

Chapter 7C: Amazon Web Services (AWS)

Time 2 ½ Hours

At this end of Chapter 7C you will understand:

How the [AWS Cloud](#) works including:

- How to provision "things" (which for semantic reasons, will be notated *thing*, a.k.a. your IoT device, in this chapter) in the AWS IoT Cloud by creating a *thing*, policies and certificates.
- AWS Security
- The *thing* shadow
- How to use the AWS IoT test Client to subscribe and publish to topics
- Understand the scope of systems that can be implemented in the AWS Cloud (SNS, Database etc.)

How to write WICED firmware to interact with the AWS IoT Cloud using MQTT

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7C.1 Amazon Web Services (AWS)

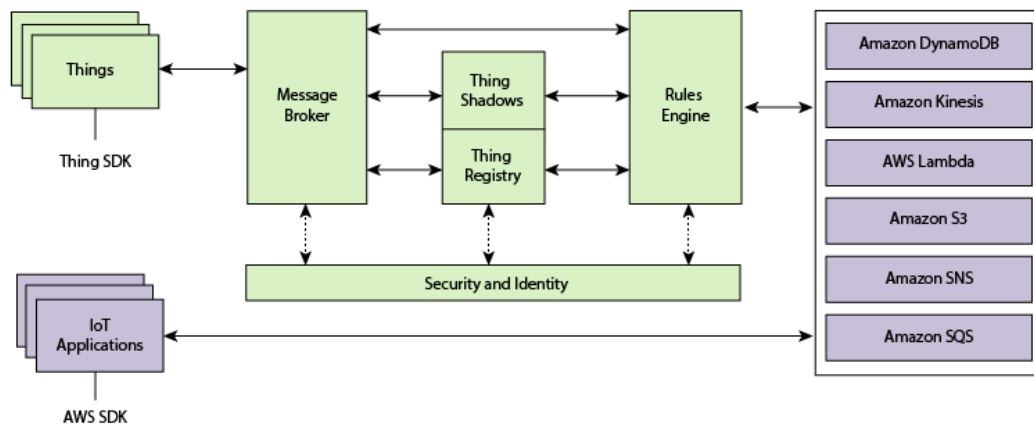
[AWS](#) is a secure cloud services platform, offering compute power, database storage, content delivery and other functionality (which makes more money for Amazon than their retail operations). AWS is built from a vast array of both virtual and actual servers and networks as well as a boatload of webserver software and administrative tools including (partial list):

- [AWS IoT](#): A cloud platform that provides Cloud services for IoT devices (the subject of this chapter).
- Amazon Elastic Cloud ([EC2](#)/[EC3](#)): A virtualized compute capability, basically Linux, Windows etc. servers that you can rent.
- [Amazon Lambda](#): A Cloud service that enables you to send event driven tasks to be executed.
- Storage: Large fast file systems called [Amazon S3](#) & [AWS Elastic File System](#).
- Databases: Large fast databases called [Dynamo DB](#), [Amazon Relational Database \(RDS\)](#), [Amazon Aurora](#).
- Networking: Fast, fault tolerant, load balanced networks with entry points all over the world.
- Developer tools: A unified programming API supporting the AWS platform supporting a bunch of different languages.
- [Amazon Simple Notification System \(SNS\)](#): A platform to send messages including SMS and Email.
- [Amazon Simple Queueing Services \(SQS\)](#): A platform to send messages between servers (NOT the same thing a MQTT messages).
- [Amazon Kinesis](#): A platform to stream and analyze "massive" amounts of data. This is the plumbing for AWS IoT.

7C.2 AWS IoT Introduction

The AWS IoT Cloud service supports MQTT Message Brokers, HTTP access, **plus** a bunch of server-side functionality that provides:

- Message Broker: A virtual MQTT Message Broker.
- A virtual HTTP Server.
- Thing Registry: A web interface to manage the access to your *things*.
- Security and identity: A web interface to manage the certificates and rules about *things*. You can create encryption keys and manage access privileges.
- A "shadow": An online cache of the most recent state of your *thing*.
- Rules Engine: An application that runs in the cloud that can subscribe to Topics and take programmatic actions based on messages – for example, you could configure it to subscribe to an "Alert" topic, and if a *thing* publishes a warning message to the alert topic, it uses Amazon SNS to send a SMS Text Message to your cell phone
- IoT Applications: An SDK to build Web pages and cell phone Apps.



7C.3 AWS IoT Resources

There are three types of resources in AWS: *Things*, *Certificates*, and *Policies*. The second exercise will take you step by step through the process to create each of them.

Thing

A *thing* is a representation of a device or logical entity. It can be a physical device or sensor (for example, a light bulb or a switch on a wall). It can also be a logical entity like an instance of an application or a physical entity that does not connect to AWS IoT but can be related to other devices that do (for example, a car that has engine sensors or a control panel).

Certificate

AWS IoT provides mutual authentication and encryption at all points of connection so that data is never exchanged between *things* and AWS IoT without a proven identity. AWS IoT supports X.509 certificate-based authentication. Connections to AWS use certificate-based authentication. You should attach policies to a certificate to allow or deny access to AWS IoT resources. A root CA (certification authority) certificate is used by your device to ensure it is communicating with the actual Amazon Web Services site. You can only connect your *thing* to the AWS IoT Cloud via TLS.

Policy

After creating a certificate for your internet-connected *thing*, you must create and attach an AWS IoT policy that will determine what AWS IoT operations the *thing* may perform. AWS IoT policies are JSON documents and they follow the same conventions as AWS Identity and Access Management policies.

You can specify permissions for specific resources such as topics and shadows. Here is an example of a Policy created for a new *thing* that allows any IoT action for any resource.

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

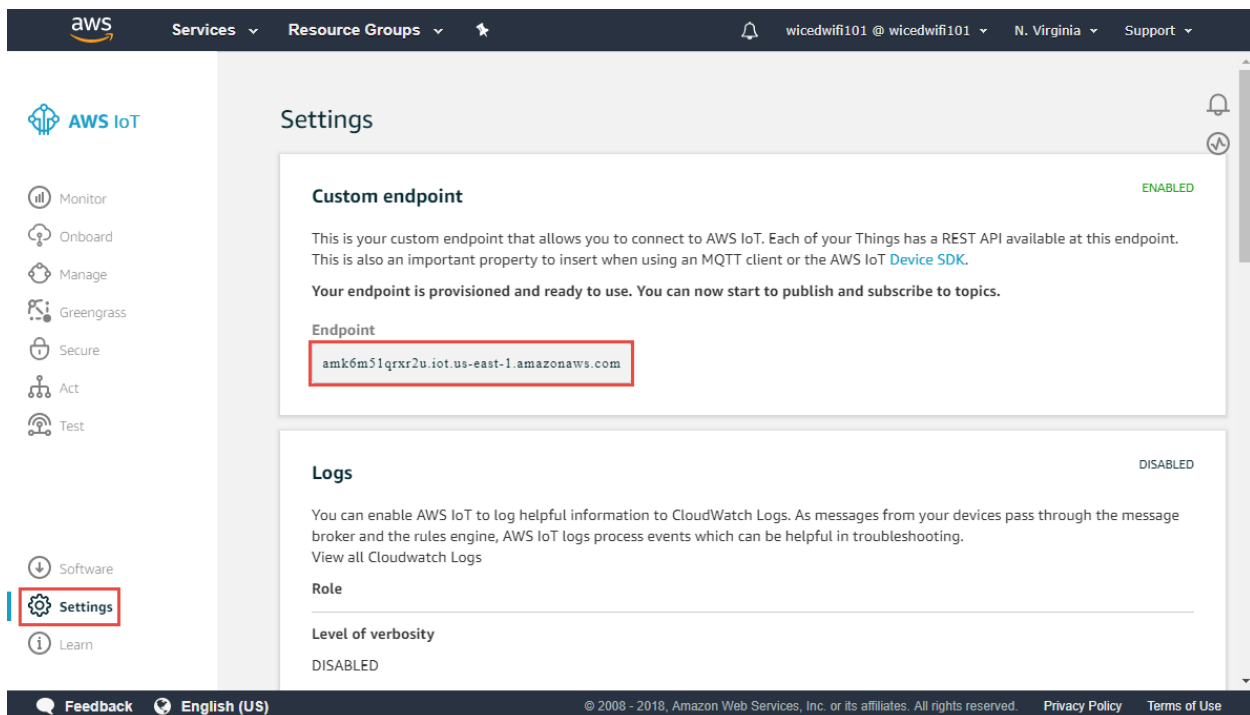
7C.4 AWS IoT Console

7C.4.1 Creating an AWS IoT Account

To create a new AWS account, you need to provide a credit card number. The basic account is free for a year but if you don't cancel before that (or remove your credit card from the Amazon payment options) it will start charging your credit card after a year. For that reason, we have setup a class AWS account (called an IAM account instead of a root account) that you can use for the exercises. However, the password for that account may be changed after the class is over and any *things* you create there will be deleted. If you want to continue to use AWS after the class you will need to setup your own account.

When you create an AWS IoT account, Amazon will create a new virtual machine for you in the Cloud and will turn on an MQTT Message Broker and HTTP server on that machine. To connect your WICED device to the machine you will need to know the DNS name of the virtual machine.

To find the virtual machine's DNS name, click on "Settings" at the lower left corner of the main console window. The name is listed as the Endpoint.



The screenshot shows the AWS IoT console interface. At the top, the AWS logo and navigation tabs (Services, Resource Groups) are visible. The user is logged in as 'wicedwifi101' in the 'N. Virginia' region. The left sidebar contains various IoT-related icons, with 'Settings' highlighted by a red box. The main content area is titled 'Settings' and features two sections: 'Custom endpoint' and 'Logs'. The 'Custom endpoint' section is marked 'ENABLED' and displays the endpoint 'amk6m51qrxr2u.iot.us-east-1.amazonaws.com' within a red-bordered box. The 'Logs' section is marked 'DISABLED' and provides information about logging to CloudWatch Logs.

7C.4.2 [Thing Shadow](#)

A *thing* shadow (sometimes referred to as a device shadow) is a JSON document that is used to store and retrieve current state information for a *thing* (device, app, and so on). The *Thing* Shadows service maintains a *thing* shadow for each *thing* you connect to AWS IoT. You can use *thing* shadows to get and set the state of a *thing* over MQTT or HTTP, regardless of whether the *thing* is currently connected to the Internet. Each *thing* shadow is uniquely identified by its name.

The JSON Shadow document representing the device has the following properties:

- state:
 - desired: The desired state of the *thing*. Applications can write to this portion of the document to update the state of a *thing* without having to directly connect to a *thing*.
 - reported: The reported state of the *thing*. *Things* write to this portion of the document to report their new state. Applications read this portion of the document to determine the state of a *thing*.
- metadata: Information about the data stored in the state section of the document. This includes timestamps, in Epoch time, for each attribute in the state section, which enables you to determine when they were updated.
- timestamp: Indicates when the message was transmitted by AWS IoT. By using the timestamp in the message and the timestamps for individual attributes in the desired or reported section, a *thing* can determine how old an updated item is, even if it doesn't feature an internal clock.
- clientToken: A string unique to the device that enables you to associate responses with requests in an MQTT environment.
- version: The document version. Every time the document is updated, this version number is incremented. Used to ensure the version of the document being updated is the most recent.

An example of a shadow document looks like this:

```
{
  "state": {
    "desired": {
      "color": "RED",
      "sequence": [ "RED", "GREEN", "BLUE" ]
    },
    "reported": {
      "color": "GREEN"
    }
  },
  "metadata": {
    "desired": {
      "color": {
        "timestamp": 12345
      },
      "sequence": {
        "timestamp": 12345
      }
    },
    "reported": {
      "color": {
        "timestamp": 12345
      }
    }
  },
  "version": 10,
  "clientToken": "UniqueClientToken",
  "timestamp": 123456789
}
```

If you want to update the Shadow, you can publish a JSON document with just the information you want to change to the correct topic. For example, you could do:

```
{
  "state" : {
    "reported" : {
      "color": "BLUE"
    }
  }
}
```

Note that spaces and carriage returns are optional, so the above could be written as:

```
{"state":{"reported":{"color": "BLUE"}}
```

7C.4.3 Topics

You can interact with AWS using either MQTT or HTTP. While topics are an MQTT concept, you will see later that topic names are important even when using HTTP to interact with *thing* shadows. The AWS Message Broker will allow you to create Topics with almost any name, with one exception: Topics named "\$aws/..." are reserved by AWS IoT for specific functions.

As the system designer, you are responsible for defining what the topics mean and do in your system. Some [best practices](#) include:

1. Don't use a leading forward slash
2. Don't use spaces
3. Keep the topic short and concise
4. Use only ASCII characters
5. Embed a unique identifier e.g. the name of the *thing*

For example, a good topic name for a temperature sensing device might be: myDevice/temperature.

7C.4.4 [Device Shadow Topics](#)

Each *thing* that you have will have a group of topics of the form "\$aws/things/<thingName>/shadow/<type>" which allow you to publish and subscribe to topics relating to the shadow. The specific shadow topics that exist are:

MQTT Topic Suffix <type>	Function
/update	The JSON message that you publish to this topic will become the new state of the shadow.
/update/accepted	AWS will publish a message to this topic in response to a message to /update indicating a successful update of the shadow.
/update/documents	When a document is updated via a publish to /update, the complete new document is published to this topic.
/update/rejected	AWS will publish a message to this topic in response to a message to /update indicating a rejected update of the shadow.
/update/delta	After a message is sent to /update, the AWS will send a JSON message if the desired state and the reported state are not equal. The message contains all attributes that don't match.
/get	If a <i>thing</i> publishes a message to this topic, AWS will respond with a message to either /get/accepted or /get/rejected with the current state of the shadow.
/get/accepted	
/get/rejected	
/delete	If a <i>thing</i> publishes a message to this topic, AWS will delete the shadow document.
/delete/accepted	AWS will publish to this topic when a successful /delete occurs.
/delete/reject	AWS will publish to this topic when a rejected /delete occurs.

The update topic is useful when you want to update the state of a *thing* on the cloud. For example, if you have a *thing* called "myThing" and want to update a value called "temperature" to 25 degrees in the state of the thing, you would publish (for MQTT) or POST (for HTTP) using the following topic and message:

topic: \$aws/things/myThing/shadow/update

message: {"state":{"reported":{"temperature":25}}}

Once the message is received, the MQTT message broker will publish to the /accepted, and /documents topics with the appropriate information.

If you are using the MQTT test server to subscribe to topics, you can use "#" as a wildcard at the end of a topic to subscribe to multiple topics. For example, you can use "\$aws/things/theThing/shadow/#" to subscribe to all shadow topics for the *thing* called "theThing".

You can also use "+" as a wildcard in the middle of a topic to subscribe to multiple topics. For example, you can use "\$aws/things/+ /shadow/update" to subscribe to update topics for all *thing* shadows.

7C.5 Using MQTT with AWS

The WICED SDK contains libraries of functions that make it easier to create MQTT firmware. These functions are contained in `libraries/protocols/MQTT` for general MQTT projects and `libraries/protocols/AWS` for AWS specific projects. To include the library in a project, two things are needed:

In the Make File: `$(NAME)_COMPONENTS := protocols/AWS`

In the C Source: `#include "wiced_aws.h"`
`#include "aws_common.h"`

In addition to the library, there are several demo applications that can be used as a starting point for using MQTT with AWS. These applications are: `apps/demo/aws/iot`:

- `apps/demo/aws/iot/pub_sub/publisher`
 - Publish a message when a button is pressed on the kit.
- `apps/demo/aws/iot/pub_sub/subscriber`
 - Subscribe to messages that control an LED on the kit.
- `apps/demo/aws/iot/shadow`
 - Interact with a *thing* via the shadow. This project also demonstrates using a configuration AP and a web server to set up the Wi-Fi configuration and security certificates.
- `apps/demo/aws/iot/greengrass/publisher`
 - A publishing app using AWS Greengrass. Greengrass is a software package that extends the AWS cloud capabilities to local devices making it possible for them to collect and analyze data closer to the source.
- `apps/demo/aws/iot/greengrass/subscriber`
 - A subscriber app using AWS Greengrass.

The security certificates and keys for each of these projects are read from `resources/apps/aws/iot/`. The keys are included in the project using the following (example shown for the publisher project):

In the Make File: `$(NAME)_RESOURCES := apps/aws/iot/rootca.cer \`
`apps/aws/iot/publisher/client.cer \`
`apps/aws/iot/publisher/privkey.cer`

In the C Source: `#include "resources.h"`

In the exercises below, we will use the publisher, subscriber, and shadow projects as starting points to learn the details of using WICED to interact with AWS using MQTT. **The exercises will use the AWS library, but the solutions also include projects that do the same thing using the general MQTT library for reference.**

7C.6 Using HTTPS with AWS

In addition to MQTT, AWS supports a [REST API](#) interface to their cloud. The REST API Endpoint is:

```
https://<your_endpoint>:8443/things/<your_thing_name>/shadow
```

Note that the port that AWS uses for secure HTTP traffic is 8443 instead of the typical 443.

The connection must have a client verified connection (you need to provide your certificate and private key). Use `wiced_tls_init_identity` to initialize the identity and then provide a pointer to the identity to the `http_client_init` function. After you have a connection you can GET, POST and DELETE the document which is in JSON format.

Here is an example of a CURL connection to AWS:

```
CURL -v --cert 6fb5d874d6-certificate.pem --key 6fb5d874d6-private.pem --cacert rootca.cer -X GET  
https://amk6m51qrxr2u.iot.us-east-1.amazonaws.com:8443/things/ww101_39/shadow
```

7C.7 Exercise(s)

Exercise - 7C.1 Run the AWS Tutorial

Run the tutorial on the Amazon IoT Console (console.aws.amazon.com)

Sign up for an AWS account or use the class account. The login for the class account is:

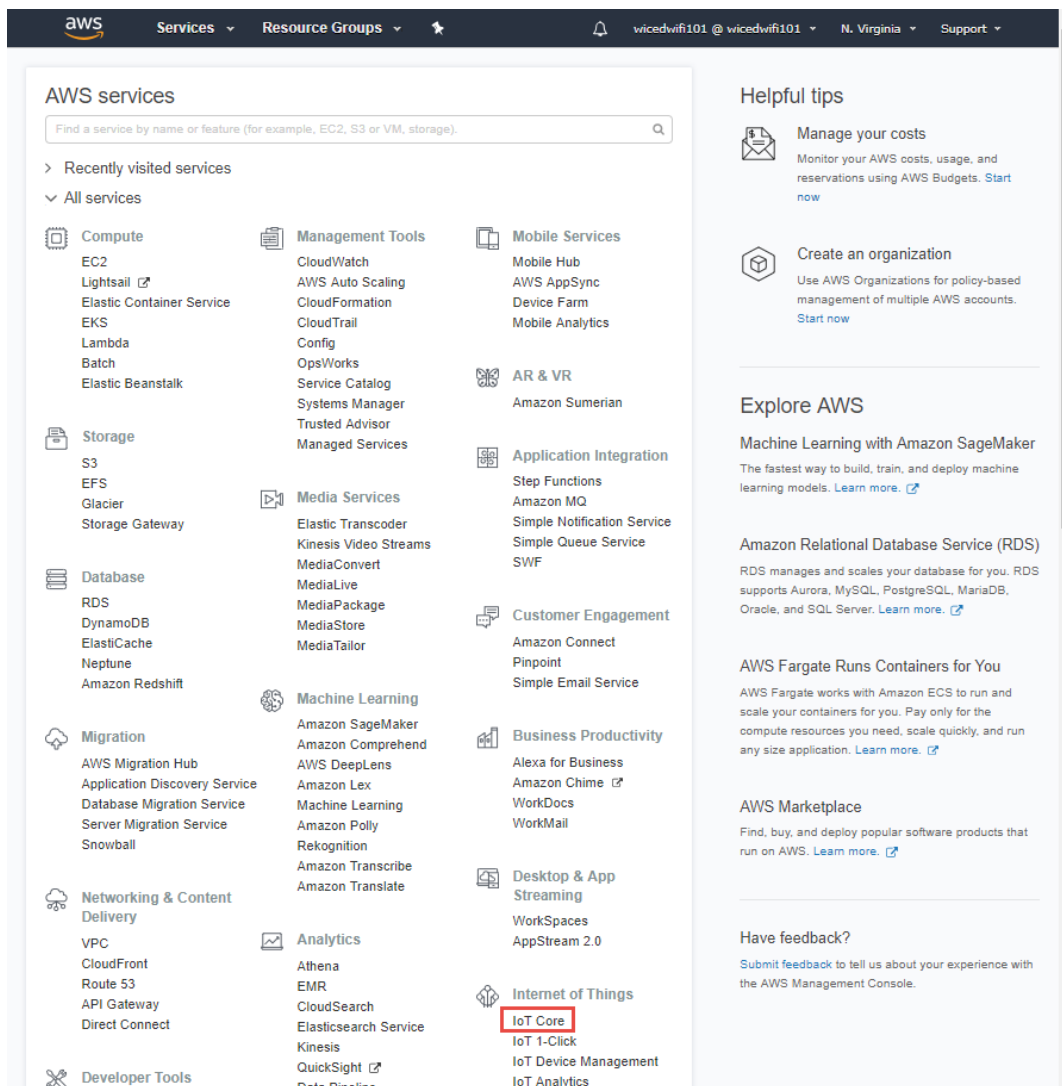
Account Alias: wicedwifi101

IAM User Name: wicedwifi101

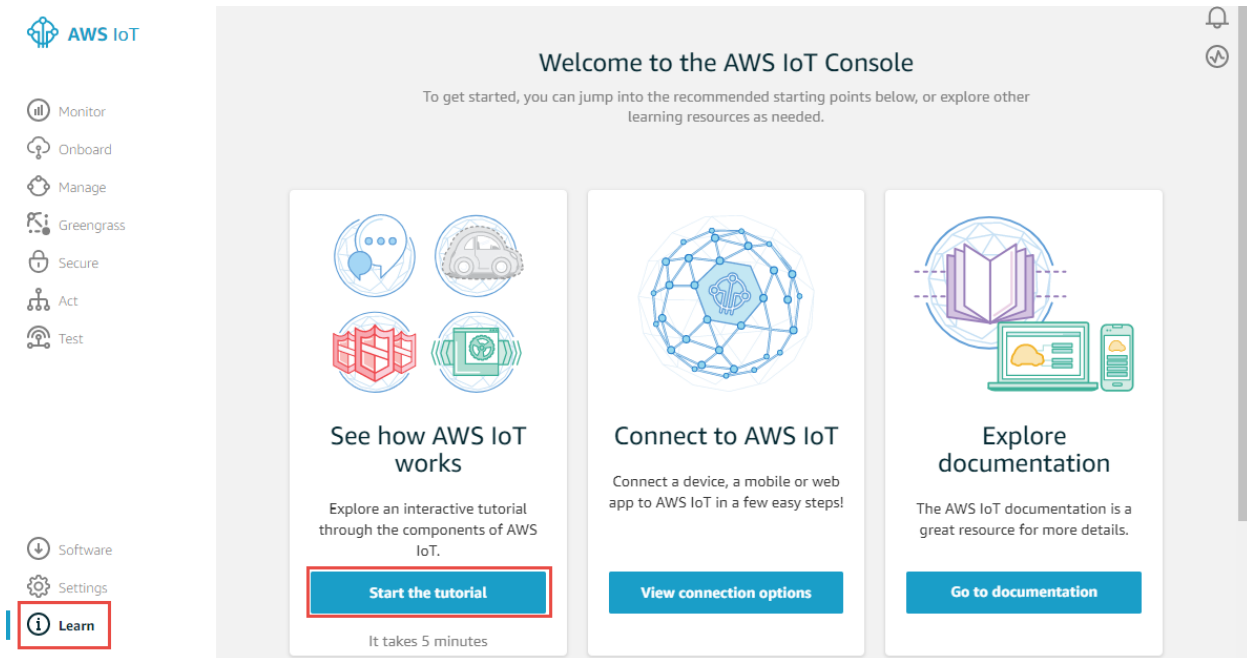
Password: See the back cover of manual for the current password or ask an instructor

If you use the class account, leave the region set to "N. Virginia". If you create your own account, you can use any region you want but the exercises assume N. Virginia.

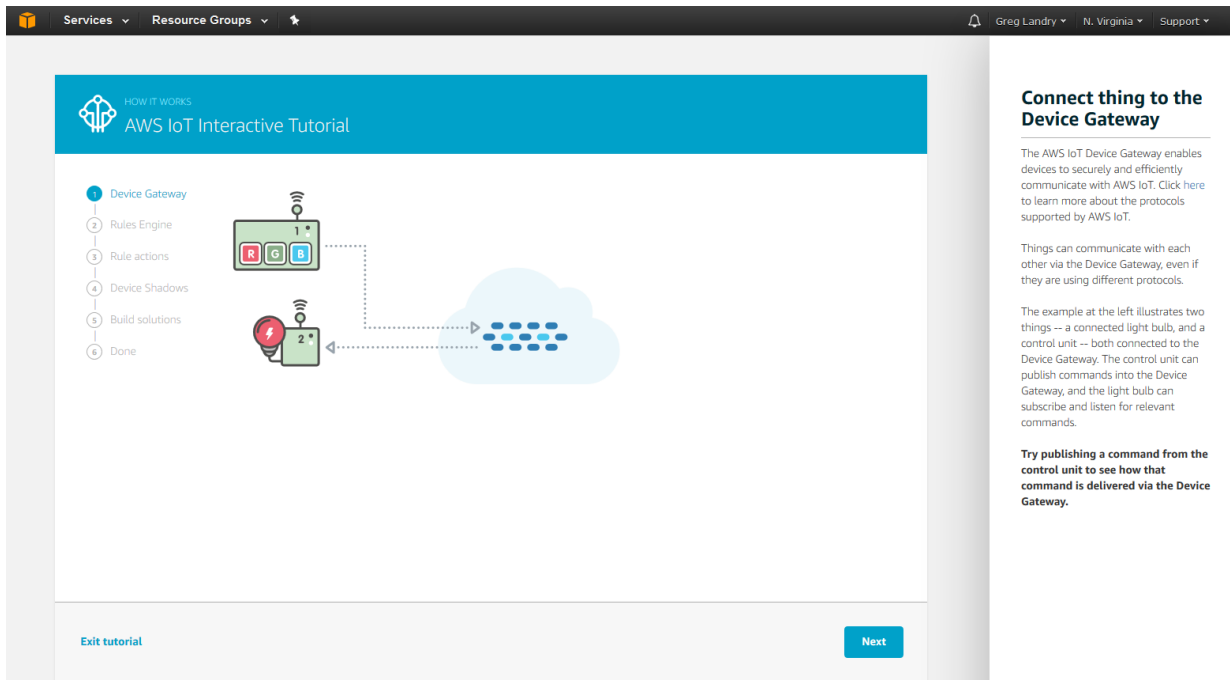
Once you are logged in, from the Services menu, select "IoT Core":



In the lower-left corner of the IoT screen click on "Learn" and then click "Start the tutorial":



Follow the instructions to complete the tutorial.

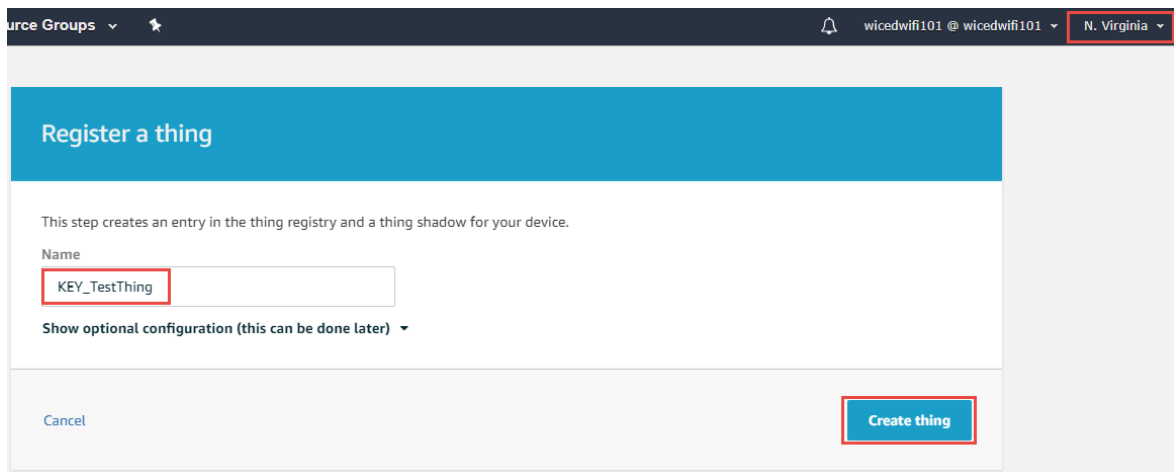


Exercise - 7C.2 Create new AWS Thing

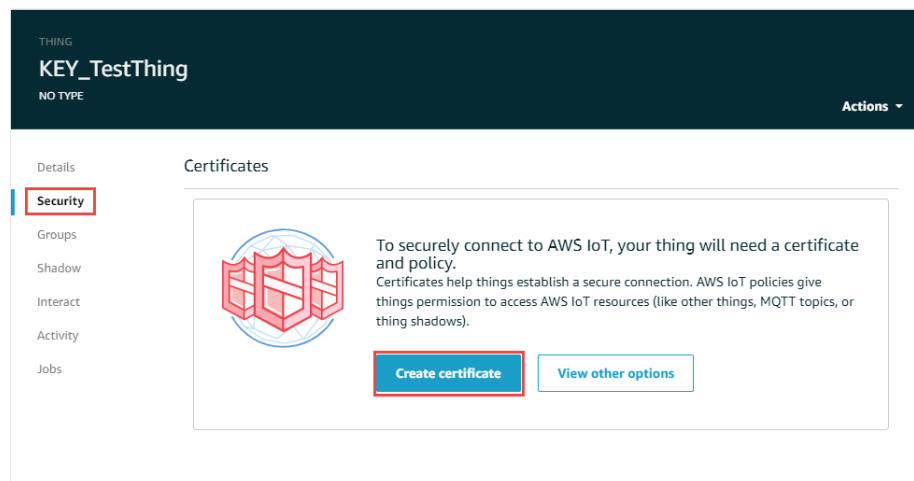
Provision a new *thing* in the AWS IOT Cloud, and establish its policy and credentials.

Note: The steps below assume that you are using the existing class AWS account. If you create your own account, the steps may be slightly different but will still follow the same flow.

- Once you have watched the tutorial, you should be on the "Register a thing" page.
Hint: The example projects use US East time zone 1 (N. Virginia). If you log into the class account, make sure it is set to that region when you log in. If you create your own AWS account and use a different time zone, you will need to search for "us-east-1" in the source code for each project in the later exercises and update as necessary.
- Name your *thing* <YourInitials>_TestThing (or whatever) and press "Create thing".



- Before you can access the broker from your WICED kit you need to create the encryption keys that enable you to identify it as an allowed device. To do this, find your *thing* in the list of *things* and click on it. If you don't see it in the list, you can search for it using the search box at the upper right corner of the window. One you get to your *thing's* page, click on Security and then on Create Certificate.



- Now you need to download the "certificate", "public key" and "private key". If you forget this step you cannot come back...so really you must download those files now to make the TLS work! You must also "Activate" the certificate.

Certificate created!

Download these files and save them in a safe place. Certificates can be retrieved at any time, but the private and public keys cannot be retrieved after you close this page.

In order to connect a device, you need to download the following:

A certificate for this thing	49e0f1dca6.cert.pem	Download
A public key	49e0f1dca6.public.key	Download
A private key	49e0f1dca6.private.key	Download

Do this first!

You also need to download a root CA for AWS IoT:
 A root CA for AWS IoT [Download](#)

Do this third!

[Activate](#) **Do this second!**

Cancel
Do this last!

[Done](#)
[Attach a policy](#)

- You should write down the certificate ID (the long string in the filenames that you downloaded) since you will need it later when you attach a policy to the certificate.
- You should download the AWS IoT root CA by clicking the Download link. This will open a new page with different certificates as shown below. You want to download the "Amazon Root CA 1" certificate by right clicking on it and selecting "Save target as..." The WICED SDK includes an AWS IoT root CA, but Amazon sometimes updates it so it is a good idea to download it one time to replace the one in the SDK.

Server Authentication

Server certificates allow your devices to verify that they're communicating with AWS IoT and not another server impersonating AWS IoT. AWS IoT server certificates are signed by one of the following CA certificates:

VeriSign Endpoints (legacy)

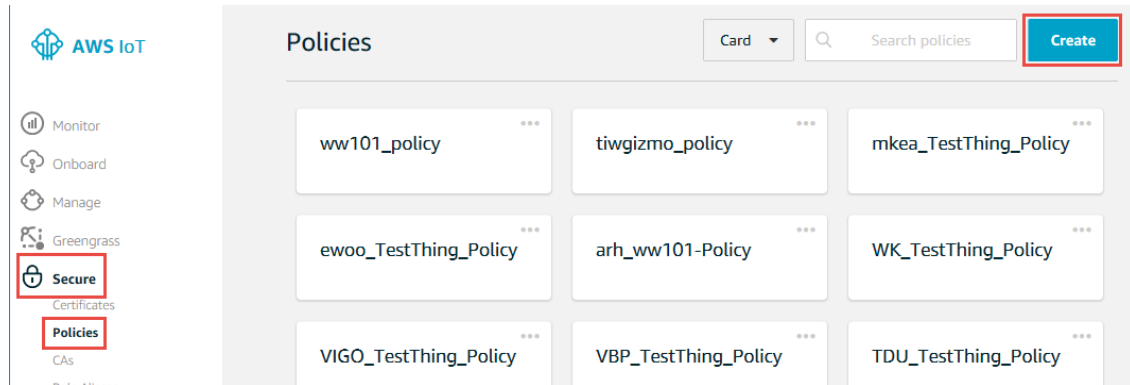
- RSA 2048 bit key: [VeriSign Class 3 Public Primary G5 root CA certificate](#)

Amazon Trust Services Endpoints (preferred)

- RSA 2048 bit key: [Amazon Root CA 1](#)
- RSA 4096 bit key: [Amazon Root CA 2](#)
- ECC 256 bit key: [Amazon Root CA 3](#)
- ECC 384 bit key: [Amazon Root CA 4](#)

We recommend that all customers create an Amazon Trust Services (ATS) endpoint and load these CA certificates onto their devices to avoid any issues with the upcoming widespread distrust by browsers of Symantec CAs (including VeriSign) in October 2018. For backward-compatibility reasons, we still support customers using these endpoints. Customers can create an ATS

- Click "Done" after you have downloaded the files and have noted down your certificate ID. This will take you back to your *thing's* page. Click the left arrow at the upper left-hand corner to go back to the top-level AWS IoT page. From that page click on "Secure", then "Policies", and finally on "Create".



- Give the new policy a name such as **<YourInitials>_TestThing_Policy**. Add the action as **"iot:*"**, use **"*"** for the Resource ARN, and select **"Allow"**. Then click the **"Create"** button.

Create a policy

Create a policy to define a set of authorized actions. You can authorize actions on one or more resources (things, topics, topic filters). To learn more about IoT policies go to the [AWS IoT Policies documentation page](#).

Name

KEY_TestThing_Policy

Add statements

Policy statements define the types of actions that can be performed by a resource. Advanced mode

Action

iot:*

Resource ARN

*

Effect

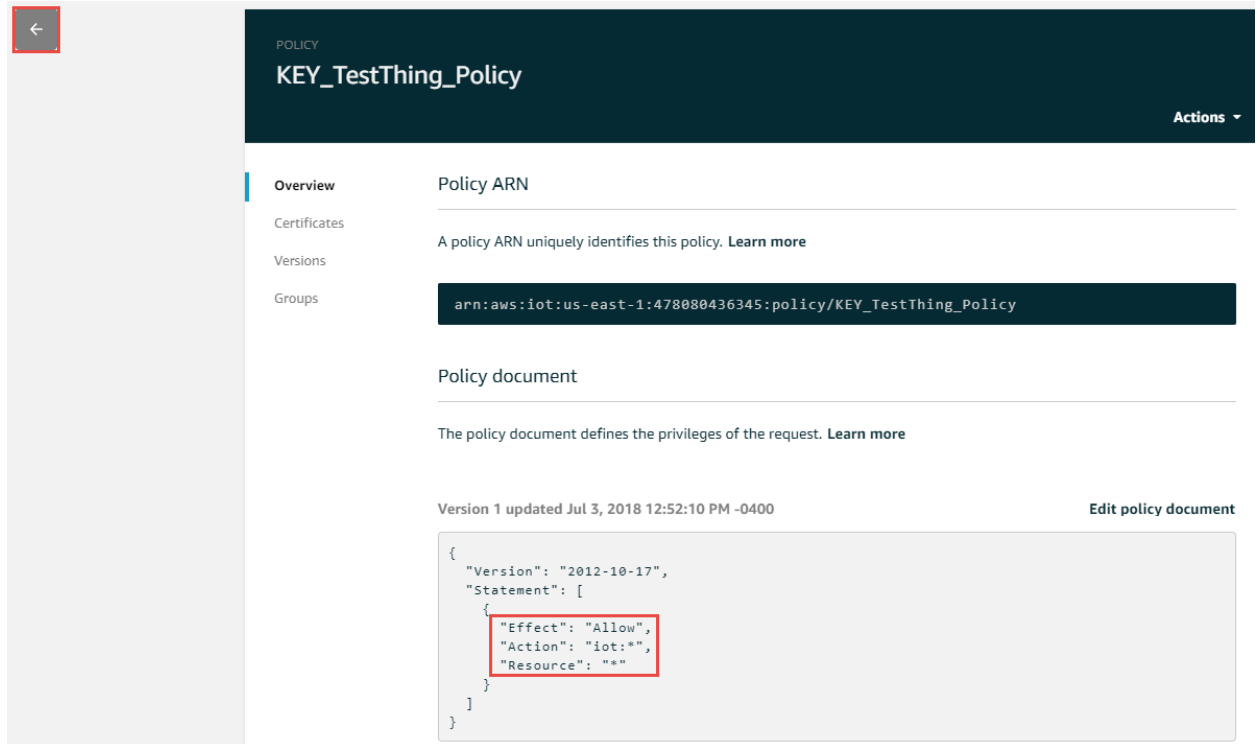
☒ Allow ☐ Deny

Remove

Add statement

Create

- If you click on the policy, you will see the policy document details. In this case, any IoT operation (iot:*) is allowed for any resource (*).



←

POLICY

KEY_TestThing_Policy

Actions ▾

Overview

Certificates

Versions

Groups

Policy ARN

A policy ARN uniquely identifies this policy. [Learn more](#)

arn:aws:iot:us-east-1:478080436345:policy/KEY_TestThing_Policy

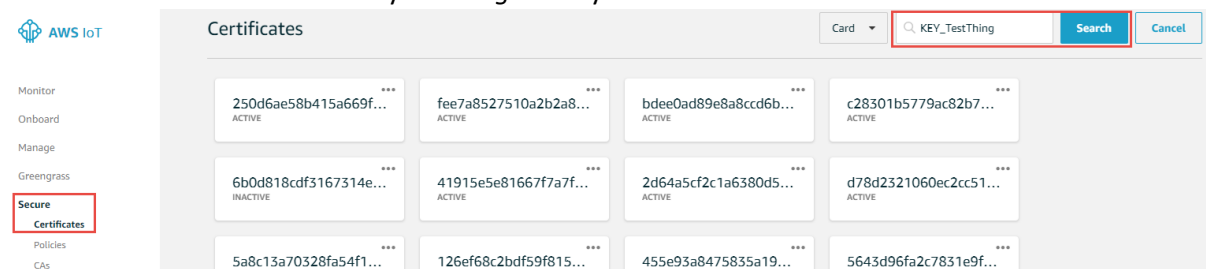
Policy document

The policy document defines the privileges of the request. [Learn more](#)

Version 1 updated Jul 3, 2018 12:52:10 PM -0400 [Edit policy document](#)

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

- You now need to attach the policy to the certificate. First click the left arrow on the left side of the screen as show above. Then select Secure -> Certificates from the left panel and click on your certificate. Again, you can use the search box in the upper right corner to find your certificate by name. In fact, you can even enter your *thing* name in the box and it will find the certificate that was attached to your *thing* when you first created it.



AWS IoT

Monitor

Onboard

Manage

Greengrass

Secure

Certificates

Policies

CAs

Certificates

Card ▾

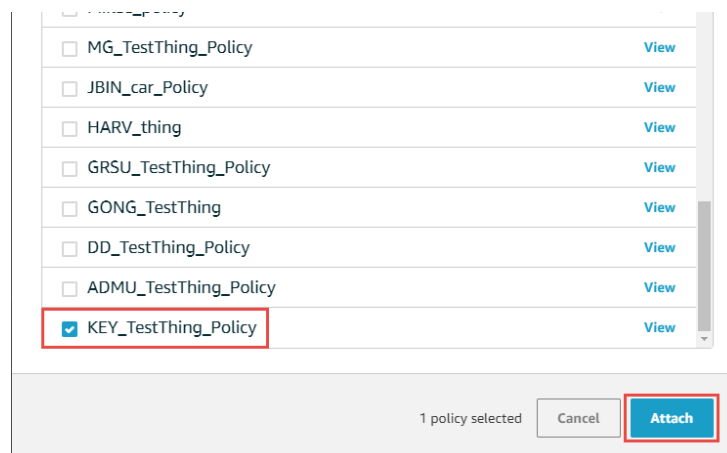
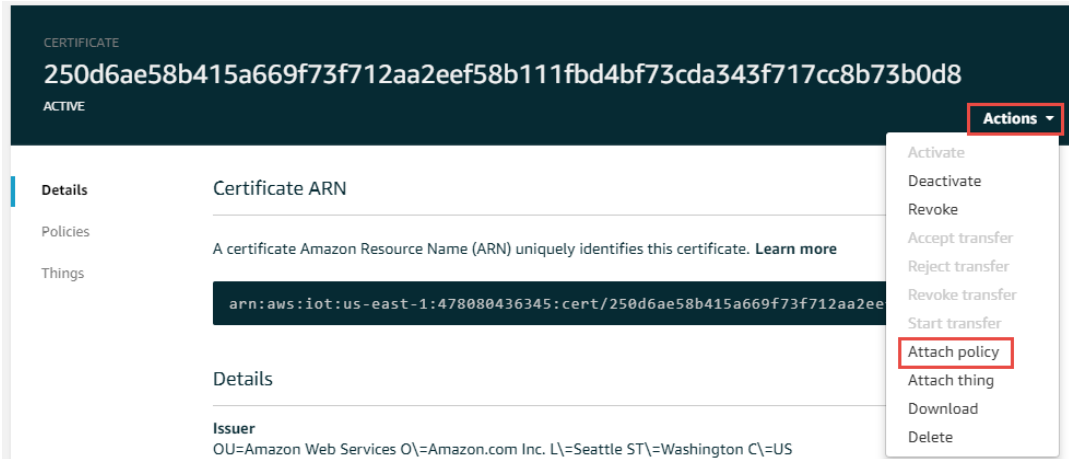
KEY_TestThing

Search

Cancel

250d6ae58b415a669f... ACTIVE	fee7a8527510a2b2a8... ACTIVE	bdee0ad89e8a8ccd6b... ACTIVE	c28301b5779ac82b7... ACTIVE
6b0d818cdf3167314e... INACTIVE	41915e5e81667f7a7f... ACTIVE	2d64a5cf2c1a6380d5... ACTIVE	d78d2321060ec2cc51... ACTIVE
5a8c13a70328fa54f1... INACTIVE	126ef68c2bdf59f815... INACTIVE	455e93a8475835a19... INACTIVE	5643d96fa2c7831e9f... INACTIVE

11. Once you click on your certificate, select "Actions -> Attach Policy". Select your policy and click "Attach". Click on the left arrow in the upper left when you are done to return to the AWS IoT main page.



12. Once you get to this point, you should verify:
- You have a *thing* (Manage -> *Things*).
 - You have a certificate attached to the thing (from the *thing*, click on Security).
 - The certificate is Active (click on the Certificate and look for "Active" in the upper left).
 - The certificate has a policy attached to it (from the Certificate, click on Policies).
 - The policy allows all IoT actions (iot:*) for any resource (*) (click on the Policy).

If any of the above is not true, fix it before proceeding. Most of this can be accomplished from the "Actions" menus in the appropriate page. Ask for help from an instructor if you need it.

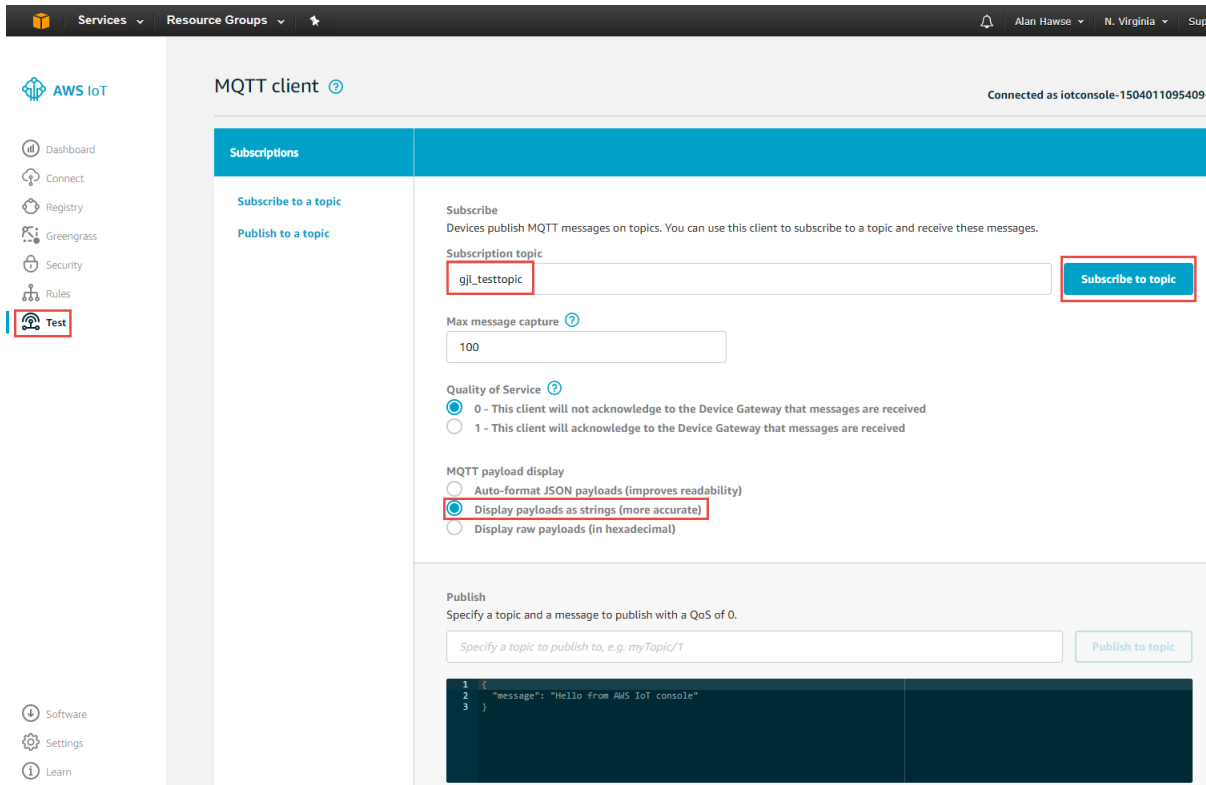
Exercise - 7C.3 Learn how to use the AWS MQTT Test Client

The AWS website has an MQTT Test Client that you can use to test publishing and subscribing to topics. Think of it as a terminal window into your message broker, or as a generic IoT *thing* that can publish and subscribe. You will use this client to test the later exercises.

To make the subscribe/publish actions more understandable, it is useful to team up with another student for this exercise. Alternately, you can run two tabs in your browser – one to subscribe and one to publish.

Subscribing to a Topic from the Test Client:

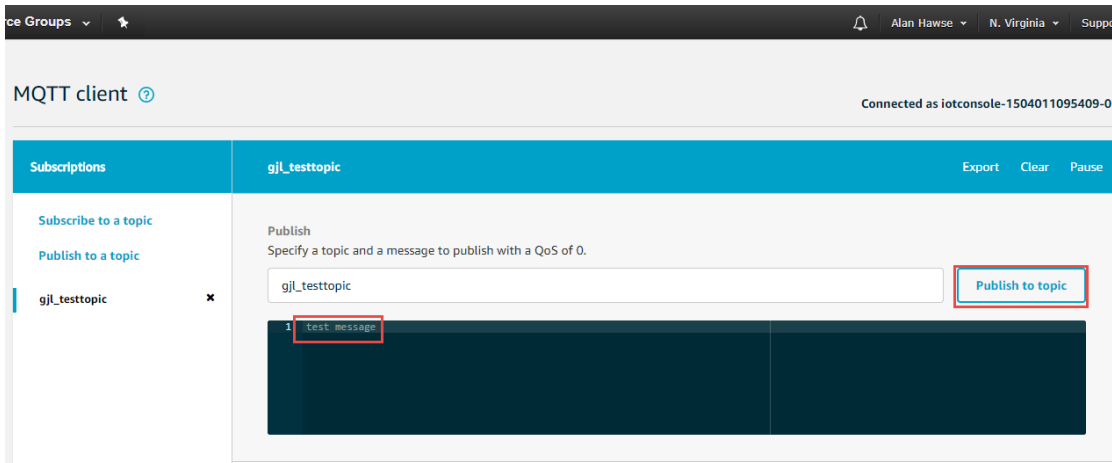
1. Select "Test" from the panel on the left of the screen. Enter a topic that you want to subscribe to such as **<your_initials>_testtopic** in the "Subscription topic" box. Select "Display payloads as strings", and click on "Subscribe to topic". Make sure to put your initials or some other unique string in the topic if you are using the class AWS account. If not, you may see messages from someone else publishing to the same topic.



The screenshot shows the AWS IoT MQTT client interface. On the left is a navigation menu with options: Dashboard, Connect, Registry, Greengrass, Security, Rules, and Test (highlighted with a red box). The main area is titled 'MQTT client' and shows 'Connected as iotconsole-1504011095409'. The 'Subscriptions' section is active, showing options to 'Subscribe to a topic' or 'Publish to a topic'. The 'Subscribe' form includes a 'Subscription topic' field with the value 'gjl_testtopic' (highlighted with a red box), a 'Max message capture' field set to 100, and 'Quality of Service' options. The 'MQTT payload display' section has three radio buttons: 'Auto-format JSON payloads (improves readability)', 'Display payloads as strings (more accurate)' (selected and highlighted with a red box), and 'Display raw payloads (in hexadecimal)'. A 'Publish' section at the bottom allows specifying a topic and message to publish.

Publishing to a Topic from the Test Client:

- Now that I am subscribed to a topic I can publish messages to that topic from another instance of the MQTT test client. First, open another web browser tab, login to the AWS account, and go to the Test page. (Note: team up with another student if you can so that one person subscribes and the other publishes to the same topic).
- Scroll down to the "Publish" section of the page and fill in the name of the topic that you subscribed to earlier. The name must be exactly the same (including case). Then type in your message and press "Publish to topic". You can see in the box below I sent "test message".



MQTT client ⓘ Connected as iotconsole-1504011095409-0

Subscriptions **gjl_testtopic** Export Clear Pause

Subscribe to a topic
Publish to a topic

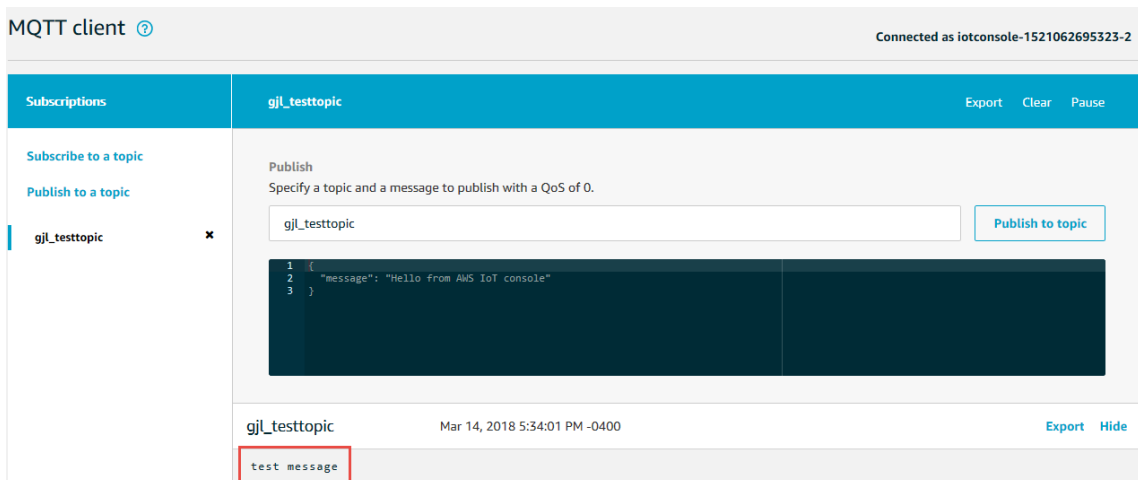
gjl_testtopic ×

Publish
Specify a topic and a message to publish with a QoS of 0.

gjl_testtopic **Publish to topic**

```
1 test message
```

- Now, go back to the tab with the subscription and see that the published message was sent to the subscriber.



MQTT client ⓘ Connected as iotconsole-1521062695323-2

Subscriptions **gjl_testtopic** Export Clear Pause

Subscribe to a topic
Publish to a topic

gjl_testtopic ×

Publish
Specify a topic and a message to publish with a QoS of 0.

gjl_testtopic **Publish to topic**

```
1 {
2  "message": "Hello from AWS IoT console"
3 }
```

gjl_testtopic Mar 14, 2018 5:34:01 PM -0400 Export Hide

```
test message
```

Exercise - 7C.4 Run the demo.aws.iot.pub_sub.publisher App

- Copy the WICED apps/demo/aws/iot/pub_sub/publisher project to your own directory (i.e. ww101/07c/04_publisher) and update the files.
 - Hint: Make sure you add your platform to the valid platforms in the makefile.
- Modify the DCT for your network.
- Copy the device certificate and private key that you generated and saved previously into the resources/apps/aws/iot/publisher folder. Replace the existing files in that directory as follows:

Name of Downloaded File	New Name	Description
<name>-certificate.pem.crt	client.cer	The certificate for your thing. This is how AWS knows that it is a valid <i>thing</i> that is trying to talk to it.
<name>-private.pem.key	privkey.cer	The private key that your application will use to decrypt data that it gets back from AWS. Since Amazon created the key, it already has the public key.

Make sure you change the file extensions to match what is shown above. Windows explorer will hide some file extensions, so it is best to look at them inside the WICED Studio Project Explorer to make sure they are right.

- Copy the root CA certificate for AWS into the resources/apps/aws/iot folder. This allows your thing to know that it is really talking to the AWS Cloud. The certificate is included in the WICED SDK, but Amazon sometimes updates it so it is a good idea to replace the one in the SDK one time.

Name of Downloaded File	New Name	Description
AmazonRootCA1.pem	rootca.cer	The certificate for AWS. This is how your <i>Thing</i> knows that it is talking to AWS.

The other file that you downloaded called "<name>-public.pem.key" is a public key for your thing. In this case, Amazon already has the public key, so you don't need to provide it.

- Run a "clean" before rebuilding or else your project may not see the new keys. You will find clean at the top of the list of Make Targets. Just double-click on it to run it.
- Create a Make Target for your project.
- Modify the broker address in the project. It can be found by searching for *.uri* in the C file. The correct address can be found by clicking on "Settings" at the lower left corner of the main Amazon AWS console window. The broker address is listed as the "Endpoint".
- Modify the #define for WICED_TOPIC. You can use the topic from the previous exercise with your initials in the name.
- Modify the *thing* name to the name that you created previously. You can find this by searching for *.name* in the C file. This is necessary to prevent conflicts between multiple devices on a broker – every device connected to a broker MUST have a *thing* name.
- Build and program your project.

11. Open the serial port and watch your terminal session.
12. Subscribe to your topic using the AWS MQTT Test Client. When you press the button on the shield, you should see updates to the topic in the test window.

Exercise - 7C.5 WICED AWS MQTT Firmware Flow

Explain in detail the firmware flow for the publisher app by answering the following questions:

1. How do the AWS library functions (e.g. `wiced_aws_publish()`) get into your project?
2. What function is called when the button is pressed?
3. How does the button callback unlock the main thread?
4. Are all messages sent to the AWS IOT MQTT Message Broker required to be in JSON format?
5. What are the 6 WICED AWS events? What file are they defined in?
6. Do you have to name the client certificate `client.cer`? How would you change the name if you wanted to use a different name?

7. What is the callback function for an AWS event? How is it registered?

8. What steps are required to get an AWS connection established?

9. What function is called to send data to the server?

10. What is the name of the flag that prevents the firmware from sending multiple button presses before the publish is finished?

Exercise - 7C.6 Build and Run the demo.aws.iot.pub_sub.subscriber App

1. Copy the WICED application from apps/demo/aws/iot/pub_sub/subscriber to your directory (i.e. wa101/07c/06_subscriber) and modify the DCT and makefile.
2. Update the topic (WICED_TOPIC) and broker names (.uri) to the same ones you used for exercise 4.
3. Update the .name to be the name of your *thing* so that it is a unique value.
4. We will use the same *thing*, certificate, and keys that we did for exercise 2. You will need to copy the client.cer and privkey.cer files from resources/apps/aws/iot/publisher to resources/apps/aws/iot/subscriber.
5. Program the project to your kit.
6. Publish messages using the AWS Test MQTT Client.
 - a. Determine what string needs to be sent to turn the light on or off.
 - i. Hint: Look in the source code to find the string that is being looked for when a message is received.
 - ii. Hint: If you are successful, the LED on the shield should turn on/off.

Exercise - 7C.7 (Advanced) Implement the publisher and subscriber in two different kits

1. In a real-world application, you would typically have one or more devices publishing data to a broker and one or more devices subscribing to updates from that same broker. So, let's try that out with two different kits. You should team up with another student for this lab.
 - a. Have one student use the subscriber project and the other student use the publisher project.
 - b. Use the same Topic Name the same in both projects.
 - c. The two projects MUST have different *thing* names or it will not work – the two kits will interfere with each other. Remember that every *thing* connected to a broker MUST have a unique name.
 - i. Note: It isn't actually required to create a *thing* on the AWS site to connect a device. It will connect as long as it has a unique name and the firmware has a valid certificate and policy to use. The only time a *thing* is required on the AWS site is to use a *thing* shadow to store and retrieve state information. Therefore, if you do this exercise yourself, you need to change the *thing* name for one of the projects – either the publisher or subscriber. Since the projects just use a fixed Topic name rather than a *thing* shadow, you don't have to create a new *thing* on the AWS site.
 - d. Program the updated firmware into the two kits – one publisher and one subscriber.
 - e. Power up both kits.
 - f. Subscribe to the topic that you chose using the AWS test MQTT Client.
 - g. Press the button on the publisher kit and watch it change the state of the LED on the subscriber kit. Also watch the messages in the AWS test MQTT Client window.

Exercise - 7C.8 (Advanced) Build and test the Shadow App

1. This example uses a configuration Access Point serving a web browser so that the *thing* name, credentials, keys, and settings for the network to connect to can be configured from a web browser on a device attached to the configuration AP.
2. Copy the WICED application from `apps/demo/aws/iot/shadow/thing_shadow` to your directory and update the makefile.
Update the DCT file to have a Config AP for configuration with an SSID name that is unique (so as not to collide with others in your class).
3. Update the message broker address (.uri) to match what you created in the previous exercises.
4. Program the kit.
5. Attach to the Config AP on your board from your computer's Wi-Fi.
 - a. Connect to the SSID that you programmed into the board.
 - b. Go to the webserver (The IP address is printed on the terminal when the device boots and starts the AP).
 - i. Hint: Don't use Firefox for this step – it sometimes gives strange results.
 - c. Update the *thing* name to match what you created in previous exercises.
 - i. Hint: The default name that shows up is in "`aws_config.h`" so you could also change it there before programming the board.
 - d. Follow the instructions to upload the client certificate and private key.
 - e. Click on "Wi-Fi Setup >", click on the class Wi-Fi network, enter the password, and click connect.
 - f. The board will reboot. Once it has done that, it will connect as a station to the Wi-Fi network that you configured in the previous step.
6. Attach to a Wi-Fi access point from your computer.
7. Go to `console.aws.amazon.com` and go to the test MQTT Client.
8. Subscribe to the device's shadow topics.
 - a. Hint: `$aws/things/<YourThingName>/shadow/#` will subscribe to all shadow topics for your *thing*. Replace `<YourThingName>` with the name that you chose for your *thing*. The `#` is a wildcard.
9. Press the button on the board and see the messages.

Exercise - 7C.9 (Advanced) Get a *Thing* Shadow from AWS using HTTPS

1. Create a project that uses HTTPS to connect to AWS. Get the shadow of your *thing* and print it to the UART.
 - a. Hint: Start with the `httpbin.org` GET project using TLS from the HTTP chapter.
 - b. Hint: In addition to initializing the root certificate for AWS, you will need to read in a valid *thing* certificate and private key to initialize the TLS identity. This is necessary because AWS will validate that your WICED kit is authorized to connect to the broker and interact with your *thing*.
 - c. Hint: Remember that only 1 certificate can be stored in the DCT so you will have to use another method for at least 2 of the three files required.

Related Example "Apps"

App Name	Function
demo/aws/iot/pub_sub/publisher	Demonstrates publishing information to the AWS cloud.
demo/aws/iot/pub_sub/subscriber	Demonstrates subscribing to a topic in the AWS cloud.
demo/aws/iot/shadow	Demonstrates using a shadow device with AWS.

7C.8 References

Resources	Link
AWS Developers Guide	http://docs.aws.amazon.com/iot/latest/developerguide/what-is-aws-iot.html
AWS IOT Getting Started	https://aws.amazon.com/iot/getting-started/
A nice powerpoint about MQTT	http://www.slideshare.net/PeterREgli/mq-telemetry-transport
MQTT Topic Naming Best Practices	http://www.hivemq.com/blog/mqtt-essentials-part-5-mqtt-topics-best-practices
Avnet Getting Started	http://cloudconnectkits.org/system/files/GSG-BCM4343W%20IoT%20Starter%20Kit%20-%20Getting%20Started%20%28v1.1%29.pdf
Avnet User Guide Part1 and Part2	
AWS Forum	https://forums.aws.amazon.com/forum.jspa?forumID=210