CS 498 Internet of Things
Lab 4

Team Ace

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Table of Contents

1. Introduction

In this lab, we used Amazon Web Service's IoT platform to use an emulator to simulate 120,000 Samsung Gear watches and collect their data. Then, we constructed a new to monitors people's heart rates and attempts to predict heart attacks

2. Build the Cloud

2.1 Background on AWS IoT

1. **Compared with the TCP-based client-server communication model, what're the pros and cons for MQTT-based publish/subscribe?**
   TCP-based client-server communication model only for communications between a server and one client. It transmits messages using Ethernet and aims for accuracy of the data package. For pros, MQTT is good for real time systems because it uses asynchronous messaging protocol. MQTT also is best used when the internet connection is unstable and suitable for event-driven systems. On the other hand, MQTT has some down sides. MQTT has a very light messaging protocol which is only good for sending sensor data instead of photos/audios/videos.
2. **What are the tradeoffs in MQTT when there are a large number of clients?**
   When there is a large number of clients, there is a possibility that MQTT will have server load issues. But, the server will load balance to other intermediate servers. The tradeoffs probably are to require higher cost.
   Where there are a large number of clients, a MQTT broker is needed to handle a large number of publishers and subscribers. MQTT brokers do generally expect a persistent connection, and will timeout clients that don't send ping responses (or other activity) periodically. MQTT does support the concept of 'retained' messages. The client can publish something to a topic with the retained flag, and this message will then be stored by the broker.

2.2 Device (thing)

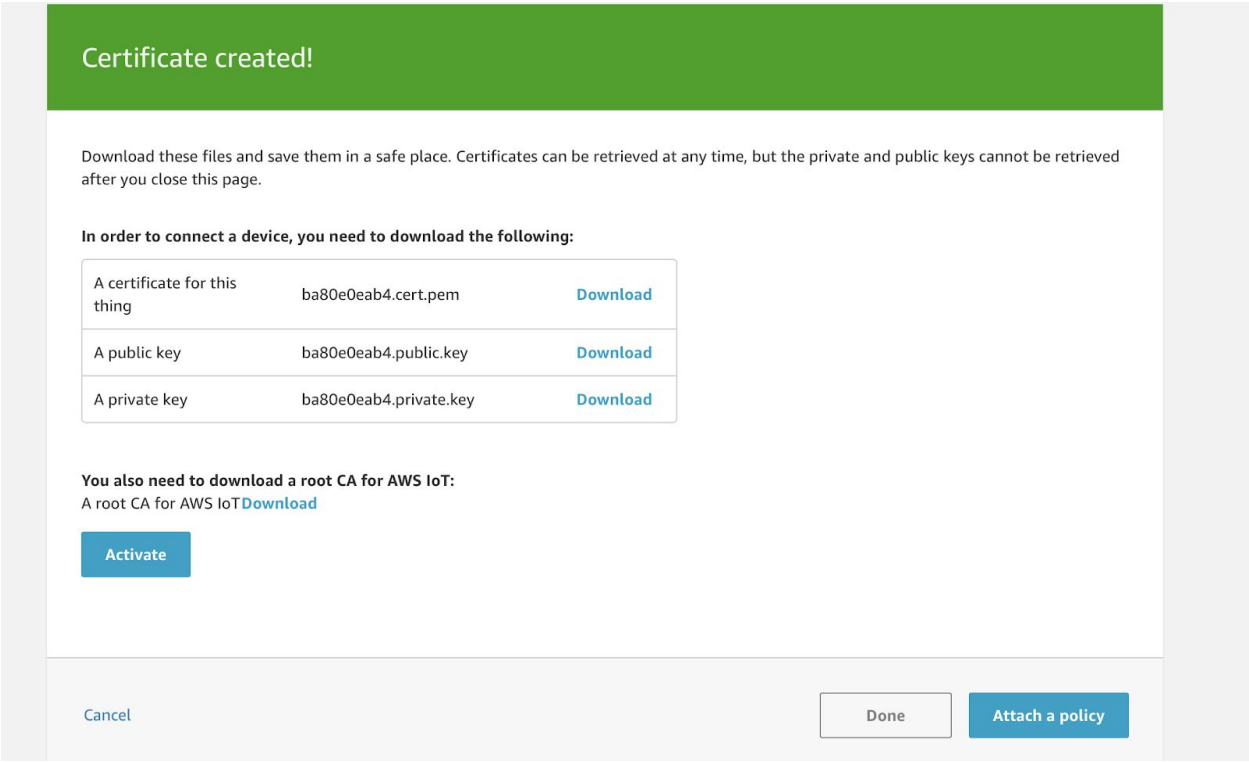


Figure 2.2.1: Screenshot of three key files created

2.3 Configure rules

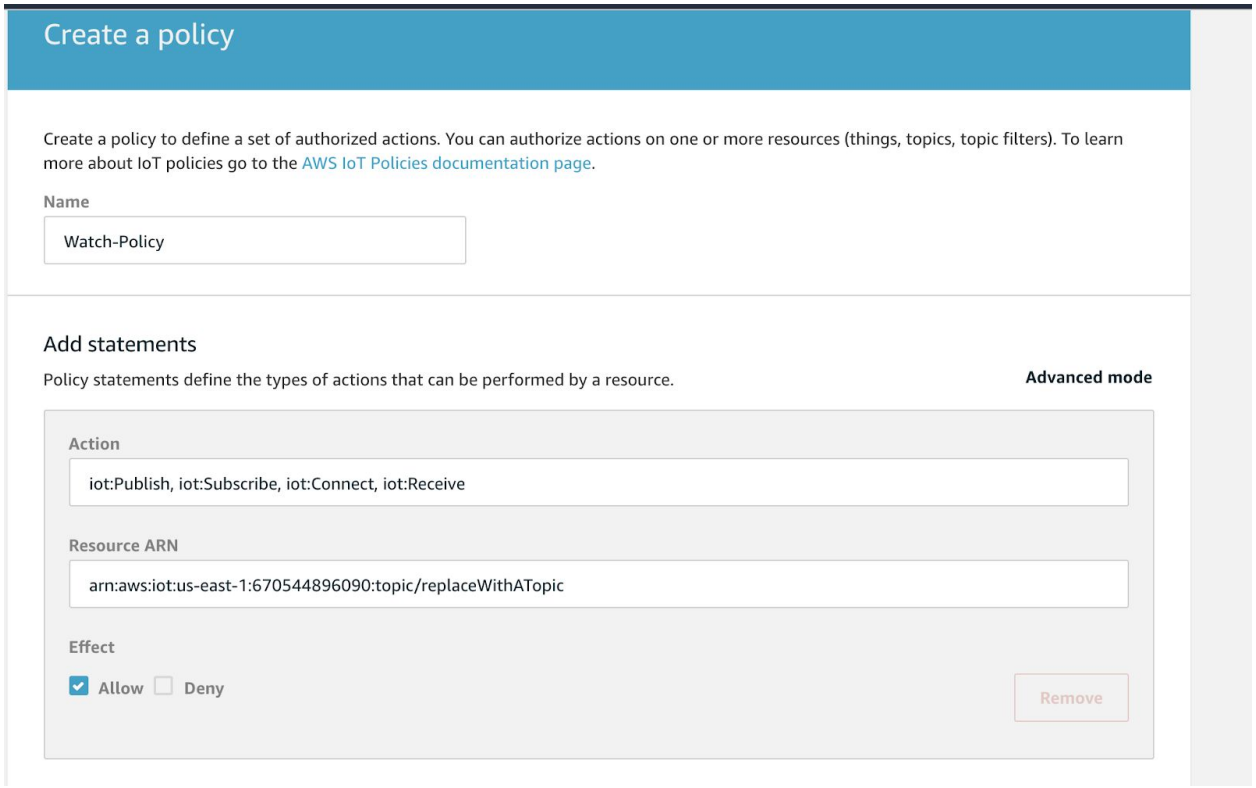


Figure 2.3.1: Screenshot of create a policy page

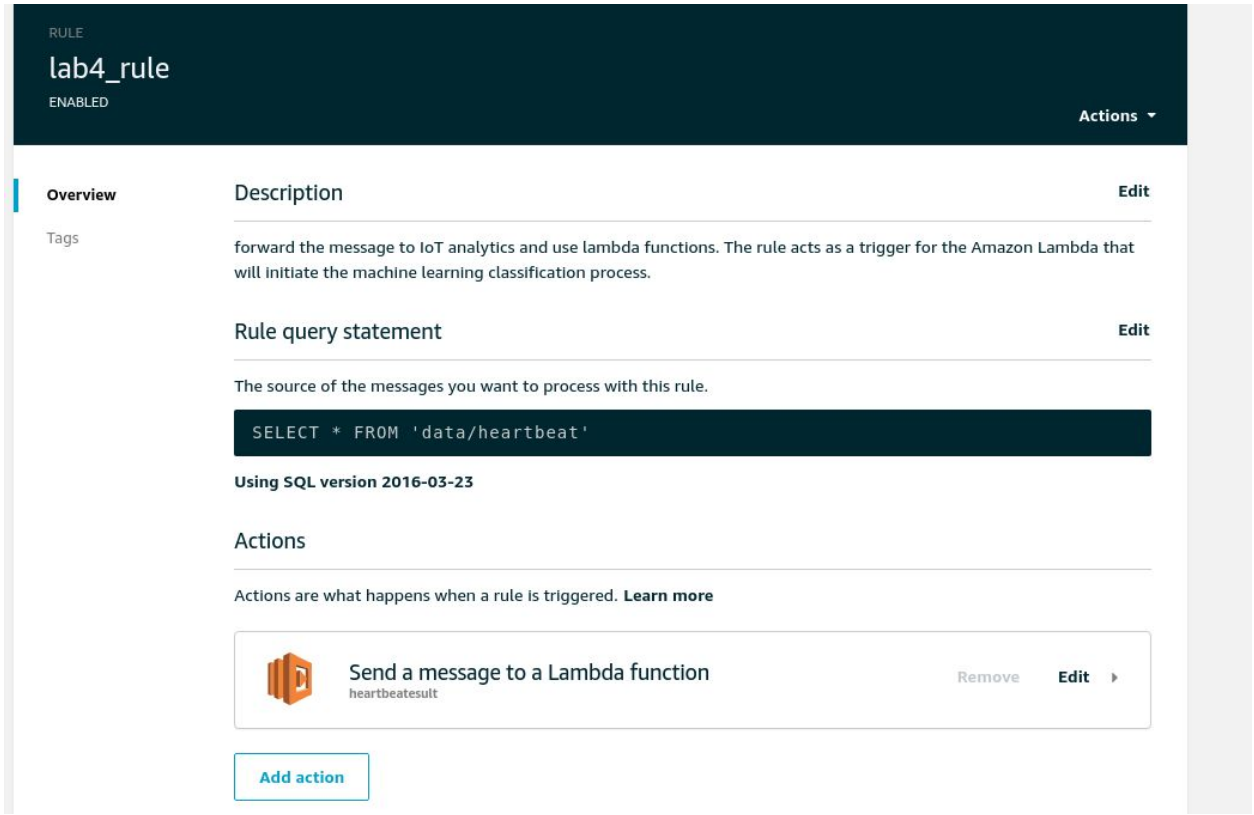

RULE
lab4_rule
ENABLED
Actions
Overview
Tags
Description
Edit
forward the message to IoT analytics and use lambda functions. The rule acts as a trigger for the Amazon Lambda that will initiate the machine learning classification process.
Rule query statement
Edit
The source of the messages you want to process with this rule.
SELECT * FROM 'data/heartbeat'
Using SQL version 2016-03-23
Actions
Actions are what happens when a rule is triggered. Learn more
Send a message to a Lambda function
heartbeatesult
Remove
Edit
Add action

Figure 2.3.2

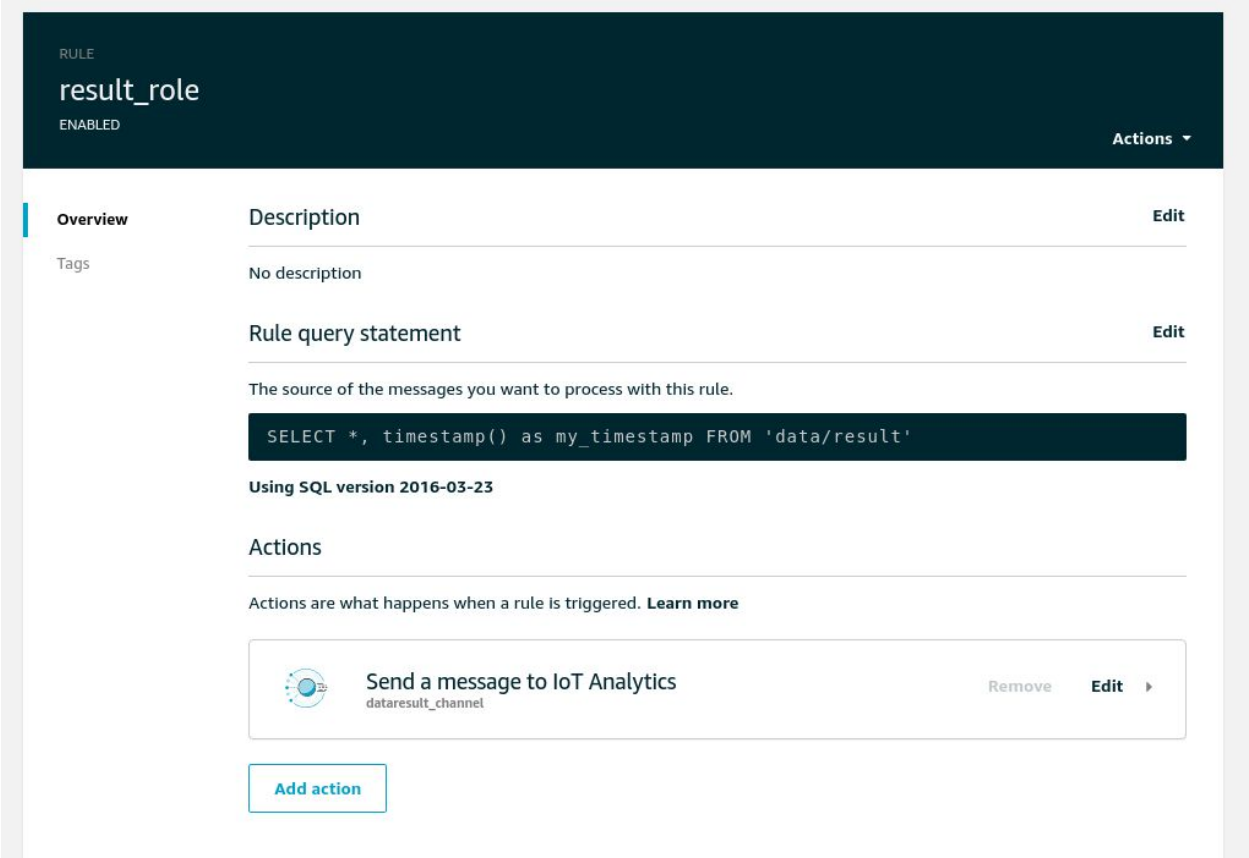


Figure 2.3.3

2.4 Create many devices

Our team modifed createThings-cert.py provided by Lab4 document, added policy names and thing certificates directory. By following the instructions, 500 things are added into AWS IoT core, and shown on aws management console. Please see the following screenshot.

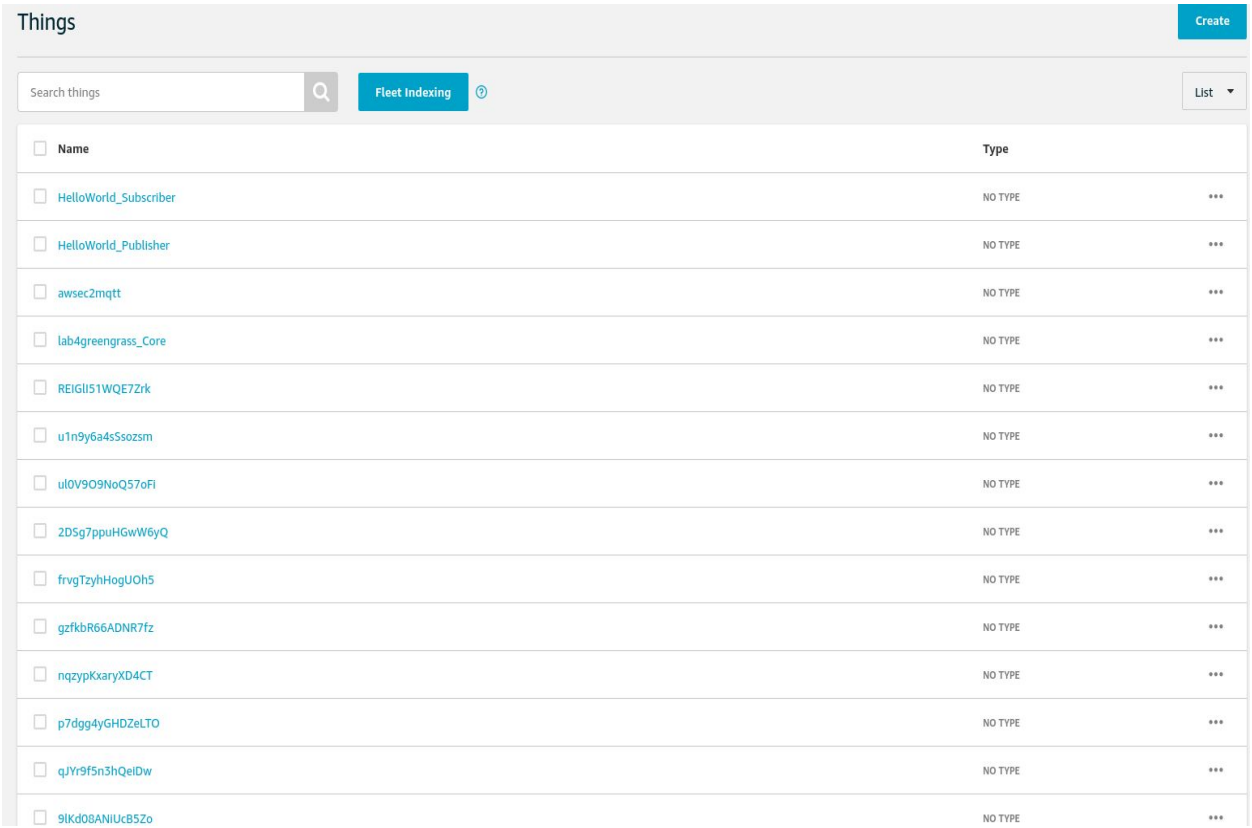

Things
Create
Search things
Fleet Indexing
List
Name
Type
HelloWorld_Subscriber
NO TYPE
HelloWorld_Publisher
NO TYPE
awsec2mqtt
NO TYPE
lab4greengrass_Core
NO TYPE
REIGlI51WQE7Zrk
NO TYPE
u1n9y6a4sSsozsm
NO TYPE
ul0V9O9NoQ57oFI
NO TYPE
2DSg7ppuHGwW6yQ
NO TYPE
frvgTzyhHogUOh5
NO TYPE
gzfkbR66ADNR7fz
NO TYPE
nqzypKxaryXD4CT
NO TYPE
p7dgg4yGHDZeLTO
NO TYPE
qJYr9f5n3hQeiDw
NO TYPE
9lKd08ANiUcB5Zo
NO TYPE

Figure 2.4.1

```
################################################ Connecting to AWS
import boto3

import json
################################################ Create random name for things
import random
import string

################################################ Parameters for Thing
thingArn = ''
thingId = ''
#thingName = ''.join([random.choice(string.ascii_letters + string.digits) for n in xrange(15)])
defaultPolicyName = 'Lab4_policy'
################################################

def createThing(i):
    global thingClient
    thingName = ''.join([random.choice(string.ascii_letters + string.digits) for n in range(15)])
    thingResponse = thingClient.create_thing(
        thingName = thingName
    )
    data = json.loads(json.dumps(thingResponse, sort_keys=False, indent=4))
    for element in data:
        if element == 'thingArn':
            thingArn = data['thingArn']
        elif element == 'thingId':
            thingId = data['thingId']
        createCertificate(thingName, i)
    return thingName

def createCertificate(thingName, i):
    global thingClient
    certResponse = thingClient.create_keys_and_certificate(
        setAsActive = True
    )
    data = json.loads(json.dumps(certResponse, sort_keys=False, indent=4))
    for element in data:
        if element == 'certificateArn':
            certificateArn = data['certificateArn']
        elif element == 'keyPair':
            PublicKey = data['keyPair']['PublicKey']
            PrivateKey = data['keyPair']['PrivateKey']
        elif element == 'certificatePem':
            certificatePem = data['certificatePem']
        elif element == 'certificateId':
```

Figure 2.4.2: screenshot of createThing-cert.py

2.5 Use the device simulator

Our team installed AWSIoTPythonSDK, and modified lab4 emulator client.py provided by lab4 instruction. First, the data and certificate directories are changed:

#Path to the dataset, modify this
data_path = "data/class_{}.csv"

#Path to your certificates, modify this
certificate_formatter = "certificates/thing_{}.certificate.pem"
key_formatter = "certificates/thing_{}.private.pem"
Second, the endpoint ARN and credential are modified:

self.client.configureEndpoint("a191olynvpydfg-ats.iot.us-west-2.amazonaws.com", 8883)
self.client.configureCredentials("root-ca-cert.pem", key, cert)
At last, we modifed publish function to publish the data from csv file properly.

```
index = np.random.randint(0, len(data[self.state]))
payload = {
        "device_id": self.device_id,
        "class": str(self.state),
        "features": list(data[self.state].iloc[index].values)
}
self.client.publishAsync("data/heartbeat", json.dumps(payload), 0,
ackCallback=self.customPubackCallback)
```

After changes above, we were able to execute the python script, and sent data with topic “data/heartbeat”

2.6 GreenGrass

We set up our GreenGrass core on an EC2 instance and open port 22 and 8883 to allow SSH and MQTT protocol to access the EC2 instance. Once we finished EC3 instance set up, we installed AWS IoT Greengrass Core software. At last, Greengrasss started by command:

```
cd /greengrass/ggc/core/
sudo ./greengrassd start
```

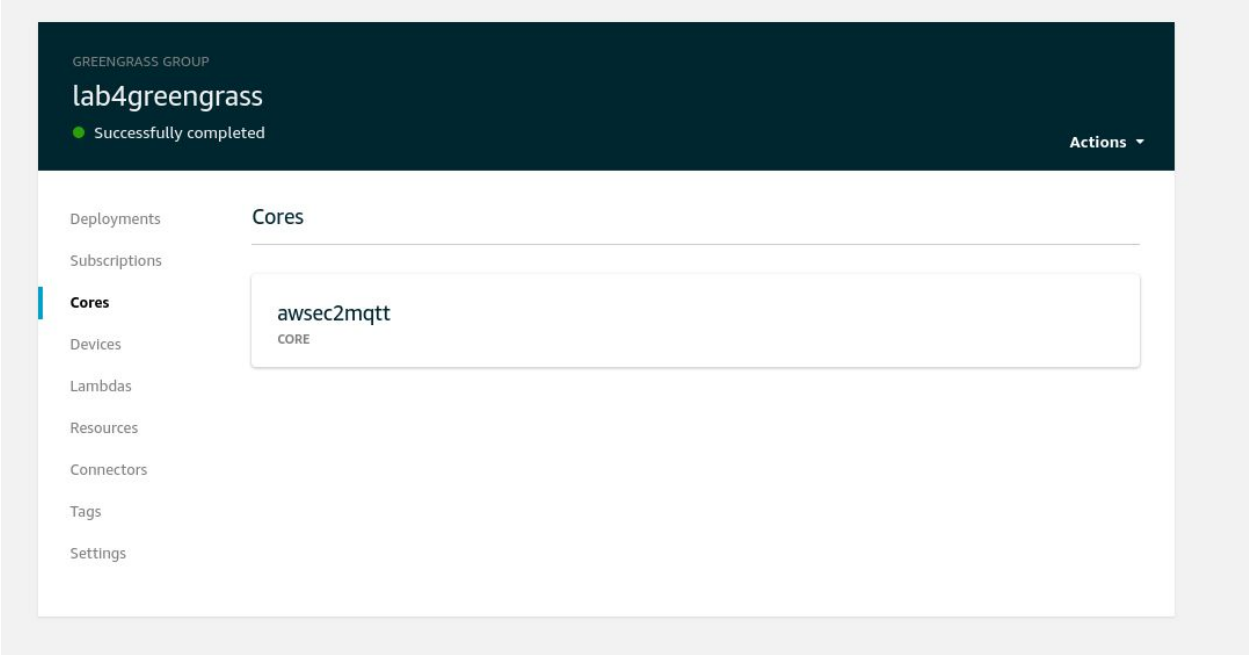


Figure 2.6.1

Following AWS instruction, we then set up few IoT devices (Python clients). We also set up numerous subscriptions
between the publisher device, subscriber device, IoT cloud, and lambda functions.

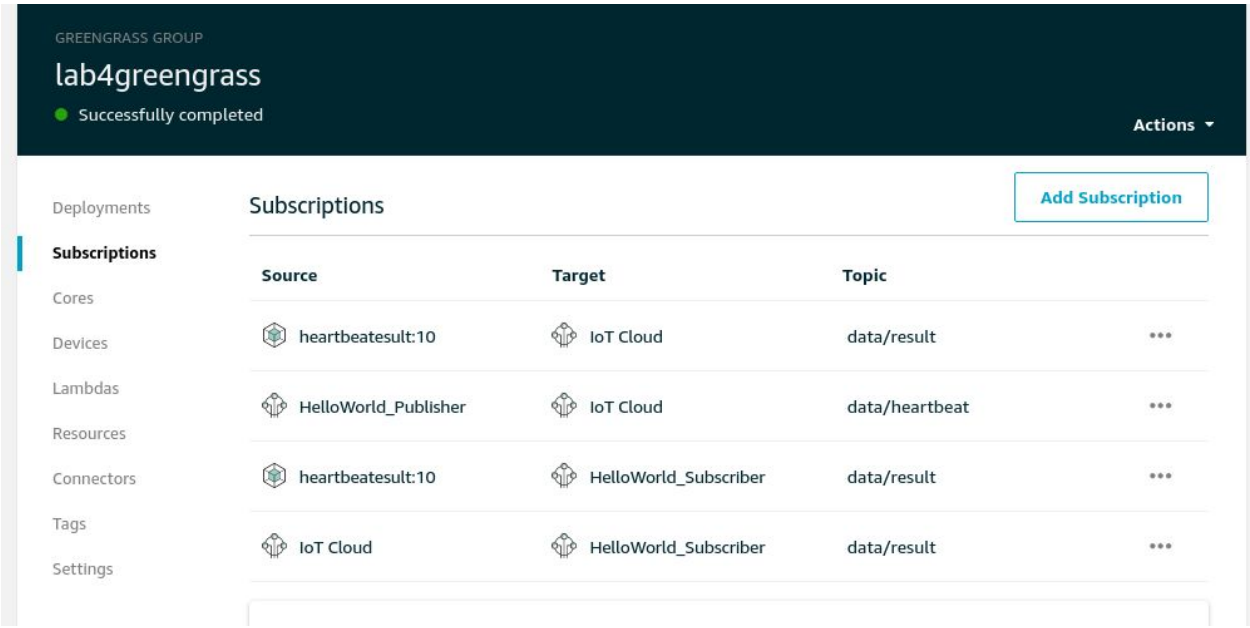


Figure 2.6.2

3. Understand the Data

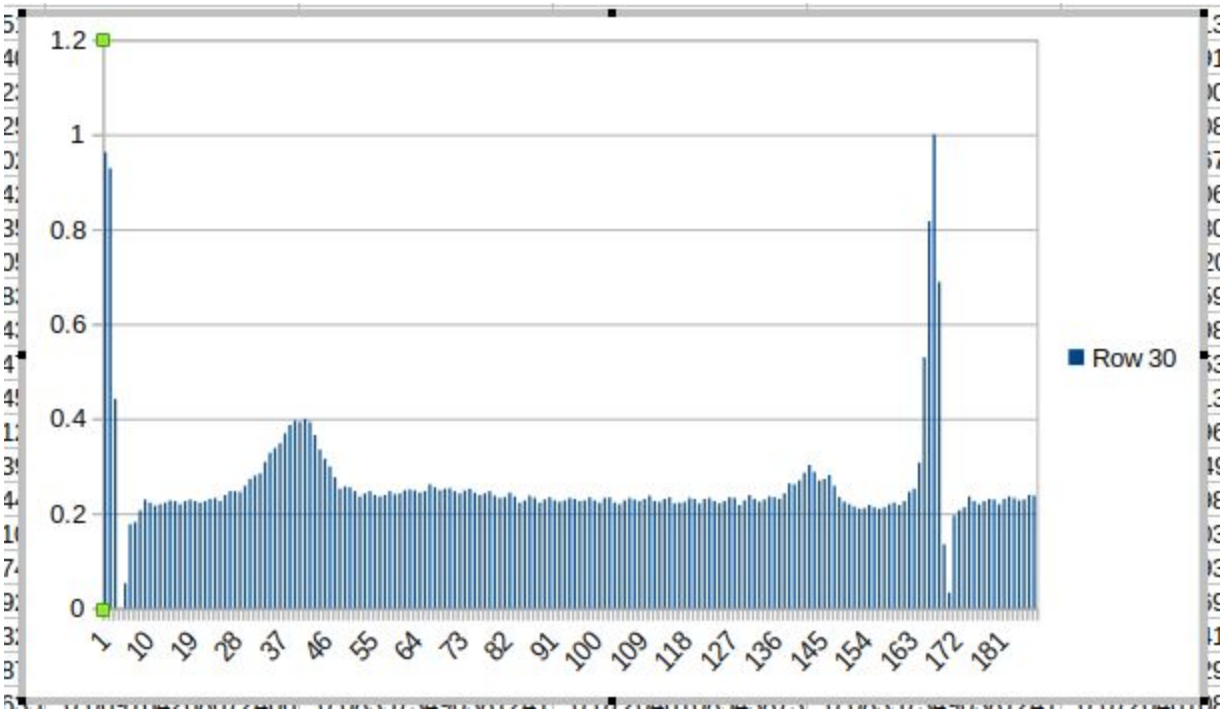


Figure 3.1

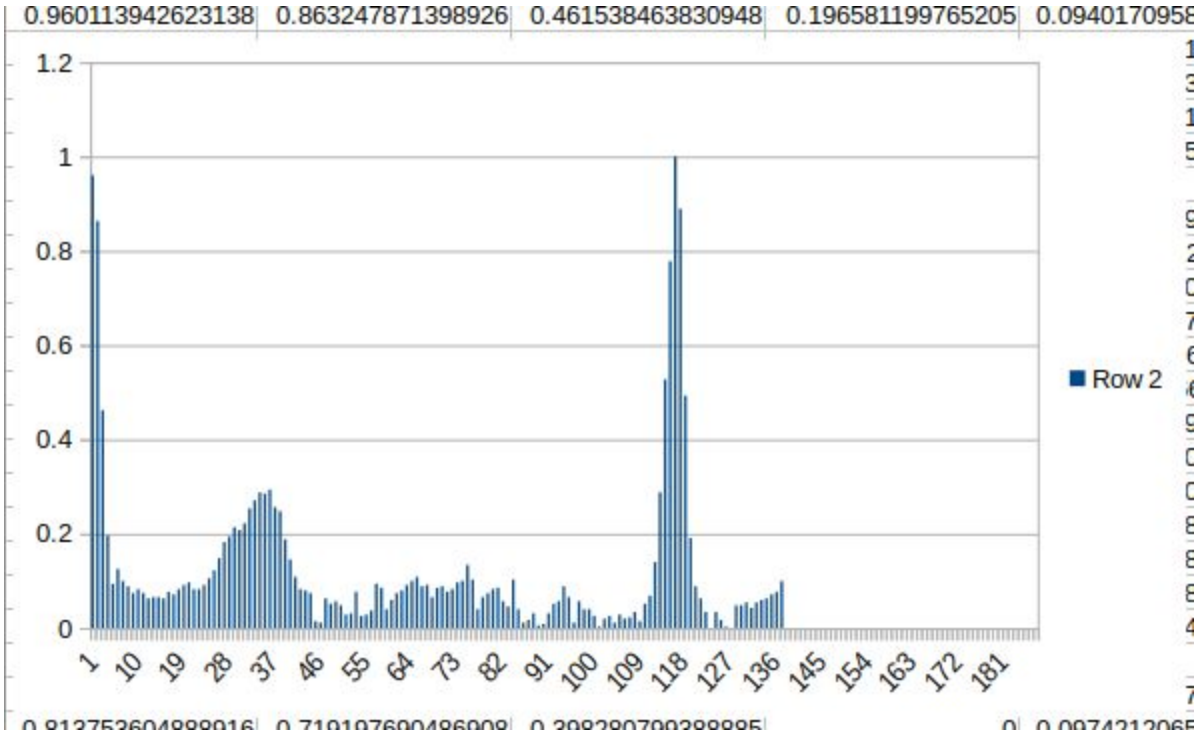


Figure 3.2

We downloaded data.zip provided by lab4 instruction. From the plot we created, we can see the figure matches "QRS complex" - electrical pattern observed on ECG from human heartbeat. There are 5 csv files in data.zip: we put the data source directory in our publishing python script. We learned each row represents heartbeats from one watch. We used the topic ‘data/heartbeat’ to publish messages to IOT Core. IoT Core then forwards messages to Lambda functions and IoT analytics.

4. Data Inference with ML

4.1 Process incoming messages in Lambda

1. Create Amazon Lambda with Python 2.7
2. Add Trigger with Forward Rule

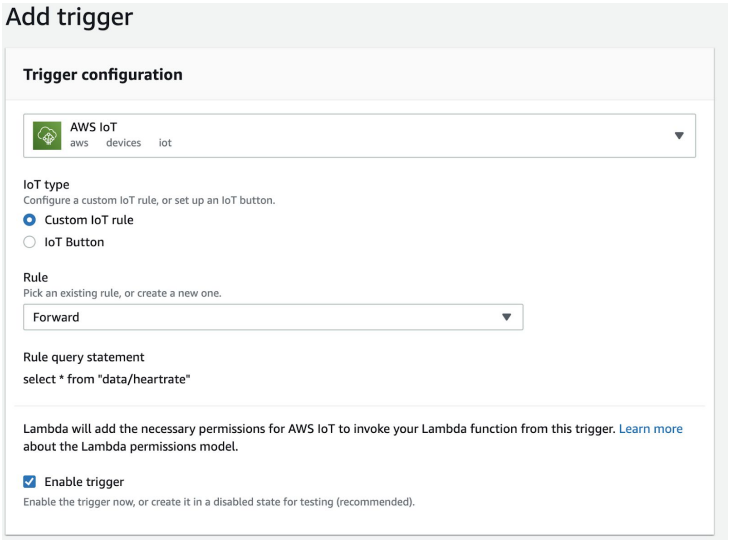


Figure 4.1.1

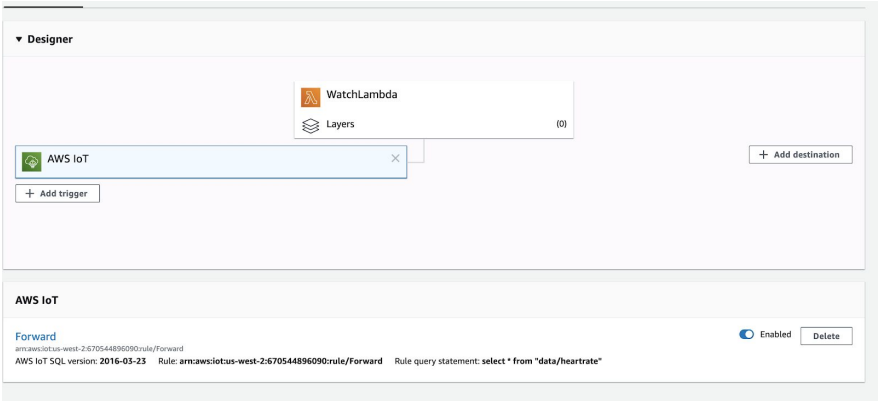


Figure 4.1.2

3. Add functional code

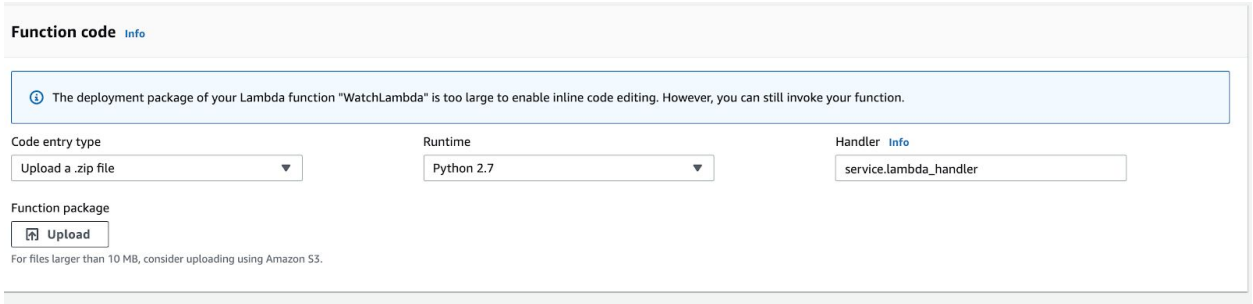


Figure 4.1.3

4. Configure proper role policy to allow write back to AWS IoT (AWSIoTDataAccess)

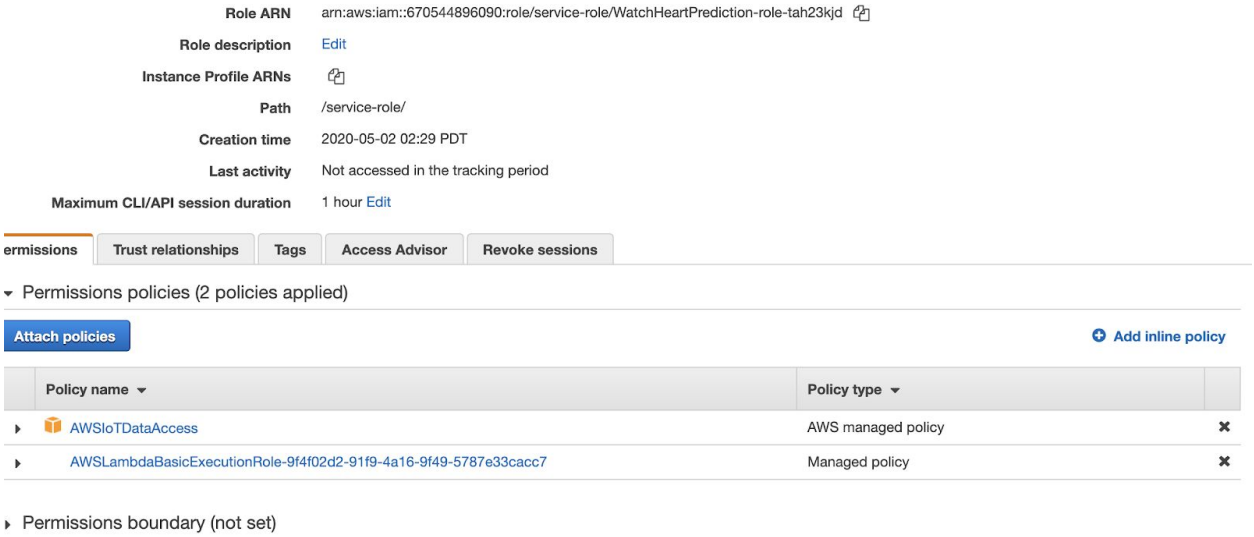


Figure 4.1.4

4.2 Return your results back to device

Add IoT communication client back to service.py

```
#-*- coding: utf-8 -*-
import boto3
import numpy as np
import scipy
import sklearn
import json
import pickle


class Classifier:
    def __init__(self):
        with open("model.pkl", "rb") as f:
```

```
            self.model = pickle.load(f)

    def predict(self, data):
        z = self.model.predict([data])
        return z[0]


classifier = Classifier()
iot_data = boto3.client('iot-data', region_name='us-west-2')

def lambda_handler(event, context):
    # TODO1: Get your data
    data = event["features"]
    data = np.array(data).astype(np.float)
    out = classifier.predict(data)

    response = iot_data.publish(
        topic='data/heartattack',
        qos=1,
        payload=json.dumps({
            "device_id": event["device_id"],
            "classification": out
        })
    )
```

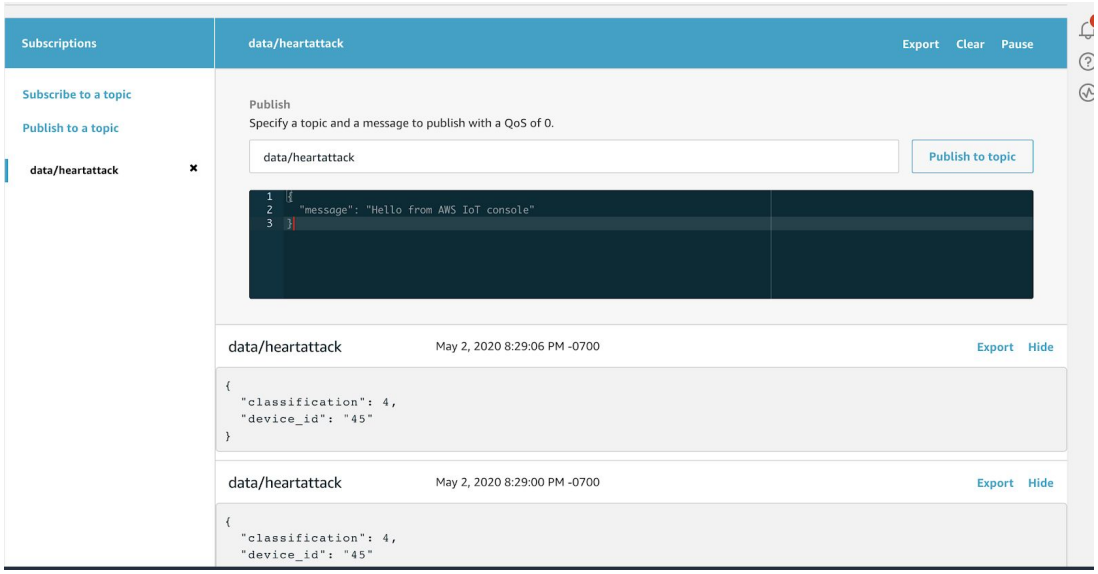


Figure 4.2.1

Ideally one device should only see its own result, for privacy and security. Given the Pub/Sub mechanism of MQTT protocol, it is impractical as the number of topics will grow linearly as the number of devices. Given the current data is not sensitive, there are no personal identifiable attributes or location, each device can see others' prediction results, allowing us to use shared topic for returning results. Each device needs to listen and filter on the result topic and only respond to topics addressing itself.

5. Use IoT Analytics to visualize the Data

5.1 Background

We configure the AWS IoT Analytics Stack using the Wizard. Many steps are automatically created and later configured with detail connection info.

Figure 5.1.1

5.2 Setup data path

Configure AWS IoT Analytics Pipeline to stream data from Channel to Storage

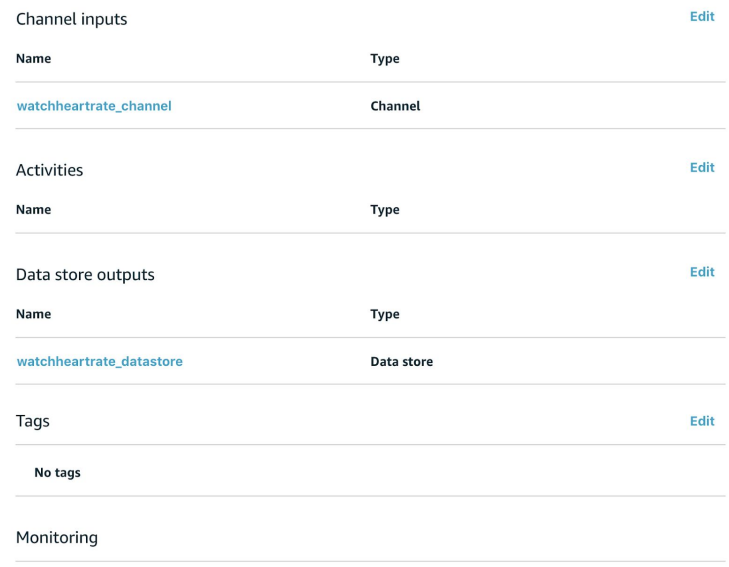


Figure 5.2.1
Define data attributes

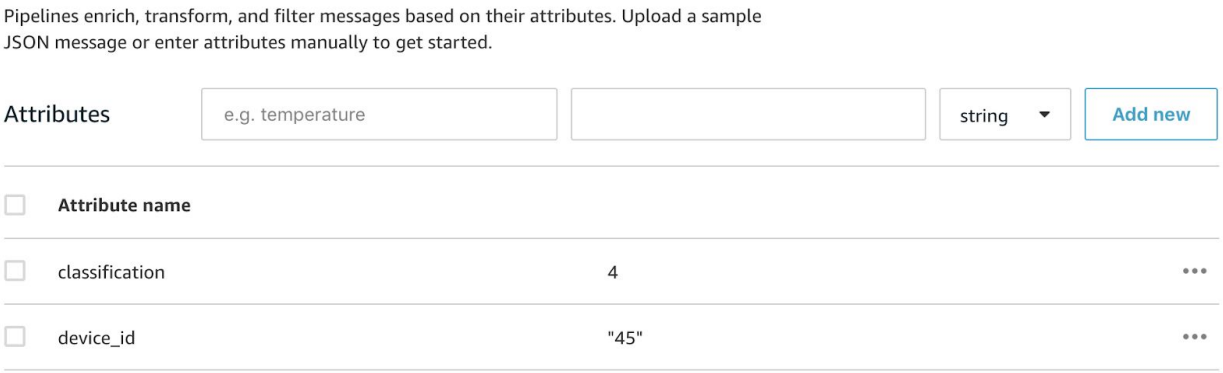


Figure 5.2.2

5.3 Set up the data set and test if you can receive data

The data from the previous Lambda function test is present here.

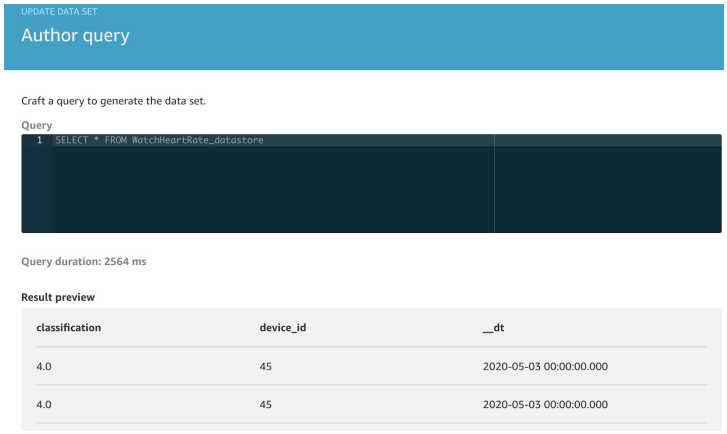
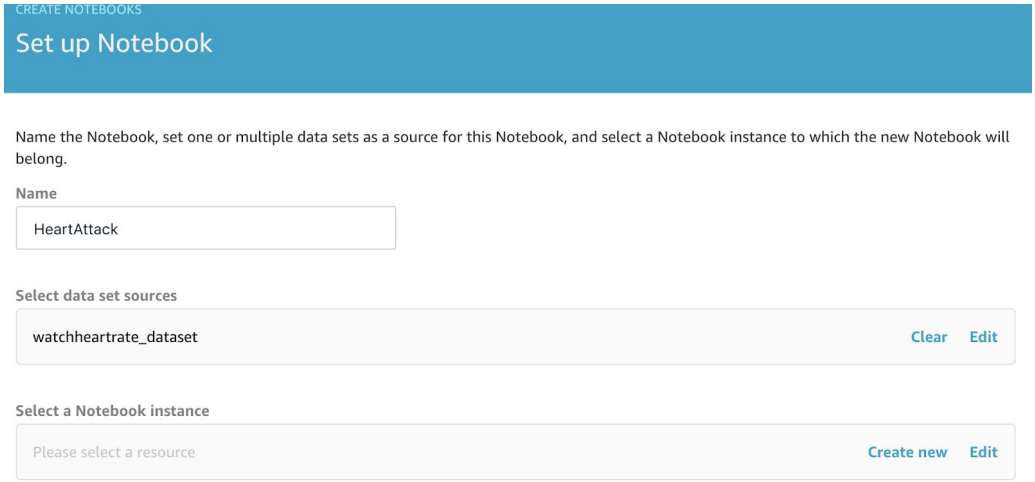


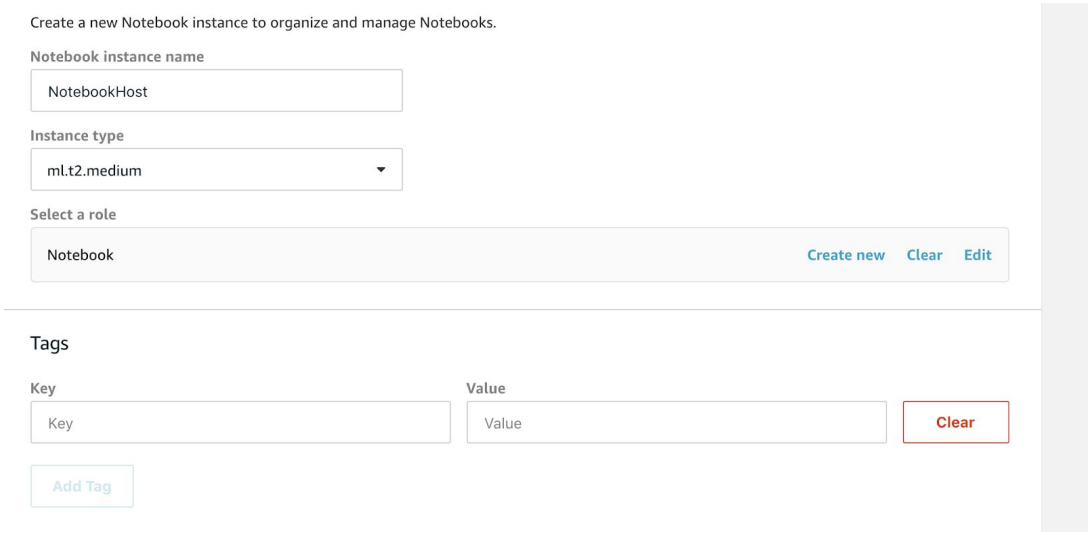
Figure 5.3.2

5.4 Create Jupyter notebook

Create Notebook



Create Notebook Instance to host notebook execution



5.5 Visualize the data

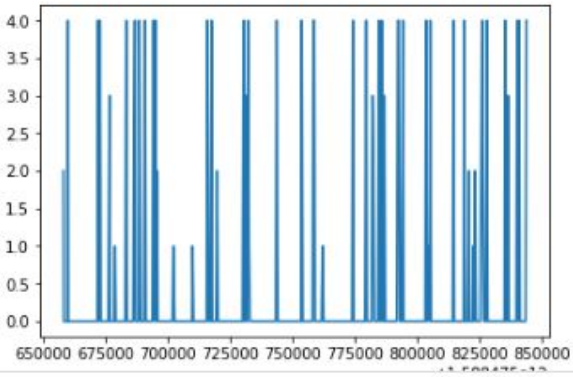
After steps above, we opened notebook in Jupyter Notebook.
Dataset and dataset_url are already loaded. We need to plot the data in the datastore. As the requirement of Lab4.
“When you are done, connect your cloud to our emulator. Write some scripts to predict heart attacks. Produce a chart of the number of lives you save.”
We plotted prediction result vs. timestamp. Please see the following figure includes the python script.

In [1]:
```
import boto3
import pandas as pd
from matplotlib import pyplot as plt

# create IoT Analytics client
client = boto3.client('iotanalytics')
```

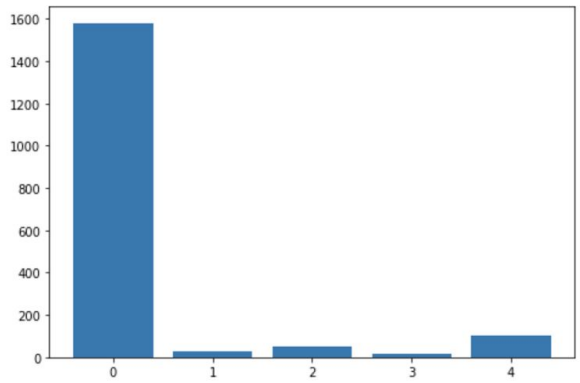
Now we can get the data location (URL) for the given dataset and start working with the data (In order to need to perform grant iot analytics corresponding IAM permission):

In [2]:
```
dataset = "dataresult_dataset"
dataset_url = client.get_dataset_content(datasetName = dataset)['entries'][0]['dataURI']

# start working with the data
```

In [3]:
```
df = pd.read_csv(dataset_url)
x = df.my_timestamp
y = df.prediction
fig, ax = plt.subplots()
ax.plot(x,y)
#df.my_timestamp.plot(legend=True)
#df.prediction.plot(legend=True)
plt.show()
```



```
df=pd.read_csv(dataset_url)
df= df.classification.value_counts()
df = df.reset_index()
df = df.sort_values(['index'])
fig = plt.figure()
ax = fig.add_axes([0,0,1,1])
x = df["index"]
y = df["classification"]
ax.bar(x,y)
plt.show()
```



6. Problems that encountered

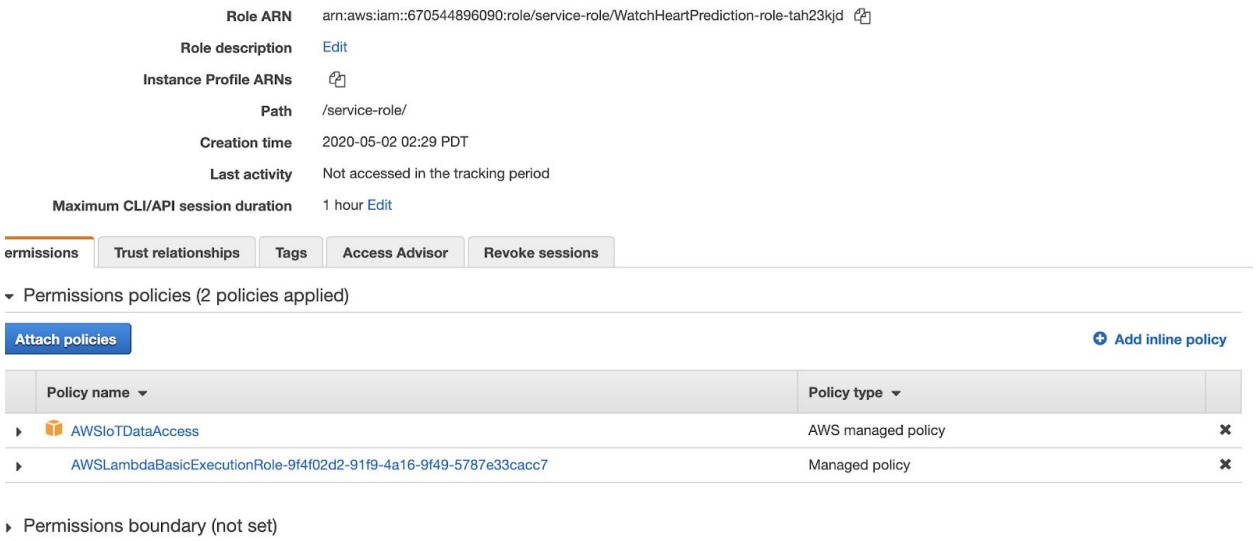
1. Boto3, AWSCLI on different versions of Python.
   The example provided for creating Certificates and IoT things are on Python 2.
   Resolution is to use mixed Python2 and Python3 in development.
2. Automatically created policies sometimes are too restrictive or using default generated ARN.

```
➜ lab4 python test.py
No handlers could be found for logger "AWSIoTPythonSDK.core.protocol.mqtt_core"
Traceback (most recent call last):
  File "test.py", line 16, in <module>
    myMQTTClient.connect()
  File "/usr/local/lib/python2.7/site-packages/AWSIoTPythonSDK/MQTTLib.py", line 513, in connect
    return self._mqtt_core.connect(keepAliveIntervalSecond)
  File "/usr/local/lib/python2.7/site-packages/AWSIoTPythonSDK/core/protocol/mqtt_core.py", line 199, in connect
    raise connectTimeoutException()
AWSIoTPythonSDK.exception.AWSIoTExceptions.connectTimeoutException
➜ lab4 python test.py
```

Solution: change policy to something like below -- key is to set resources to “*” or a predetermined set of topic names.

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": [
        "iot:*",
        "iot:Publish",
        "iot:Subscribe",
        "iot:Connect",
        "iot:Receive"
      ],
      "Resource": "*"
    }
  ]
}
```

3. AWS Lambda failed to write back to the IoT Data stream
   Solution: grant permission through AWS Lambda execution role by attaching correct policy.



4. AWS Lambda throws error
   "errorMessage": "Unable to import module 'service': dynamic module does not define module export function (PyInit_multiarray)",
   "errorType": "Runtime.ImportModuleError"
   The instruction of importing and configuring Lambda functions follows after GreenGrass configuration. In GreenGrass configuration, the python version is 3.7. The code provided in the Lab instruction is based on Python 2.7.
   Solution: modify runtime of the AWS Lambda function to 2.7.

7. Individual Contributions:

Team members are working on the project individually on section 1 -4. But, when issues were encountered, we discussed and helped each other to troubleshoot. Each team member has full understanding of lab4, and is able to demo any part of the lab.