet Rlogin [✓ SSH] Serial

Load, save or delete a stored session

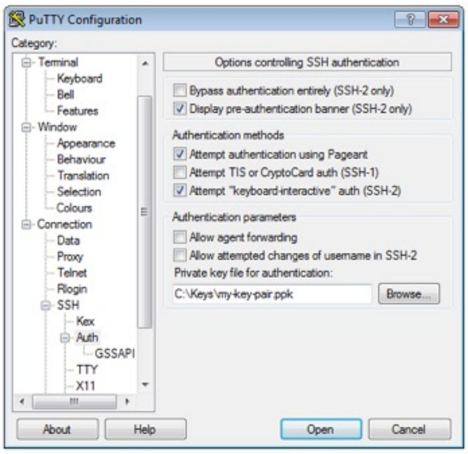
Saved Sessions

Default Settings

Close window on exit: Always Never [✓ Only on clean exit]

Figure 8 - Using putty to connect to EC2 instance

4. In the Category pane, expand Connection, expand SSH, and then choose Auth. Complete the following:
   a. Choose Browse.
   b. Select the **.ppk** file that you generated for your key pair, and then choose Open.
   c. Click “Connection”, on the right hand pane, set “Seconds between keepalives” value to 20”
   d. Save the session information for future use. Choose Session in the Category tree, enter a name for the session in Saved Sessions, and then choose Save.
   e. Choose Open to start the PuTTY session.



Options controlling SSH authentication

[ ] Bypass authentication entirely (SSH-2 only)
[✓] Display pre-authentication banner (SSH-2 only)

Authentication methods

[✓] Attempt authentication using Pageant
[ ] Attempt TIS or CryptoCard auth (SSH-1)
[✓] Attempt "keyboard-interactive" auth (SSH-2)

Authentication parameters

[ ] Allow agent forwarding
[ ] Allow attempted changes of username in SSH-2

Private key file for authentication: C:\Keys\my-key-pair.ppk

Figure 9 - Openning the PuTTy session

f. Choose Yes. A window opens and you are connected to your instance

Step 4 - Check the Python installation

Run the following command to check Python on your EC2 instance:

```
python --version
```

> Python 2.7.12

Step 5 - Check boto3 installation

Boto3 is the Amazon Web Services (AWS) Software Development Kit (SDK) for Python, which allows Python developers to write software that makes use of AWS services.

In the command line, open the python console and enter the following Python code lines:

```
python
```

```
import boto3
ddb = boto3.client('dynamodb')
ddb.describe_limits()
```

You will see the following result:

> {u'TableMaxWriteCapacityUnits': 20000, u'TableMaxReadCapacityUnits': 20000, u'AccountMaxReadCapacityUnits': 20000, 'ResponseMetadata': {'RetryAttempts': 0, 'HTTPStatusCode': 200, 'RequestId': 'S0HV25PJ3JP3DQKJSK90IFQ99BVV4KQNSO5AEMVJF66Q9ASUAAJG', 'HTTPHeaders': {'x-amzn-requestid': 'S0HV25PJ3JP3DQKJSK90IFQ99BVV4KQNSO5AEMVJF66Q9ASUAAJG', 'content-length': '143', 'server': 'Server', 'connection': 'keep-alive', 'x-amz-crc32': '3868495339', 'date': 'Fri, 10 Nov 2017 18:33:57 GMT', 'content-type': 'application/x-amz-json-1.0'}}, u'AccountMaxWriteCapacityUnits': 20000}

To close Python console, type:

```
quit()
```

Step 6 - Check the content of the workshop folder

Go to the workshop folder and run the ls command:

```
cd /home/ec2-user/workshop
ls -l .
```

You will see the following content:

Python code:

- ddbreplica_lambda.py
- load_employees.py
- load_tlog_parallel.py
- load_tlog.py
- query_city_dept.py
- query_employees.py
- query_managers_gsi.py
- query_managers_table.py
- scan_tlog_parallel.py
- scan_tlog_simple.py
- update_employees.py

JSON:

- gsi_city_dept.json
- gsi_manager.json
- iam-role-policy.json
- iam-trust-relationship.json

Run the ls command to show the sample data files:

```
ls -l ./data
```

./data

- employees.csv
- logfile_medium1.csv
- logfile_medium2.csv
- logfile_small1.csv
- logfile_stream.csv

Step 7 - Check the files format and content

You will be working with two different data contents during this lab: (1)Server logging data and (2)Employees data.

The log files have the following structure:

- requestid (number)
- host (string)
- date (string)
- hourofday (number)
- timezone (string)
- method (string)
- url (string)
- responsecode (number)
- bytessent (number)
- useragent (string)

To view a sample record in the file, execute:

```
head ./data/logfile_small1.csv -n 1
```

Sample log record:

> 1,66.249.67.3,2017-07-20,20,GMT-0700,GET,"/gallery/main.php?g2_controller=exif.SwitchDetailMode&g2_mode=detailed&g2_return=%2Fgallery%2Fmain.php%3Fg2_itemId%3D15741&g2_returnName=photo",302,5,"Mozilla/5.0 (compatible; Googlebot/2.1; +http://www.google.com/bot.html)"

The employees files have the following structure:

- employeeid (number)

- name (string)
- title (string)
- dept (string)
- city (string)
- state (string)
- dob (string)
- hire_date (string)
- previous title (string)
- previous title end date (string)
- is a manager (string), 1 for manager employees, non-existent for others

To view a sample record in the file, execute:

```
head ./data/employees.csv -n 1
```

Sample employee record:

> 1,Onfroi Greeno,Systems Administrator,Operation,Portland,OR,1992-03-31,2014-10-24,Application Support Analyst,2014-04-12

Step 8 - Preload the items for the scan exercise

In the exercise 2 we will discuss table scan and the alternatives. In this step, you are going to load the table with 1 milliton rows in preparation for the exercise.

Run the command to create a new table:

```
aws dynamodb create-table --table-name tlog_scan \
--attribute-definitions AttributeName=requestid,AttributeType=N AttributeName=gsi_responsecode_hk,AttributeType=N AttributeNam
--key-schema AttributeName=requestid,KeyType=HASH \
--provisioned-throughput ReadCapacityUnits=5000,WriteCapacityUnits=5000 \
--global-secondary-indexes  IndexName=gsi_responsecode,\
KeySchema=["{AttributeName=gsi_responsecode_hk,KeyType=HASH},{AttributeName=gsi_responsecode_sk,KeyType=RANGE}"],\
Projection="{ProjectionType=KEYS_ONLY}",\
ProvisionedThroughput="{ReadCapacityUnits=3000,WriteCapacityUnits=5000}"
```

This command will create a new table and one GSI with the following definition:

Table: tlog_scan

- Attribute: requestid
- Key Type: Hash
- Table RCU = **5000**
- Table WCU = **5000**

Run the command to wait until the table becomes Active:

```
aws dynamodb wait table-exists --table-name tlog_scan
```

Populate the table

Run the following command to load the server logs data into the tlog_scan table. It will load 78688 rows to the table.

```
python load_tlog_parallel.py tlog_scan
```

> total rows 1000000 in 514.663530111 seconds

Exercise 1: DynamoDB Capacity Units & Partitioning

In this exercise you will load data into DynamoDB tables that are provisioned with different Write/Read capacity units, and compare the load times. You will be using the “log” data.

Step 1 – Create the DynamoDB table

Run the following AWS CLI command to create the first DynamoDB table called 'tlog':

```
aws dynamodb create-table --table-name tlog \
--attribute-definitions AttributeName=requestid,AttributeType=N AttributeName=host,AttributeType=S \
--key-schema AttributeName=requestid,KeyType=HASH \
--provisioned-throughput ReadCapacityUnits=5,WriteCapacityUnits=5 \
--global-secondary-indexes  IndexName=host-requestid-gsi,\
KeySchema=["{AttributeName=host,KeyType=HASH},{AttributeName=requestid,KeyType=RANGE}"],\
Projection="{ProjectionType=INCLUDE,NonKeyAttributes=['bytessent']}",\
ProvisionedThroughput="{ReadCapacityUnits=5,WriteCapacityUnits=5}"
```

The table you just created will have the following structure.

Table:

- Name: tlog
- Partition Key: requestid
- Table RCU = **5**
- Table WCU = **5**

GSI:

- Name: host-requestid-gsi
- Partition Key: host
- Sort Key: requestid
- Projection Include: bytessent
- GSI RCU = **5**
- GSI WCU = **5**

Run the command to wait until the table becomes Active:

```
aws dynamodb wait table-exists --table-name tlog
```

You can run the following command to get only the table status:

```
aws dynamodb describe-table --table-name tlog | grep TableStatus
```

Step 2 - Load sample data into the table

Now that you have the table created, you can load some sample data running the Python script:

```
python load_tlog.py tlog ./data/logfile_small1.csv
```

Parameters in the above command:
1) Table Name = **tlog**
2) File Name = **logfile_small1.csv**

The output should be like:

```
row: 100 in 0.790903091431
row: 200 in 0.746693134308
row: 300 in 0.797533035278
row: 400 in 0.695877075195
row: 500 in 0.715097904205
RowCount: 500, Total seconds: 3.79715394974
```

Step 3 - Load a larger file to compare the execution time

Run the script again but at this time with a larger input data file:

```
python load_tlog.py tlog ./data/logfile_medium1.csv
```

Parameters:
1) Table Name = **tlog**
2) File Name = **logfile_medium1.csv**

The output should be like:

```
row: 100 in 0.490761995316
row: 200 in 0.449488162994
row: 300 in 0.450911045074
row: 400 in 0.450123071671
row: 500 in 0.445238828659
row: 600 in 0.58230304718
row: 700 in 0.581787824631
row: 800 in 0.595230102539
row: 900 in 0.588124990463
row: 1000 in 0.589934110641
row: 1100 in 0.588397979736
row: 1200 in 5.44571805
row: 1300 in 19.9914531708
row: 1400 in 20.033246994
row: 1500 in 19.9791162014
row: 1600 in 20.0433659554
row: 1700 in 19.9400119781
row: 1800 in 20.002464056
row: 1900 in 19.998513937
row: 2000 in 20.0029530525
RowCount: 2000, Total seconds: 171.298333883
```

After loading some rows, the load time increased. In the sample output, the time increased from less than 1 sec to around 20 seconds.

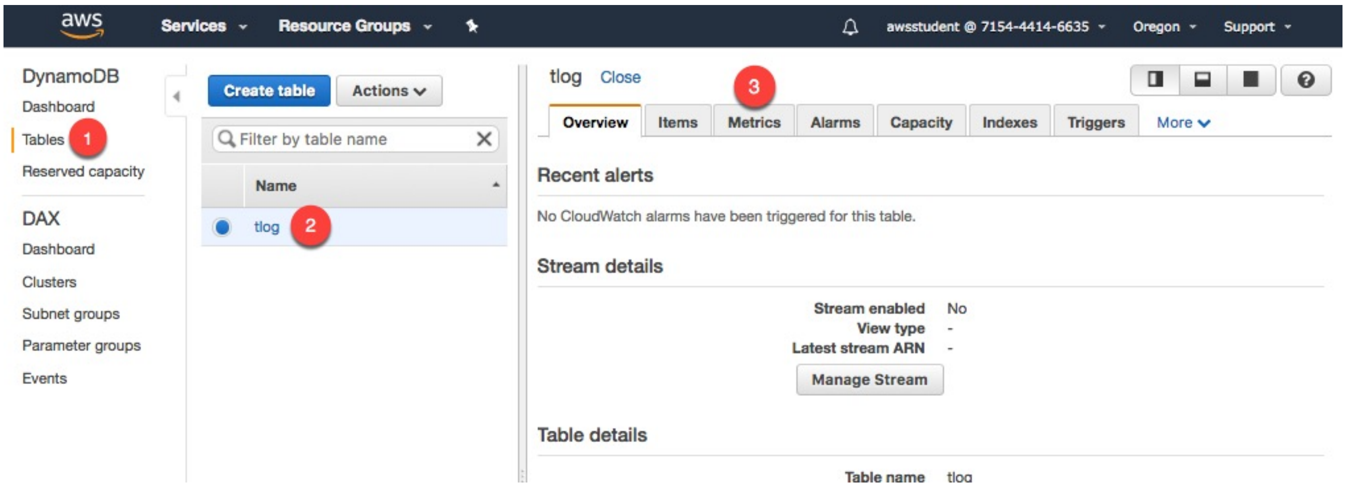
Question: How long did it take for increasing the capacity? And why?

Step 4 - View the CloudWatch metrics on your table

Open the browser tab in the AWS console. If you don't have the AWS console opened, see the step 2 of the Preparation section above.

Refresh the page if necessary to be able to see the left menu.

On the left menu, click Tables, on the table click "Metrics".



Recent alerts

No CloudWatch alarms have been triggered for this table.

Stream details

Stream enabled	No
View type	-
Latest stream ARN	-

Table details

Table name	tlog

Figure 10 - Open the CloudWatch metrics for the table

You see the metrics like the sample below:

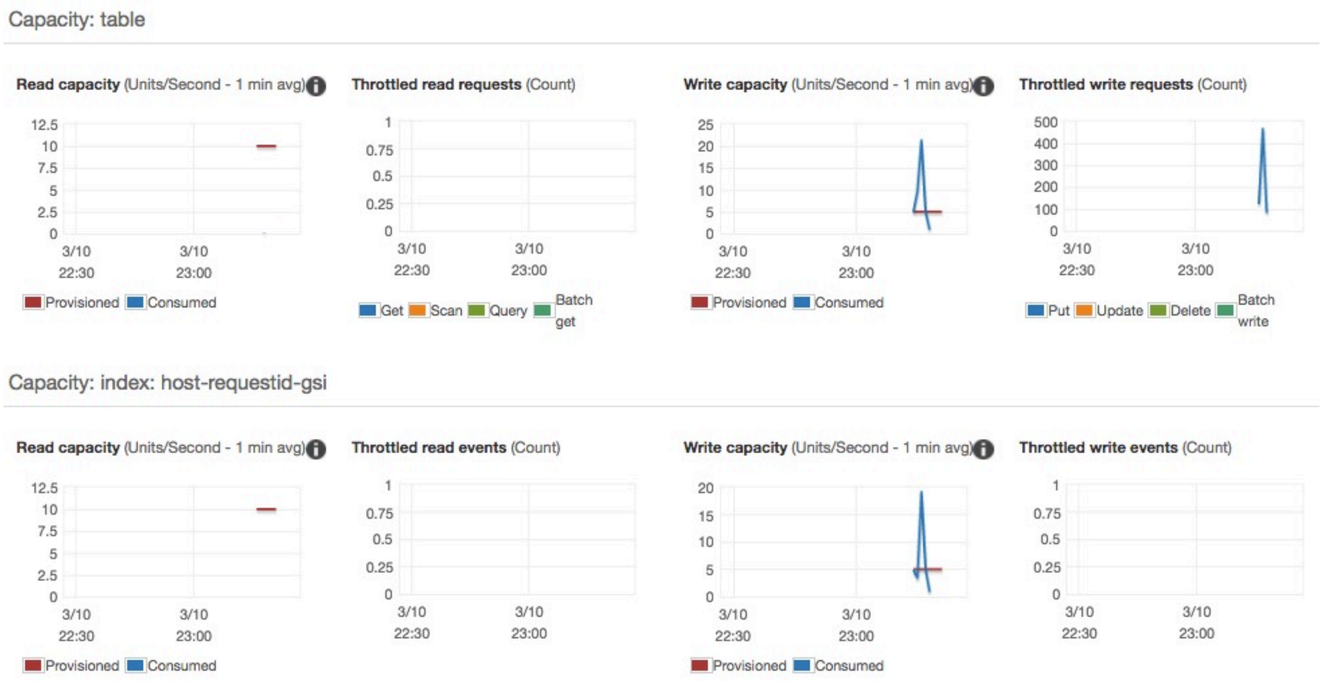


Figure 11 - DynamoDB metrics for the table tlog

Question: Why there are throttling events on the table and there are not on the GSI?

Step 5 – Increase the capacity

Run the following AWS CLI command to increase the **WCU** and **RCU** from 5 to 100.

```
aws dynamodb update-table --table-name tlog \
--provisioned-throughput ReadCapacityUnits=100,WriteCapacityUnits=100
```

Run the command to wait until the table becomes Active.

```
aws dynamodb wait table-exists --table-name tlog
```

Question: How long did it take for increasing the capacity?

Step 6 - Load more data with the new capacity

After the update, run the Python script again to populate the table with file **logfile_medium2.csv** with the same number of rows of the previous run. You will see that at this time the execution will be faster.

```
python load_tlog.py tlog ./data/logfile_medium2.csv
```

The output should show a result like:

```
row: 100 in 0.678274869919
row: 200 in 0.637241125107
row: 300 in 0.623446941376
row: 400 in 0.666973114014
row: 500 in 0.694450139999
row: 600 in 0.643283843994
row: 700 in 0.644812107086
row: 800 in 0.63000702858
row: 900 in 0.76971411705
row: 1000 in 0.684530973434
row: 1100 in 0.667228937149
row: 1200 in 0.66502404213
row: 1300 in 0.681458950043
row: 1400 in 0.644996166229
row: 1500 in 0.657227993011
row: 1600 in 0.650546073914
row: 1700 in 0.643900156021
row: 1800 in 0.62757897377
row: 1900 in 0.646264076233
row: 2000 in 0.701603889465
RowCount: 2000, Total seconds: 13.3077070713
```

Note: With the new capacity the load time was consistent for the whole dataset.

Step 7 – Low capacity GSI

For the next step, we are going to create a new table with different capacity units. At this time, the GSI will have on 1 WCU and 1 RCU, for the purpose of this exercise.

Run the following command:

```
aws dynamodb create-table --table-name tlog_gsi_low \
--attribute-definitions AttributeName=requestid,AttributeType=N AttributeName=host,AttributeType=S \
--key-schema AttributeName=requestid,KeyType=HASH \
--provisioned-throughput ReadCapacityUnits=1000,WriteCapacityUnits=1000 \
--global-secondary-indexes  IndexName=host-requestid-gsi,\
KeySchema=["{AttributeName=host,KeyType=HASH},{AttributeName=requestid,KeyType=RANGE}"],\
Projection="{ProjectionType=INCLUDE,NonKeyAttributes=['bytessent']}",\
ProvisionedThroughput="{ReadCapacityUnits=1,WriteCapacityUnits=1}"
```

Run the command to wait until the table becomes Active:

```
aws dynamodb wait table-exists --table-name tlog_gsi_low
```

This command will create a new table and one GSI with the following definition:

Table: tlog_gsi_low

- Attribute: requestid
- Key Type: Hash
- Table RCU = **1000**
- Table WCU = **1000**

GSI: host-requestid-gsi

- Attribute: host
- Key Type: Hash
- Attribute: requestid
- Key Type: Range
- Projection Include: bytessent
- GSI RCU = **1**
- GSI WCU = **1**

You can, now, populate the new table with a large dataset. At this time, you will run a script that uses a multi-thread version to have more writes per second on the DynamoDB table.

```
python load_tlog_parallel.py tlog_gsi_low
```

Eventually, the execution will be throttled and show the error message like below:

> Error:Error: (, ProvisionedThroughputExceededException(u'An error occurred (ProvisionedThroughputExceededException) when calling the PutItem operation (reached max retries: 9): The level of configured provisioned throughput for one or more global secondary indexes of the table was exceeded. Consider increasing your provisioning level for the under-provisioned global secondary indexes with the UpdateTable API',),)

You can cancel the operation, typing Ctrl+C**. It can take some time to cancel.**

Note: This new table has more RCU=1000 and WCU=1000 but we received an error and the load time increased.

Question: Could you explain the behavior of the test?

Open the AWS console to view the metrics for the table tlog_gsi_low.

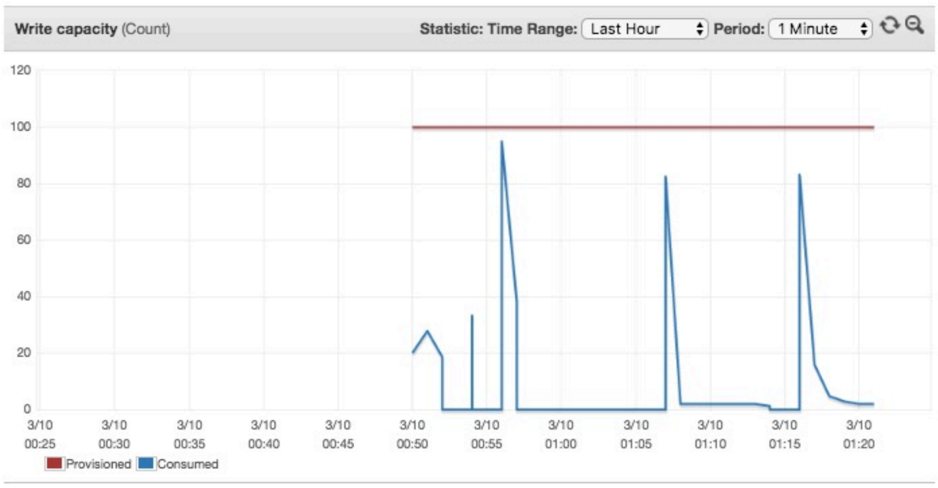


Figure 12 - Write capacity metric for the table`

Note above that the consumed writes were below the provisioned writes for the table during the test.

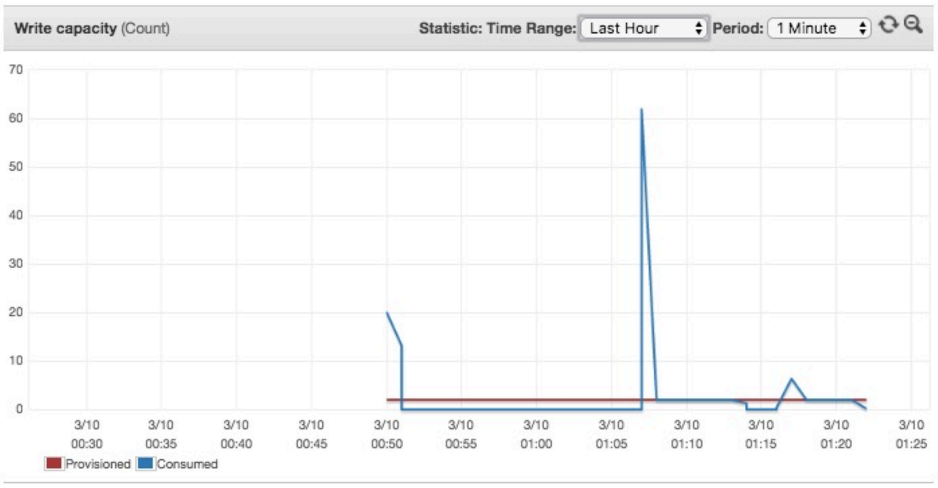


Figure 13 - Write capacity metric for the GSI

Note above that the consumed writes were high than the provisioned writes for the GSI.

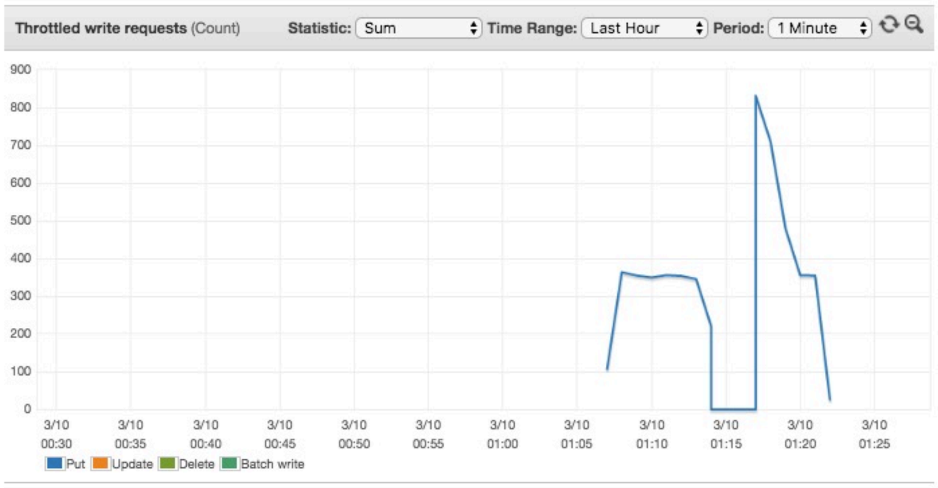


Figure 14 - Throttled writes for the table

Note that the table was throttled, even having enough write capacity.

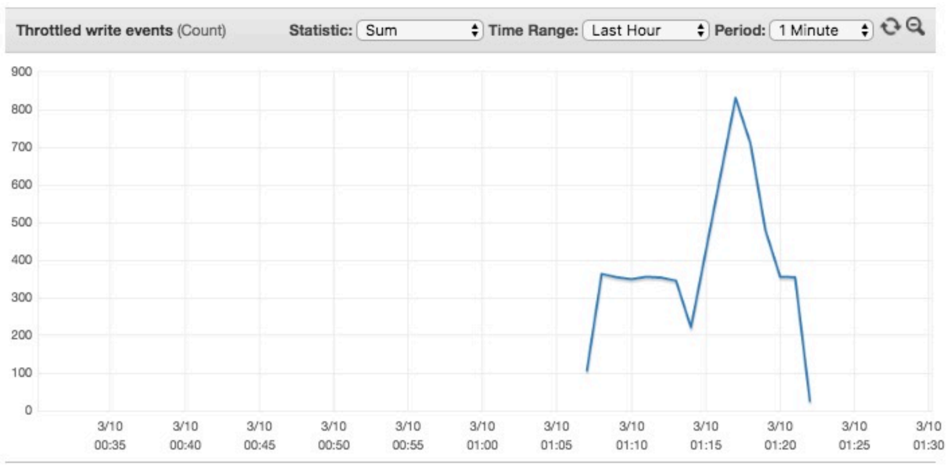


Figure 15 - Throttled writes for the GSI

Exercise 2 - Table Scan and Parallel Table Scan

This exercise will demonstrate the two methods of table scan, sequential and parallel.

Even though DynamoDB distributes a large table data across multiple physical partitions, a Scan operation can only read one partition at a time. For this reason, the throughput of a Scan is constrained by the maximum throughput of a single partition.

To address these issues, the Scan operation can logically divide a table or secondary index into multiple segments, with multiple application workers scanning the segments in parallel.

./media/image7.jpg)
Figure 16 - http://docs.aws.amazon.com/amazondynamodb/latest/developerguide/QueryAndScan.html

Step 1 – Execute a simple Scan

Imagine you need to calculate the total of bytes sent for all records with **response code <> 200**.
You can run a scan operation with a filter expression to filter out the uninteresting records. The application will them sum up the values of all the returned records where response code <> 200.

The Python file **scan_tlog_simple.py** has the command to do the scan with filter and sum the value of bytes sent.

Take a look at the code block for the scan the table:

```
fe = "responsecode <> :f"
eav = {":f": 200}
response = table.scan(
  FilterExpression=fe,
  ExpressionAttributeValues=eav,
  Limit=pageSize
)
```

Notice how there is a Limit parameter set in the scan command. A single Scan operation will read up to the maximum number of items set (if using the Limit parameter) or a maximum of 1 MB of data and then apply any filtering to the results using FilterExpression. If the total number of scanned items exceeds the maximum set by the limit parameter (or) the data set size limit of 1 MB, the scan stops and results are returned to the user as a LastEvaluatedKey value, which can then be used in a subsequent operation, so that you can pick up where you left off.

See the code below. The LastEvaluatedKey value in the response is then passed to the subsequent scan method via the ExclusiveStartKey parameter.

```
while 'LastEvaluatedKey' in response:
  page += 1
  response = table.scan(
    FilterExpression=fe,
    ExpressionAttributeValues=eav,
    Limit=pageSize,
    ExclusiveStartKey=response['LastEvaluatedKey'])
  for i in response['Items']:
    totalbytessent += i['bytessent']
```

When the last page is returned, LastEvaluatedKey is not part of the response, so you will know that the scan is complete.

Now lets execute this code we just discussed:

```
python scan_tlog_simple.py tlog_scan
```

Parameters:

- Tablename: **tlog_scan**

Output:

> Scanning 1 million rows of table tlog_scan to get the total of bytes sent
> Total bytessent 6054250 in 23.5063591003 seconds

Note down the time it took for the scan to complete.

Step 2 – Execute a parallel scan

To perform a parallel scan, each worker issues its own Scan request with the following parameters:

- **Segment** -- A segment to be scanned by a particular worker. Each worker should use a different value for Segment.
- **TotalSegments** -- The total number of segments for the parallel scan. This value must be the same as the number of workers that your application will use.

Take a look at the code block from the **scan_tlog_parallel.py** for the parallel scan.

We need to include the parameters:
Segment : For a parallel Scan request, Segment identifies an individual segment to be scanned by an application worker.
TotalSegments: For a parallel Scan request, TotalSegments represents the total number of segments into which the Scan operation will be divided. The value of TotalSegments corresponds to the number of application workers that will perform the parallel scan.

```
  fe = "responsecode <> :f"
  eav = {":f": 200}
  response = table.scan(
    FilterExpression=fe,
    ExpressionAttributeValues=eav,
    Limit=pageSize,
    TotalSegments=totalsegments,
    Segment=threadsegment
  )
```

And after the first scan, we can continue scanning the table until LastEvaluatedKey equals null.

```
  while 'LastEvaluatedKey' in response:
    page += 1
    response = table.scan(
      FilterExpression=fe,
      ExpressionAttributeValues=eav,
      Limit=pageSize,
      TotalSegments=totalsegments,
      Segment=threadsegment,
      ExclusiveStartKey=response['LastEvaluatedKey'])
```

To run the code execute the following command:

```
python scan_tlog_parallel.py tlog_scan 8
```

Parameters:
1) Table name: **tlog_scan**
2) Number of threads: **8** <<-- number of threads to be executed in parallel, it will be used for number of segments as well.

Output:

> Scanning 1 million rows of table tlog_scan to get the total of bytes sent
> Total bytessent 6054250 in 11.1443469524 seconds

- Note: The execution time using parallel scan will be shorter than the execution time for a regular scan. The difference will be even bigger for larger tables. *

Exercise 3 – GSI Write Sharding

If we need to query the log using the response code, it is possible to create a GSI using that field. But the record logs do not have an even distribution by response code. For example, the code "200 OK" has much more records than the others as expected for any application. You can see the distribution of the log records by response code for the sample file "logfile_medium1.csv" in the graph below.

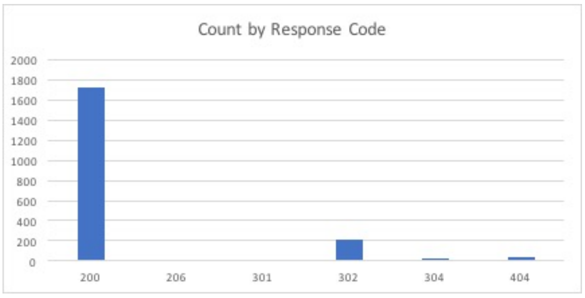


Figure 17 - Log records by response code

One way to increase the write and read throughput of the application would be to randomize the writes across multiple partition key values. You can create a random number from a fixed set (for example, 1 to 10) and use this number as the hash key for a GSI. Because you are randomizing the partition key, the writes to the table are spread evenly across all of the partition key values independent of any attribute; this will yield better parallelism and higher overall throughput.

If you need, for example, to query the log records by a specific response code in a specific date, you can create a sort key using a composition of the response code and the date.

In this exercise, we will create a GSI using the random values for the Hash Key and the composite key "responsecode#date#hourofday" as the Sort Key. The table tlog_scan created and populated during the preparation phase of the workshop already has these two attributes. The attributes were created using the following code:

```
SHARDS = 10
newitem['gsi_responsecode_hk'] = (newitem['requestid'] % SHARDS) + 1
newitem['gsi_responsecode_sk'] = row[7] + "#" + row[2] + "#" + row[3]
```

Step 1 - Creating the GSI

The GSI for this exercise was created durint the Step 8 of the preparation phase. You can see the description of the GSI executing the following command:

```
aws dynamodb describe-table --table-name tlog_scan
```

You will see the description of the Global Secondary Indexes, like:

```
    "GlobalSecondaryIndexes": [
         {
             "IndexSizeBytes": 0,
             "IndexName": "gsi_responsecode",
             "Projection": {
                 "ProjectionType": "KEYS_ONLY"
             },
             "ProvisionedThroughput": {
                 "NumberOfDecreasesToday": 0,
                 "WriteCapacityUnits": 5000,
                 "ReadCapacityUnits": 3000
             },
             "IndexStatus": "ACTIVE",
             "KeySchema": [
                 {
                     "KeyType": "HASH",
                     "AttributeName": "gsi_responsecode_hk"
                 },
                 {
                     "KeyType": "RANGE",
                     "AttributeName": "gsi_responsecode_sk"
                 }
             ],
             "IndexArn": "arn:aws:dynamodb:::table/tlog_scan/index/gsi_responsecode",
             "ItemCount": 0
         }
     ],
```

Step 2 - Querying the GSI with shards

To get all the log records with response code equals to 404, you need to query all the GSI partitions using the sort key. You can do that using parallel threads in your application, and using the hash key and sort key.

```
if date == "all":
    ke = Key('gsi_responsecode_hk').eq(shardid) & Key('gsi_responsecode_sk').begins_with(responsecode)
else:
    ke = Key('gsi_responsecode_hk').eq(shardid) & Key('gsi_responsecode_sk').begins_with(responsecode+"#"+date)

response = table.query(
    IndexName='gsi_responsecode',
    KeyConditionExpression=ke
    )
```

Run the script again but at this time with a larger input data file:

```
python query_responsecode.py tlog_scan 404
```

The output should be like:

```
Records with response code 404 in the shardid 0 = 0
Records with response code 404 in the shardid 1 = 1746
Records with response code 404 in the shardid 4 = 997
Records with response code 404 in the shardid 3 = 1248
Records with response code 404 in the shardid 5 = 997
Records with response code 404 in the shardid 2 = 2496
Records with response code 404 in the shardid 7 = 1497
Records with response code 404 in the shardid 6 = 1745
Records with response code 404 in the shardid 8 = 3243
Records with response code 404 in the shardid 9 = 2745
Number of records with responsecode 404 is 16714. Query time: 2.48985695839 seconds
```

If you query the same GSI for the same response code but specifying a date.

```
python query_responsecode.py tlog_scan 404 --date 2017-07-21
```

The output should be like:

```
Records with response code 404 in the shardid 0 = 0
Records with response code 404 in the shardid 1 = 749
Records with response code 404 in the shardid 2 = 750
Records with response code 404 in the shardid 3 = 250
Records with response code 404 in the shardid 4 = 499
Records with response code 404 in the shardid 5 = 0
Records with response code 404 in the shardid 6 = 250
Records with response code 404 in the shardid 7 = 999
Records with response code 404 in the shardid 8 = 1000
Records with response code 404 in the shardid 9 = 999
Number of records with responsecode 404 is 5496. Query time: 1.10212612152 seconds
```

Exercise 4 - GSI key overloading

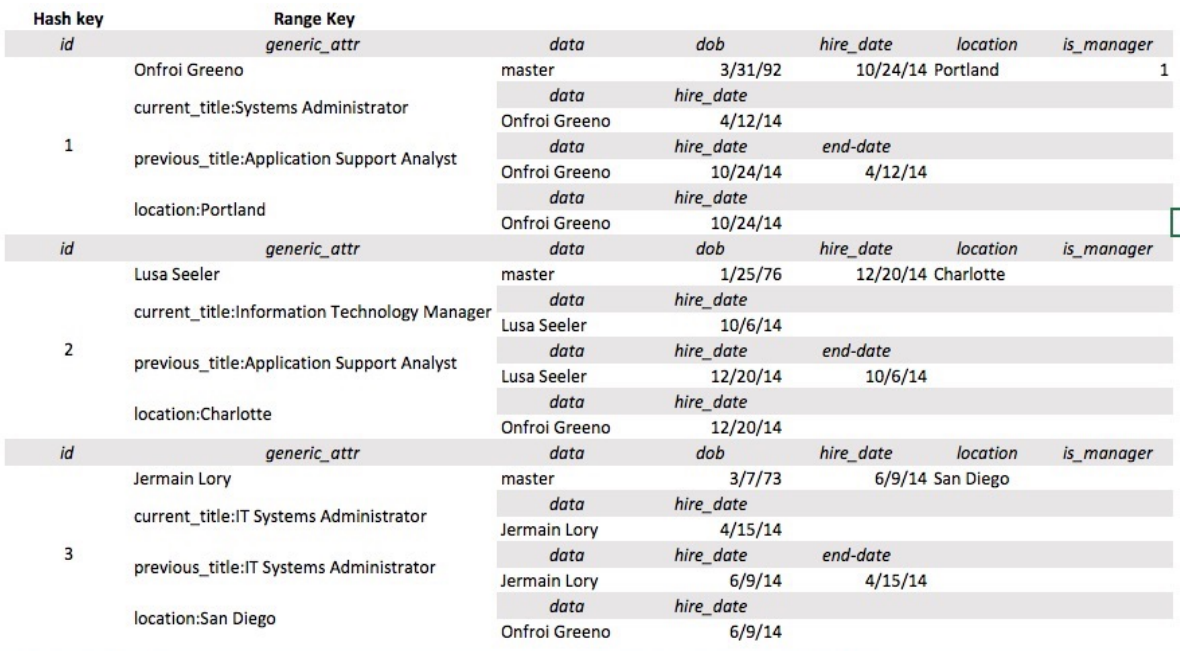
In some cases, when you are designing the DynamoDB tables, your application requires multiple access patterns, more than the current limit of number of GSI allowed per table in DynamoDB.

One possible pattern is to design the tables re-using the attribute name (column header) across different items types. So when you create a GSI on an attribute, you are indexing multiple attributes, each for a different item type, and have used only 1 GSI. For example, considers the Employees table – an employee can contain items of type "metadata" (for employee details), "employee-title" (save all titles that the employee take along your career in the company), or "employee-location" (tracking all the location the employee has worked).

The access patterns required for this scenario are:

- query all employees of a state
- query all employees with one specific current title
- query all employees who had ever one specific current title
- query employees by name

The following figure presents the design of the table to



Hash key	Range Key					
id	*generic_attr*	*data*	*dob*	*hire_date*	*location*	*is_manager*
	Onfroi Greeno	master	3/31/92	10/24/14	Portland	1
	current_title:Systems Administrator	*data*	*hire_date*			
		Onfroi Greeno	4/12/14			
1	previous_title:Application Support Analyst	*data*	*hire_date*	*end-date*		
		Onfroi Greeno	10/24/14	4/12/14		
	location:Portland	*data*	*hire_date*			
		Onfroi Greeno	10/24/14			
id	*generic_attr*	*data*	*dob*	*hire_date*	*location*	*is_manager*
	Lusa Seeler	master	1/25/76	12/20/14	Charlotte	
	current_title:Information Technology Manager	*data*	*hire_date*			
		Lusa Seeler	10/6/14			
2	previous_title:Application Support Analyst	*data*	*hire_date*	*end-date*		
		Lusa Seeler	12/20/14	10/6/14		
	location:Charlotte	*data*	*hire_date*			
		Onfroi Greeno	12/20/14			
id	*generic_attr*	*data*	*dob*	*hire_date*	*location*	*is_manager*
	Jermain Lory	master	3/7/73	6/9/14	San Diego	
	current_title:IT Systems Administrator	*data*	*hire_date*			
		Jermain Lory	4/15/14			
3	previous_title:IT Systems Administrator	*data*	*hire_date*	*end-date*		
		Jermain Lory	6/9/14	4/15/14		
	location:San Diego	*data*	*hire_date*			
		Onfroi Greeno	6/9/14			

Figure 18 - Sample design for the Employees table using the GSI overloading pattern

Step 1 – Create the Employees table for GSI overloading

Run the AWS CLI command to create the table:

```
aws dynamodb create-table --table-name employees \
--attribute-definitions AttributeName=employeeid,AttributeType=N AttributeName=colA,AttributeType=S AttributeName=name,Attribu
--key-schema AttributeName=employeeid,KeyType=HASH AttributeName=colA,KeyType=RANGE \
--provisioned-throughput ReadCapacityUnits=100,WriteCapacityUnits=100 \
--global-secondary-indexes  IndexName=gsi_overload,\
KeySchema=["{AttributeName=colA,KeyType=HASH},{AttributeName=name,KeyType=RANGE}"],\
Projection="{ProjectionType=ALL}",\
ProvisionedThroughput="{ReadCapacityUnits=100,WriteCapacityUnits=100}"
```

Run the command to wait until the table becomes Active:

```
aws dynamodb wait table-exists --table-name employees
```

Lets take a closer look at this create-table command. You are creating a table named “employees”. The Partition key on the table is “employeeID”. And the Sort key is “colA” which will be a derived value we will build in the python script. We will revisit this shortly. We will also create a GSI on this table and we will name this index as “gsi-overload”. The partition key on the GSI is “colA” and the sort key is “name”.

Step 2 – Load data to the new table

You will now execute a script that will load the data from the file named ./employees.csv into the table named “employees”.

The sample employees.csv record looks like the below:

> 1000,Nanine Denacamp,Programmer Analyst,Development,San Francisco,CA,1981-09-30,2014-06-01,Senior Database Administrator,2014-01-25

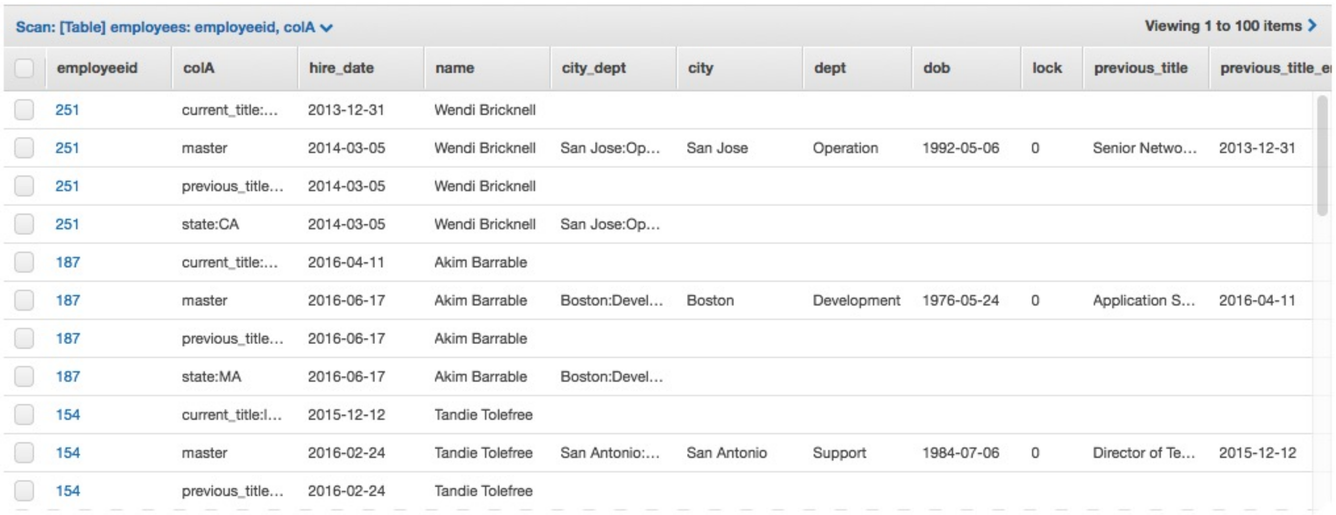
When we ingest this data into the table, we will concatenate some of the attributes, such as city#department (example: San Fancisco:Develoment) because we have an access pattern in our query that will take advantage of this concatenated attribute. The “colA” attribute is also a derived attribute. All of this concatenation is handled in the python script where the record is assembled, and then executes a put_item() to write the record to the table.

```
python load_employees.py employees ./data/employees.csv
```

Output:

```
employee count: 100 in 2.29093313217
employee count: 200 in 2.14961791039
employee count: 300 in 2.18812584877
employee count: 400 in 2.21543097496
employee count: 500 in 2.14153599739
employee count: 600 in 2.14949512482
employee count: 700 in 2.13088917732
employee count: 800 in 2.2102689743
employee count: 900 in 2.12640690804
employee count: 1000 in 2.12910103798
RowCount: 1000, Total seconds: 21.7805070877
```

Take a look on the DynamoDB table 'employees' using the AWS console: (On the console, click on the table “employees” on the left, and on the right side pane, select the “Items” tab.



Scan: [Table] employees: employeeid, colA

Viewing 1 to 100 items

employeeid	colA	hire_date	name	city_dept	city	dept	dob	lock	previous_title	previous_title_e
251	current_title:...	2013-12-31	Wendi Bricknell							
251	master	2014-03-05	Wendi Bricknell	San Jose:Op...	San Jose	Operation	1992-05-06	0	Senior Netwo...	2013-12-31
251	previous_title...	2014-03-05	Wendi Bricknell							
251	state:CA	2014-03-05	Wendi Bricknell	San Jose:Op...						
187	current_title:...	2016-04-11	Akim Barrable							
187	master	2016-06-17	Akim Barrable	Boston:Devel...	Boston	Development	1976-05-24	0	Application S...	2016-04-11
187	previous_title...	2016-06-17	Akim Barrable							
187	state:MA	2016-06-17	Akim Barrable	Boston:Devel...						
154	current_title:I...	2015-12-12	Tandie Tolefree							
154	master	2016-02-24	Tandie Tolefree	San Antonio:...	San Antonio	Support	1984-07-06	0	Director of Te...	2015-12-12
154	previous_title...	2016-02-24	Tandie Tolefree							

Figure 19 - Employees table

The GSI will have the following content: On the same page, in the right hand pane, select the dropdown item that says [Index] and click Start Search.

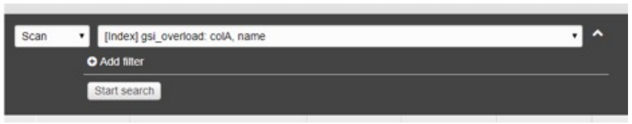
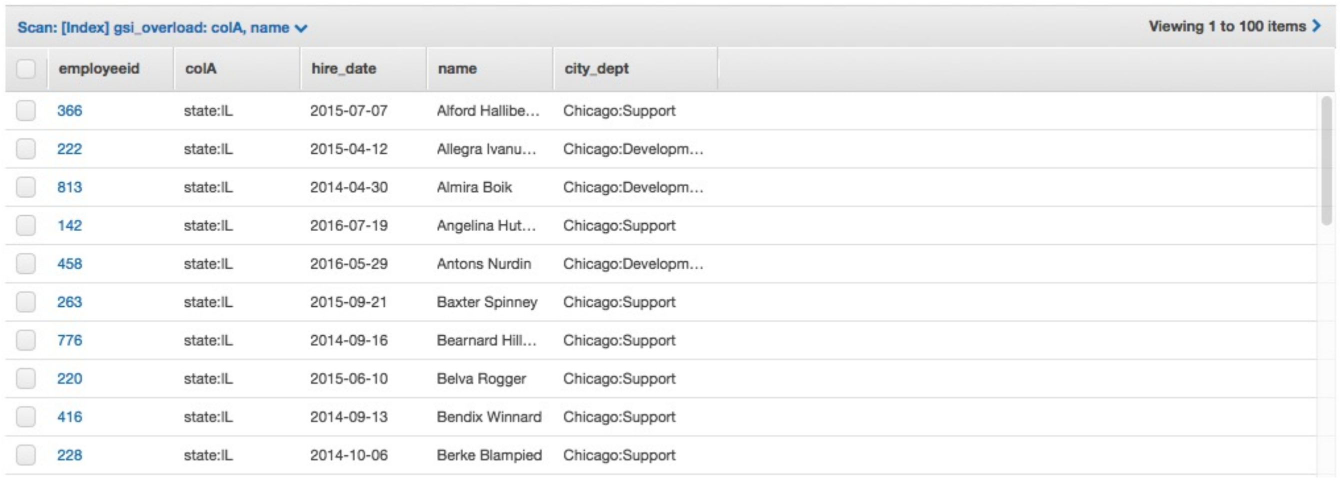


Figure 20 - Searching the GSI



Scan: [Index] gsi_overload: colA, name   Viewing 1 to 100 items

employeeid	colA	hire_date	name	city_dept
366	state:IL	2015-07-07	Alford Hallibe...	Chicago:Support
222	state:IL	2015-04-12	Allegra Ivanu...	Chicago:Developm...
813	state:IL	2014-04-30	Almira Boik	Chicago:Developm...
142	state:IL	2016-07-19	Angelina Hut...	Chicago:Support
458	state:IL	2016-05-29	Antons Nurdin	Chicago:Developm...
263	state:IL	2015-09-21	Baxter Spinney	Chicago:Support
776	state:IL	2014-09-16	Bearnard Hill...	Chicago:Support
220	state:IL	2015-06-10	Belva Rogger	Chicago:Support
416	state:IL	2014-09-13	Bendix Winnard	Chicago:Support
228	state:IL	2014-10-06	Berke Blampied	Chicago:Support

Figure 21 - Global Secondary Index

Step 3 – Query the Employees table using the GSI with overloaded attributes

You can query all the employees based in WA state using the sample Python script:

The query_employees.py script has the following code to query table using the GSI overloading:

```
if attribute == 'name':
ke = Key('colA').eq('master') & Key('name').eq(value)
else:
ke = "colA = :f"
ke = Key('colA').eq(attribute + ":" + value)
response = table.query(
IndexName='gsi_overload',
KeyConditionExpression=ke
)
```

```
python query_employees.py employees state 'WA'
```

You will see an output like:

```
>
List of employees with WA in the attribute state:
Employee name: Alice Beilby - hire date: 2014-12-03
Employee name: Alla Absalom - hire date: 2015-06-25
Employee name: Alvan Heliar - hire date: 2016-05-15
Employee name: Anders Galtone - hire date: 2015-12-22
Employee name: Ashil Hutchin - hire date: 2015-02-11
...
Employee name: Sula Prattin - hire date: 2014-01-11
Employee name: Vittoria Edelman - hire date: 2014-10-01
Employee name: Willie McCuthais - hire date: 2015-05-27
Total of employees: 46. Execution time: 0.265305995941 seconds
```

You can try a different State changing the last parameter of the command above, like:

```
python query_employees.py employees state 'TX'
```

The list of States with some data is in the sample data is: AZ, CA, CO, IL, IN, MA, MD, MI, NC, NY, OR, PA, TN, TX, and WA

Using the same query, you can query the employees by job title. Run the following command as an example:

```
python query_employees.py employees current_title 'Software Engineer'
```

You will get the result:

```
List of employees with Software Engineer in the attribute current_title:
Employee name: Alice Beilby - hire date: 2014-11-03
Employee name: Anetta Byrne - hire date: 2017-03-15
Employee name: Ardis Panting - hire date: 2015-08-06
Employee name: Chris Randals - hire date: 2016-10-27
Employee name: Constantine Barendtsen - hire date: 2016-06-10
Employee name: Eudora Janton - hire date: 2015-01-05
Employee name: Florella Allsep - hire date: 2015-03-31
Employee name: Horatius Trangmar - hire date: 2013-10-21
Employee name: Korey Daugherty - hire date: 2016-11-03
```

> Employee name: Lenka Luquet - hire date: 2014-10-01
> Employee name: Leonora Hyland - hire date: 2016-06-14
> Employee name: Lucretia Ruffell - hire date: 2015-07-04
> Employee name: Malcolm Adiscot - hire date: 2014-04-17
> Employee name: Melodie Sebire - hire date: 2013-08-27
> Employee name: Menard Ogborn - hire date: 2014-06-27
> Employee name: Merwyn Petters - hire date: 2014-06-19
> Employee name: Niels Buston - hire date: 2014-10-30
> Employee name: Noelani Studde - hire date: 2015-03-30
> Total of employees: 18. Execution time: 0.316555976868 seconds

You can try a different title, for example:

```
python query_employees.py employees current_title 'IT Support Manager'
```

The list of the titles is: Application Developer,Application Support Analyst,Applications Engineer,Associate Developer,Chief Technology Officer (CTO) ,Chief Information Officer (CIO) ,Computer and Information Systems Manager,Computer Systems Manager,Customer Support Administrator,Customer Support Specialist,Data Center Support Specialist,Data Quality Manager,Database Administrator,Desktop Support Manager,Desktop Support Specialist,Developer,Director of Technology,Front End Developer,Help Desk Specialist,Help Desk Technician,Information Technology Coordinator,Information Technology Director,Information Technology Manager,IT Support Manager,IT Support Specialist,IT Systems Administrator,Java Developer,Junior Software Engineer,Management Information Systems Director,.NET Developer,Network Architect,Network Engineer,Network Systems Administrator,Programmer,Programmer Analyst,Security Specialist,Senior Applications Engineer,Senior Database Administrator,Senior Network Architect,Senior Network Engineer,Senior Network System Administrator,Senior Programmer,Senior Programmer Analyst,Senior Security Specialist,Senior Software Engineer,Senior Support Specialist,Senior System Administrator,Senior System Analyst,Senior System Architect,Senior System Designer,Senior Systems Analyst,Senior Systems Software Engineer,Senior Web Administrator,Senior Web Developer,Software Architect,Software Developer,Software Engineer,Software Quality Assurance Analyst,Support Specialist,Systems Administrator,Systems Analyst,System Architect,Systems Designer,Systems Software Engineer,Technical Operations Officer,Technical Support Engineer,Technical Support Specialist,Technical Specialist,Telecommunications Specialist,Web Administrator,Web Developer,Webmaster

And using the same query, you can query the employees by name:

```
python query_employees.py employees name 'Dale Marlin'
```

You will get the result:

> List of employees with Dale Marlin in the attribute name:
> Employee name: Dale Marlin - hire date: 2014-10-19
> Total of employees: 1. Execution time: 0.268958091736 seconds

Exercise 5 – Sparse Indexes

You can use a sparse global secondary index to efficiently locate table items that have an uncommon attribute. To do this, you take advantage of the fact that table items that do not contain global secondary index attribute(s) are not indexed at all.

Such a query can be very efficient because the number of items in the index will be significantly fewer than the number of items in the table. In addition, the fewer table attributes you project into the index, the fewer read capacity units you will consume from the index.

Step 1 – Add a new GSI to the table employees

Execute the code to add a new GSI using the attribute 'is_manager' as the HashKey.

```
aws dynamodb update-table --table-name employees \
--attribute-definitions AttributeName=is_manager,AttributeType=S AttributeName=title,AttributeType=S \
--global-secondary-index-updates file://gsi_manager.json
```

You need to wait until the index has been created.

If you run the following command and "IndexStatus": "CREATING" you will need to wait more time until the all the "IndexStatus": "ACTIVE"

```
aws dynamodb describe-table --table-name employees | grep IndexStatus
```

> "IndexStatus": "ACTIVE",
> "IndexStatus": "CREATING",

Run the command above until you see the output (it can take some minutes.).

> "IndexStatus": "ACTIVE",
> "IndexStatus": "ACTIVE",

Step 2 – Query employees to find managers without using the GSI

Firstly, you will scan the table to find all the managers without using the GSI. In this case, you need to use a filter expression to return only the items where the attribute 'is_manager' is equal to 1.

```
fe = "is_manager = :f"
eav = {":f": 1}
response = table.scan(
  FilterExpression=fe,
  ExpressionAttributeValues=eav,
  Limit=pageSize
)
```

Run the following command:

```
python query_managers_table.py employees 100
```

Parameters:
1) Table name = **employees**
2) Page size = **100** <<-- size of the pagination for the scan

You can see the output including the scanned count and the execution time:

> Managers count: 84. # of records scanned: 4000. Execution time: 1.73592495918 seconds

Note: Observe the number of items scanned to return the values.

Step 3 – Query employees to find managers using the sparse index

Now, you will query the employees using the GSI.

```
response = table.scan(
Limit=pageSize,
IndexName='gsi_manager'
)
```

Run the following command to execute the scan using the sparse index.

```
python query_managers_gsi.py employees 100
```

Parameters:
1) Table name = **employees**
2) Page size = **100** <<-- size of the pagination for the scan

You can see the output including the scanned count and the execution time:

> Number of managers: 84. # of records scanned: 84. Execution time: 0.396322011948 seconds

Note: Observe the scanned count and execution time using the sparse index.

Exercise 6 - Composite keys

Now, imagine you need to create an application to query the employees by geographic location (State and City) and by department. Considering you have the attributes: state, city, and dept. You can create a GSI that will combine them to allow the queries by location/dept. In DynamoDB you can create a new GSI using one HASHKEY and one RANGEKEY. In this case, you query criteria needs to use more than two attributes, one alternative is to create a composite key depending on your access pattern.

The table load script created an attribute called city_dept that compound the two attributes city and dept in a single one with a separator ":" between the values. It has values in the format 'city:dept', like 'Seattle:Development'.

So, you can use the existing attributes to create a new GSI to attend the query requirements, with the structure:

HASHKEY with the attribute state. It has values in the format '', like state:WA.
RANGEKEY with the attribute city_dept. It has values in the format 'city:dept', like 'Seattle:Development'.

Step 1 - Creating a new GSI for City-Department

You can run the following command to create the new GSI gsi_city_dept:

```
aws dynamodb update-table --table-name employees \
--attribute-definitions AttributeName=state,AttributeType=S AttributeName=city_dept,AttributeType=S \
--global-secondary-index-updates file://gsi_city_dept.json
```

You need to wait until the index has been created. It can take some minutes.

If you run the following command and "IndexStatus": "CREATING" you will need to wait more time until the all the "IndexStatus": "ACTIVE"

```
aws dynamodb describe-table --table-name employees | grep IndexStatus
```

> "IndexStatus": "ACTIVE",
> "IndexStatus": "ACTIVE",
> "IndexStatus": "CREATING",

Run the command above until you see the output (it will take about 2 minutes).

> "IndexStatus": "ACTIVE",
> "IndexStatus": "ACTIVE",
> "IndexStatus": "ACTIVE",

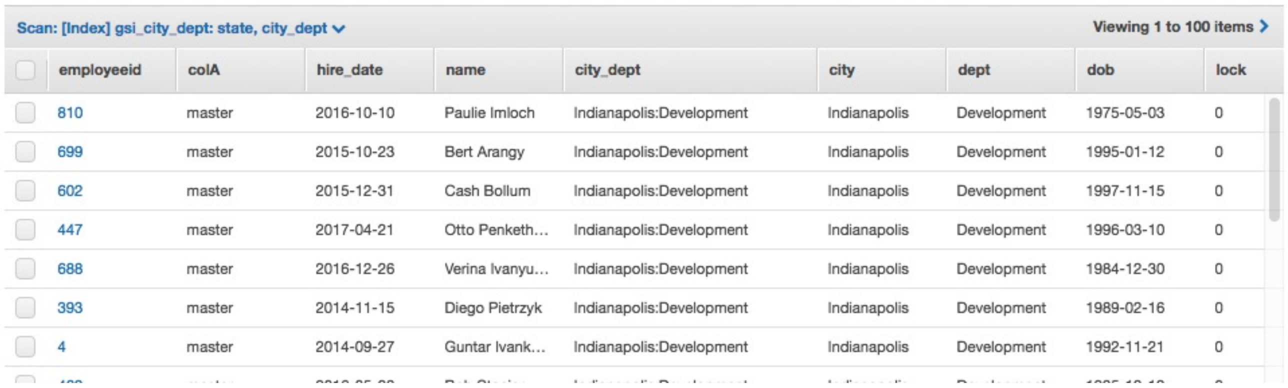
Now you can use the new GSI to query the table. You must to use the HASHKEY and you can optionally use the RANGEKEY.

For the RANGEKEY you can use the begins_with expression, so you can query using only the starting of the attribute value. This allows you to query all the city employees or only employees from a specific department.

During the query time, the KeyConditionExpression will be "Key('colA').eq(') & Key('city_dept').begins_with()"."

Step 2 - Querying all the employees from a state

We can use the new GSI to query the table. If we are using only the state the query will not use the sort key attribute. But if the query has a value for the second parameter, the code will use the attribute city_dept of the GSI to query all the values that begin with the parameter value.



Scan: [Index] gsi_city_dept: state, city_dept

Viewing 1 to 100 items

employeeid	colA	hire_date	name	city_dept	city	dept	dob	lock
810	master	2016-10-10	Paulie Imloch	Indianapolis:Development	Indianapolis	Development	1975-05-03	0
699	master	2015-10-23	Bert Arangy	Indianapolis:Development	Indianapolis	Development	1995-01-12	0
602	master	2015-12-31	Cash Bollum	Indianapolis:Development	Indianapolis	Development	1997-11-15	0
447	master	2017-04-21	Otto Penketh...	Indianapolis:Development	Indianapolis	Development	1996-03-10	0
688	master	2016-12-26	Verina Ivanyu...	Indianapolis:Development	Indianapolis	Development	1984-12-30	0
393	master	2014-11-15	Diego Pietrzyk	Indianapolis:Development	Indianapolis	Development	1989-02-16	0
4	master	2014-09-27	Guntar Ivank...	Indianapolis:Development	Indianapolis	Development	1992-11-21	0

Figure 22 - Composite key to query by city and department

```
if value2 == "-":
    ke = Key('state').eq(value1)
else:
    ke = Key('state').eq(value1) & Key('city_dept').begins_with(value2)

response = table.query(
    IndexName='gsi_city_dept',
    KeyConditionExpression=ke
    )
```

Run the following Python application:

```
python query_city_dept.py employees TX
```

Output:

```
List of employees . State: TX
Name: Bree Gershom. City: Austin. Dept: Development
Name: Lida Flescher. City: Austin. Dept: Development
Name: Tristam Mole. City: Austin. Dept: Development
Name: Malinde Spellman. City: Austin. Dept: Development
Name: Giovanni Goutcher. City: Austin. Dept: Development
...
Name: Cullie Sheehy. City: San Antonio. Dept: Support
Name: Ari Wilstead. City: San Antonio. Dept: Support
Name: Odella Kringe. City: San Antonio. Dept: Support
Total of employees: 197. Execution time: 0.352508068085 seconds
```

Step 3 - Querying all the employees of a city

Now, you have a new GSI you can use for query employees by state. Run the following Python application:

```
python query_city_dept.py employees TX --citydept Dallas
```

Output:

```
List of employees . State: TX
Name: Grayce Duligal. City: Dallas. Dept: Development
Name: Jere Vaughn. City: Dallas. Dept: Development
Name: Valeria Gilliatt. City: Dallas. Dept: Development
...
Name: Brittani Hunn. City: Dallas. Dept: Support
```

> Name: Oby Peniello. City: Dallas. Dept: Support
> Total of employees: 47. Execution time: 0.275814056396 seconds

Step 3 - Querying all the employees of a city and a department

Now, you have a new GSI you can use for query employees by state. Run the following Python application:

```
python query_city_dept.py employees TX --citydept Dallas:Op
```

Output:

> List of employees . State: TX
> Name: Brady Marvel. City: Dallas. Dept: Operation
> Name: Emmye Fletcher. City: Dallas. Dept: Operation
> Name: Audra Leahey. City: Dallas. Dept: Operation
> Name: Waneta Parminter. City: Dallas. Dept: Operation
> Name: Lizbeth Proudler. City: Dallas. Dept: Operation
> Name: Arlan Cummings. City: Dallas. Dept: Operation
> Name: Bone Ruggs. City: Dallas. Dept: Operation
> Name: Karlis Prisk. City: Dallas. Dept: Operation
> Name: Marve Bignold. City: Dallas. Dept: Operation
> Total of employees: 9. Execution time: 0.290292024612 seconds

Exercise 7 - Transaction locking

The Employees table has many items related to the same employee. It is possible that you need to update an attribute of the employee record, to avoid inconsistency it is recommended that your application does not allow two different clients change the table records for the same employee at same time.

Once the DynamoDB does not provide ACID transactions, you can implement a transaction locking for your records using a simple solution.

The table has an attribute called 'lock' that will have the values 0 or 1. You will change the lock value to 1 when you start the update operation, if the value is equal to 0, i.e., the item is released. If the lock was successfully acquired you can update the remaining item for the same employee. If the record was already locked (lock=1) your operation will not complete and you can resubmit the change after a while.

In this exercise you will run some code to show this design pattern. You need to update the location of the employee 'Wendi Bricknell', employeeid 251 from **Seattle** to **Portland**. Other execution will try to update the location to `Chicago` for the same employee.

To update the item you will use the script that has the following code block, for the update operation:

```
masterresponse = table.update_item(
    Key={'employeeid': decimal.Decimal(employeeid), 'colA': 'master'},
    UpdateExpression="set #a = :v1, #b = :v2, #c = :v3, #l = :l1",
    ConditionExpression="#l = :l0",
    ExpressionAttributeNames={'#a': 'state', '#b': 'city', '#c': 'city_dept', '#l': 'lock'},
    ExpressionAttributeValues={':v1': newstate, ':v2': newcity, ':v3': newcity+":"+newdept, ':l1': '1', ':l0' : '0'},
    ReturnValues="ALL_OLD"
)
```

Step 1 - Get the current data for the employee

Run the AWS CLI command to get the current values for the employee with employeeid 251:

```
aws dynamodb get-item --table-name employees \
--key '{"employeeid": {"N": "251"}, "colA": {"S": "master"}}' \
--output text
```

The output of the initial status is:

> CITY San Jose
> CITY_DEPT San Jose:Operation
> COLA master
> DEPT Operation
> DOB 1992-05-06
> EMPLOYEEID 251
> HIRE_DATE 2014-03-05
> LOCK 0
> NAME Wendi Bricknell
> PREVIOUS_TITLE Senior Network System Administrator
> PREVIOUS_TITLE_END 2013-12-31
> STATE CA
> TITLE Network Architect

Step 2 - Run two concurrent updates

In order to view the 'transaction locking' running, you will run the command to update the same record at same time, following the steps:

1. Open a duplicate session to the same EC2 instance. You can use the command "Duplicate Tab" in MacOS or "Duplicate Session" in Windows.
2. In the duplicated session, go to the folder "workshop".

   ```
   cd workshop
   ```

3. In the first session, run the command that will acquire the lock and update the lines related to the employee employeeid
4. In the second session, run the same command while the first execution is still running. The Python program will wait 60 seconds before release the item to be possible to simulate the error caused by the lock.

You need to open two sessions before execute the commands below

First session window:

```
python update_employees.py employees 251 OR Portland Operation
```

Second session window:

```
python update_employees.py employees 251 IL Chicago Operation
```

Output of the first window:

> Updating the items related to the employee Wendi Bricknell
> Please wait 60 seconds

Output of the second window:

> Employee: 251 cannot be updated. Employee locked.

After 60 seconds, the output of the session 1 will be:

> Updating the items related to the employee Wendi Bricknell
> Please wait 60 seconds
> Employee: 251 updated to Portland / OR.

Step 3 - Verify the current status

Run the AWS CLI command to get the current values for the employee with employeeid 251:

```
aws dynamodb get-item --table-name employees --key '{"employeeid": {"N": "251"}, "colA": {"S": "master"}}' --output text
```

The output of the initial status is:

> CITY Portland
> CITY_DEPT Portland:Operation
> COLA master
> DEPT Operation
> DOB 1992-05-06
> EMPLOYEEID 251
> HIRE_DATE 2014-03-05
> LOCK 0
> NAME Wendi Bricknell
> PREVIOUS_TITLE Senior Network System Administrator
> PREVIOUS_TITLE_END 2013-12-31
> STATE OR
> TITLE Network Architect

Exercise 8 - DynamoDB Streams and AWS Lambda

This exercise will demonstrate a simple way to replicate items from one DynamoDB table to another table using DynamoDB stream and AWS Lambda function.

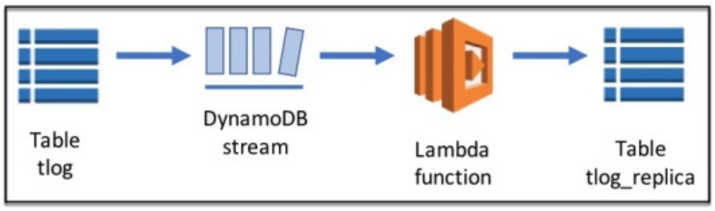


Figure 23 - DynamoDB stream with Lambda

Step 1 – Create the replica table

You can reuse the Python code to create a new table for the replication. Run the command:

```
aws dynamodb create-table --table-name tlog_replica \
--attribute-definitions AttributeName=requestid,AttributeType=N AttributeName=host,AttributeType=S \
--key-schema AttributeName=requestid,KeyType=HASH --provisioned-throughput ReadCapacityUnits=10,WriteCapacityUnits=5 \
--global-secondary-indexes  IndexName=host-requestid-gsi,KeySchema=["{AttributeName=host,KeyType=HASH},{AttributeName=requesti
```

This command will create a new table and one GSI with the following definition:

Table: tlog_replica

- Attribute: requestid
- Key Type: Hash
- Table RCU = **10**
- Table WCU = **5**

GSI: host-requestid-gsi

- Attribute: host --
- Key Type: Hash
- Attribute: requestid
- Key Type: Range
- Projection Include: bytessent
- GSI RCU = **10**
- GSI WCU = **5**

Run the command to wait until the table becomes Active:

```
aws dynamodb wait table-exists --table-name tlog_replica
```

Step 2 – Setup the IAM role required to execute the Lambda function

It is required to have an IAM role that can invoke the Lambda function with the right policies.

First, take a look in the file with name **iam-trust-relationship.json** that contains:

> { "Version": "2012-10-17", "Statement": [{"Effect": "Allow", "Principal": { "Service": "lambda.amazonaws.com"}, "Action": "sts:AssumeRole" }]}

Then, execute the following command to create the role:

```
aws iam create-role --role-name ddbreplica_role --path "/service-role/" \
--assume-role-policy-document file://iam-trust-relationship.json
```

Step 3 – Associate the policy with the role

You need to associate the correct policy with the new role. Check the file named **iam-role-policy.json**, it must have your region and account ID for the lines showed below.

> { "Version": "2012-10-17", "Statement": [{"Effect": "Allow", "Action": "lambda:InvokeFunction", "Resource": "arn:aws:lambda:**REGION:ACCOUNTID**:function:ddbreplicalambda"}, { "Effect": "Allow", "Action": ["dynamodb:DescribeStream", "dynamodb:GetRecords", "dynamodb:GetShardIterator", "dynamodb:ListStreams"], "Resource": "arn:aws:dynamodb:*REGION:ACCOUNTID:table/tlog/stream/" }, { "Effect": "Allow", "Action": ["dynamodb:DeleteItem", "dynamodb:PutItem"], "Resource": "arn:aws:dynamodb:**REGION:ACCOUNTID**:table/tlogreplica" }, { "Effect": "Allow", "Action": ["logs:CreateLogGroup", "logs:CreateLogStream", "logs:PutLogEvents"], "Resource": ["arn:aws:logs:\::"]}]}

If the file is correct, execute the following command to associate the policy with the role:

```
aws iam put-role-policy --role-name ddbreplica_role \
--policy-name ddbreplica_policy --policy-document file://iam-role-policy.json
```

Step 4 – Create the Lambda function

You need to zip the code file:

```
zip ddbreplica_lambda.zip ddbreplica_lambda.py
```

Get the IAM role ARN to associate to the Lambda function:

```
aws iam get-role --role-name ddbreplica_role
```

The output will be like:

> { "Role": { "AssumeRolePolicyDocument": { "Version": "2012-10-17", "Statement": [{ "Action": "sts:AssumeRole", "Effect": "Allow", "Principal": { "Service": "lambda.amazonaws.com" } }] }, "RoleId": "AROAJMZZJHYZWRPQOBAQY", "CreateDate": "2017-03-13T23:30:22Z", "RoleName": "ddbreplica_role", "Path": "/service-role/", **"Arn": "arn:aws:iam::accountID:role/service-role/ddbreplica_role"** } }

Now, copy the ARN from the output in the --role parameter below, and execute the command to create the Lambda function:

```
aws lambda create-function --region us-east-1 \
--function-name ddbreplica_lambda --zip-file fileb://ddbreplica_lambda.zip \
--role arn:aws:iam:::role/service-role/ddbreplica_role \
--handler ddbreplica_lambda.lambda_handler --timeout 60 --runtime python2.7 \
--description "Sample lambda function for dynamodb streams"
```

Step 5 – Enable the DynamoDB streams

Enable DynamoDB stream for the table **tlog:**

```
aws dynamodb update-table --table-name 'tlog' \
--stream-specification StreamEnabled=true,StreamViewType=NEW_IMAGE
```

Get the full ARN for the DynamoDB stream in the response, like the bold below.

> "ItemCount": 0, "CreationDateTime": 1489447719.586, "LatestStreamArn": **"arn:aws:dynamodb:REGION:ACCOUNTID:table/tlog/stream/2017-03-13T23:38:19.480"**

Step 6 – Map the DynamoDB stream with the Lambda function

So far, you have the source table with DynamoDB stream enabled and the Lambda function, now you need to map the source stream with the Lambda function.

You need to **copy the arn** from the previous step to the command below, example:

```
aws lambda create-event-source-mapping \
--event-source-arn arn:aws:dynamodb:REGION:ACCOUNTID:table/tlog/stream/2017-03-13T23:38:19.480 \
--function-name ddbreplica_lambda --enabled --batch-size 100 --starting-position TRIM_HORIZON
```

Notice that you must copy the full ARN

The expected result is:

```
"UUID": "e1237af7-1fcd-496b-97f3-f78fbf63d25b",
"StateTransitionReason": "User action",
"LastModified": 1510367309.667,
"BatchSize": 100,
"EventSourceArn": "arn:aws:dynamodb:us-west-2:234687663649:table/tlog/stream/2017-11-11T02:27:26.356",
"FunctionArn": "arn:aws:lambda:us-west-2:234687663649:function:ddbreplica_lambda",
"State": "Creating",
"LastProcessingResult": "No records processed"
}
```

Step 7 – Populate the table tlog to test the DynamoDB stream

Run the Python code to load more items into the table:

```
python load_tlog.py tlog ./data/logfile_stream.csv
```

```
RowCount: 2000, Total seconds: 15.7203409672
```

Step 8 – Verify the replica table tlog_replica

You can scan the table tlog_replica to check if the records were replicated. It takes some time, so you may need to repeat the following command until you get the records.

```
aws dynamodb scan --table-name 'tlog_replica' --max-items 2 --output text
```

You will see the first 2 items of the replica table:

```
2000 2000
BYTESSENT 1015
DATE 2017-07-21
HOST 85.137.49.58
HOUROFDAY 13
METHOD GET
REQUESTID 7315
RESPONSECODE 200
TIMEZONE GMT-0700
URL /gwidgets/blackjack.html
USERAGENT Java/1.6.0_13
BYTESSENT 1160
DATE 2017-07-21
HOST 72.14.194.1
HOUROFDAY 13
METHOD GET
```

```
REQUESTID 7455
RESPONSECODE 200
TIMEZONE GMT-0700
URL /gadgets/adpowers/AlexaRank/ALL_ALL.xml
USERAGENT Mozilla/5.0 (compatible) Feedfetcher-Google; (+http://www.google.com/feedfetcher.html)
NEXTTOKEN eyJFeGNsdXNpdmVTdGFydEtleSI6IG51bGwsICJib3RvX3RydW5jYXRlX2Ftb3VudCI6IDJ9
```

End of Lab

Congratulations!!! You finished all the exercises of the workshop.