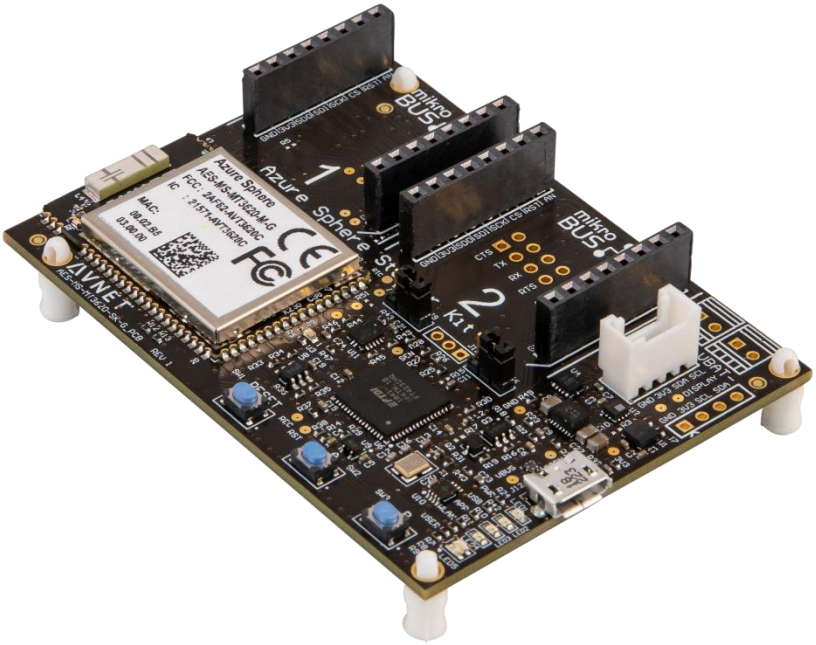
Avnet Technical Training Course

Azure Sphere: Getting Data to the Cloud

Lab 4



Azure Sphere SDK:	19.05
Training Version:	v1
Date:	1 July 2019

Introduction

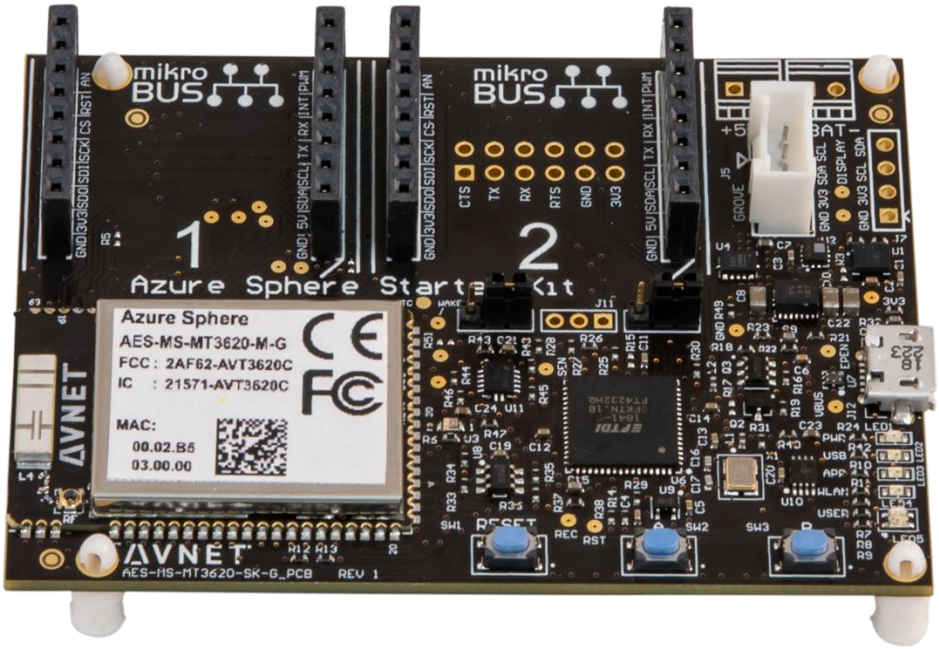
This Lab will walk the student through connecting the example application to an Azure Device Provisioning Service (DPS), then to an IoT Hub. We'll send data to our IoT Hub and then configure a Time Series Insights (TSI) environment to visualize our data.

Avnet Azure Sphere Starter Kit Overview

The Avnet Azure Sphere Starter Kit from Avnet Electronics Marketing provides engineers with a complete system for prototyping and evaluating systems based on the MT3620 Azure Sphere device.

The Avnet Azure Sphere MT3620 Starter Kit supports rapid prototyping of highly secure, end-to-end IoT implementations using Microsoft's Azure Sphere. The small form-factor carrier board includes a production-ready MT3620 Sphere module with Wi-Fi connectivity, along with multiple expansion interfaces for easy integration of off-the-shelf sensors, displays, motors, relays, and more.

The Starter Kit includes Avnet's MT3620 Module. Having the module on the Starter Kit means that you can do all your development work for your IoT project on the Starter Kit and then easily migrate your Azure Sphere Application to your custom hardware design using Avnet's MT3620 Module.



Avnet Azure Sphere Starter Kit

Lab 4: Objectives

The Lab-4 objectives are to teach the student how to connect an Azure Sphere application to Azure IoT services to send telemetry data to the cloud and then use a cloud based system, Time Series Insights, to visualize the data.

- Learn how to create an IoT Hub
- Learn how to create a Device Provisioning Service (DPS)
- Configure the example application for the IoT Hub configuration
- Complete a code assignment
- Learn how to create a Time Series Insights (TSI) Environment

Lab-4 builds on the previous labs and should not be started until Labs 0-3 have been completed.

Requirements

Hardware

- A PC running Windows 10 Anniversary Update or later (Version 1607 or greater)
- An unused USB port on the PC
- An Avnet Azure Sphere Starter Kit
- A micro USB cable to connect the Starter Kit to your PC

Software

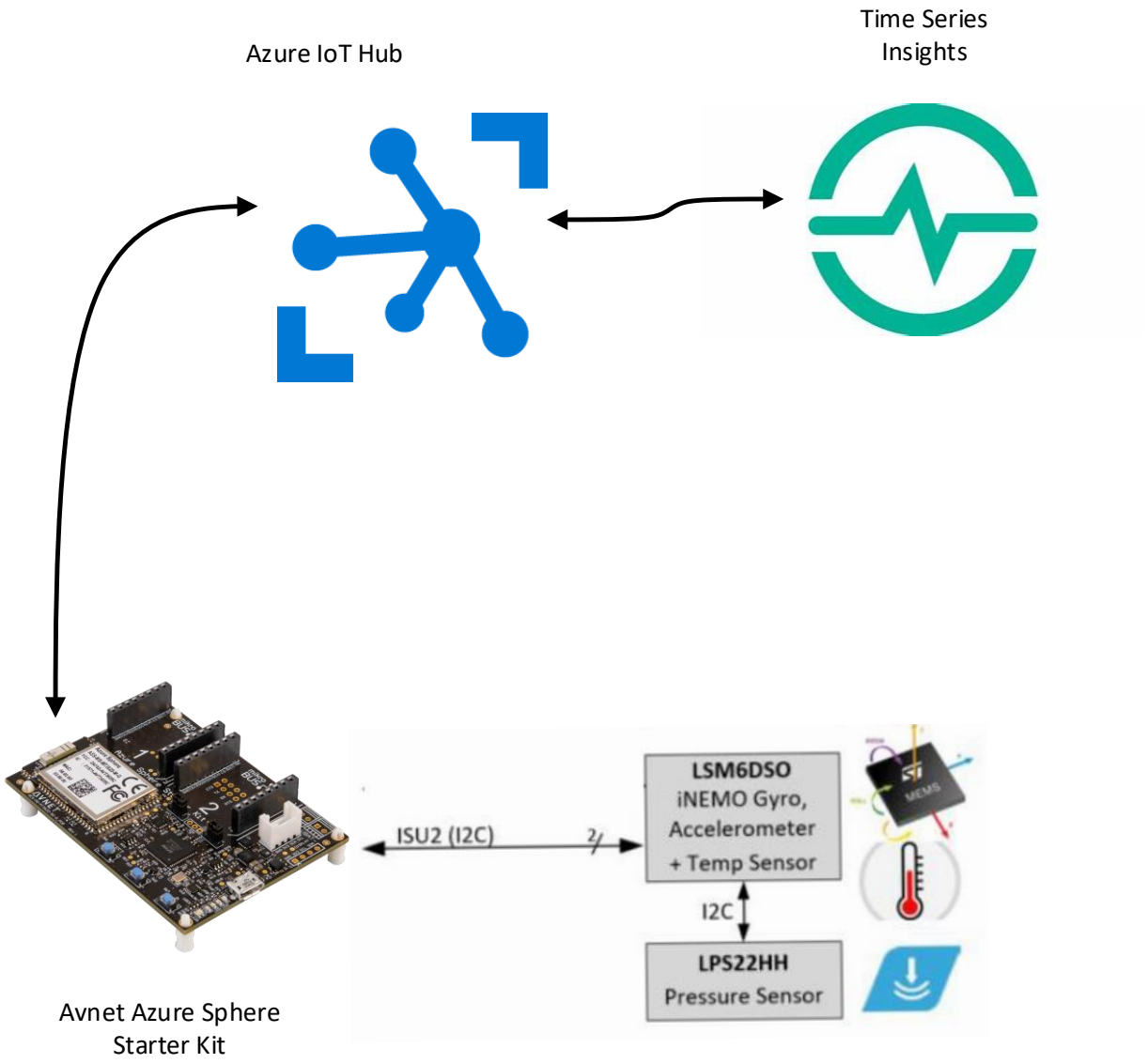
- Visual Studio 2019 Enterprise, Professional, or Community version 16.04 or later; or Visual Studio 2017 version 15.9 or later **installed**
- Azure Sphere SDK 19.05 or the current SDK release **installed**

Other

- Your Azure Sphere device must be connected to a Wi-Fi access point or hotspot with access to the internet.
- Labs 4 and 5 both require an Azure Account. You can sign up for a free Azure account with a $200 credit here.

The Big Picture

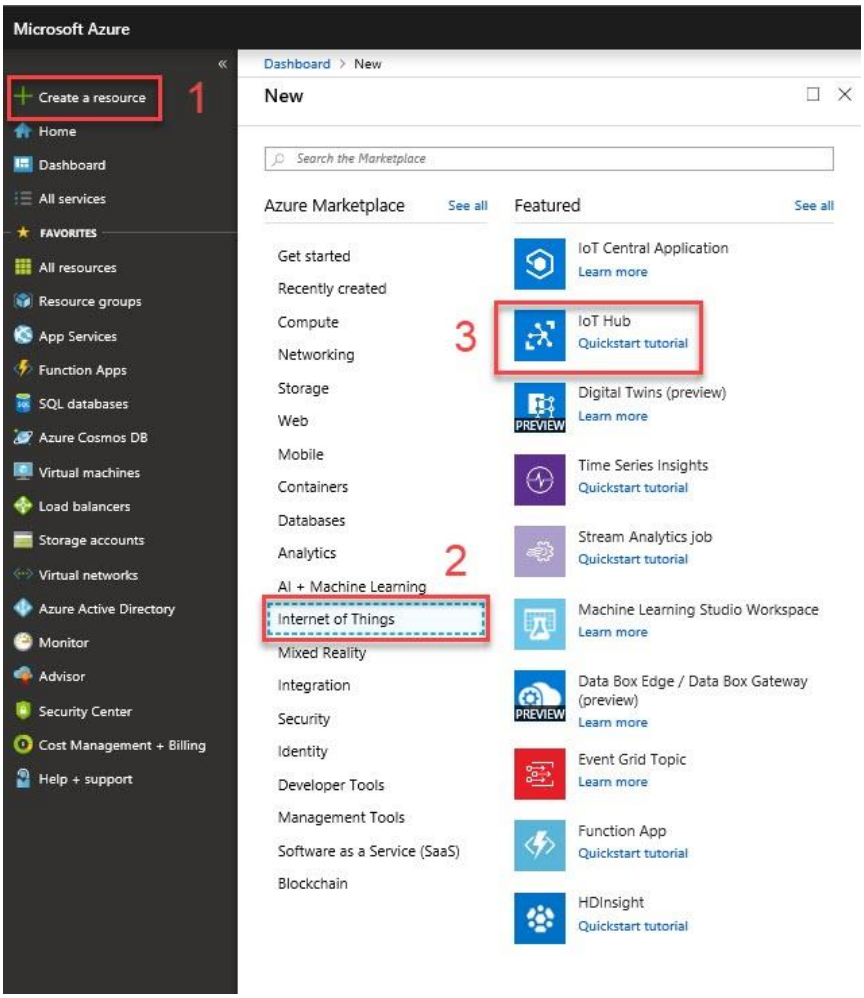
The diagram below shows the system we'll be building out in this lab. Starting at the bottom right of the graphic, we'll use the on-board I2C sensors to read accelerometer and pressure data. That data will be sent as telemetry to an IoT Hub. Next we'll connect a Time Series Insights resource to our IoT Hub so that we can visualize the sensor data in the cloud.



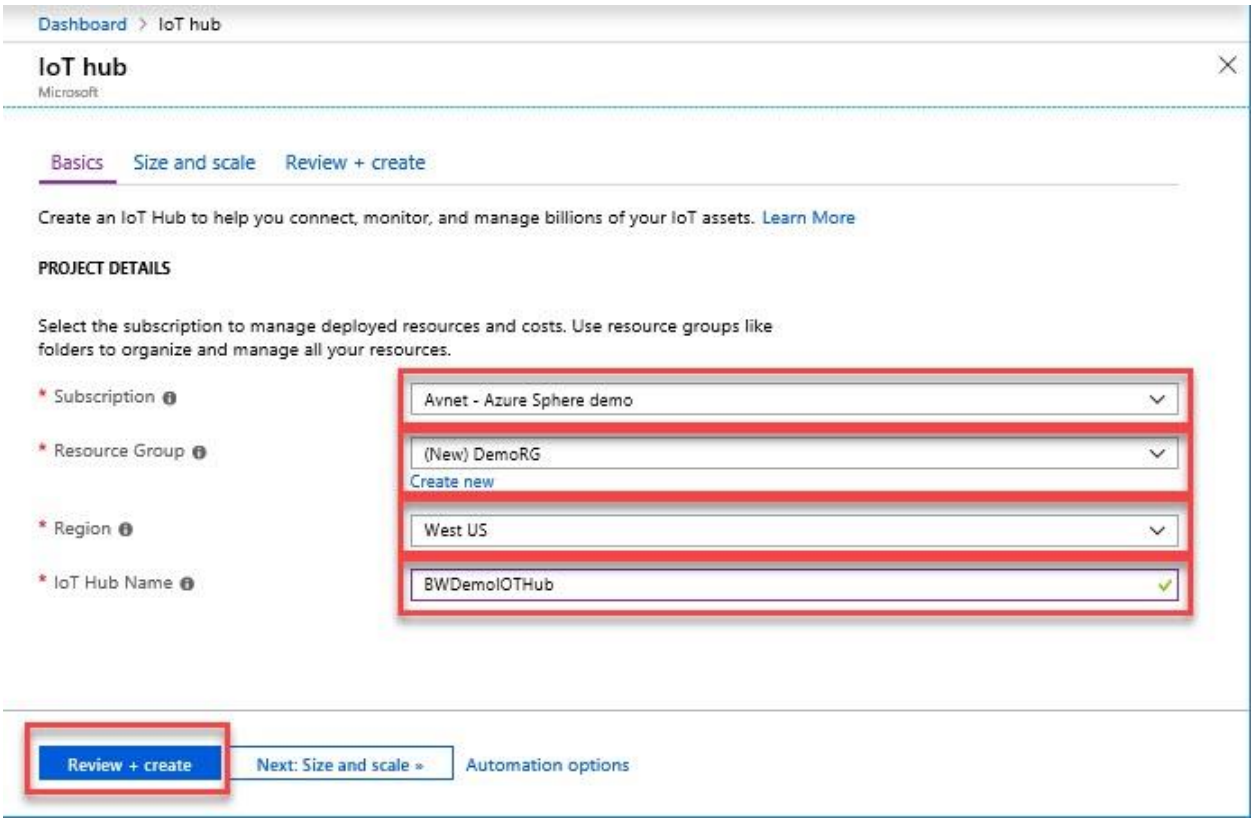
Create an IoT Hub

The first thing we need to do is create an IoT Hub. The IoT Hub is a collection point for IoT devices connecting into Azure. Once a device is connected to an IoT Hub and streaming telemetry data, other Azure services can ingest the data and do meaningful things. A single Azure IoT Hub can manage connections to hundreds of thousands of devices.

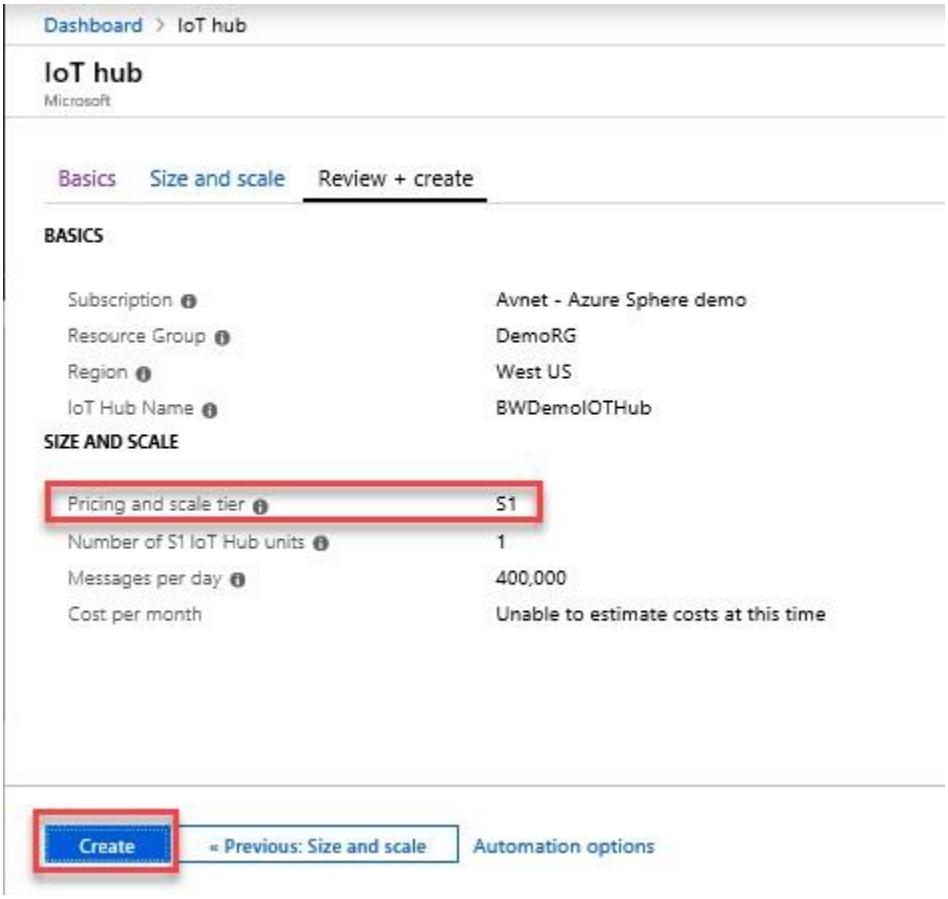
- Log into Azure https://portal.azure.com
- Click on "+ Create a resource" → "Internet of Things" → "IoT Hub." The IoT hub form will open.
    - You can also use the search bar to search for "IoT Hub."



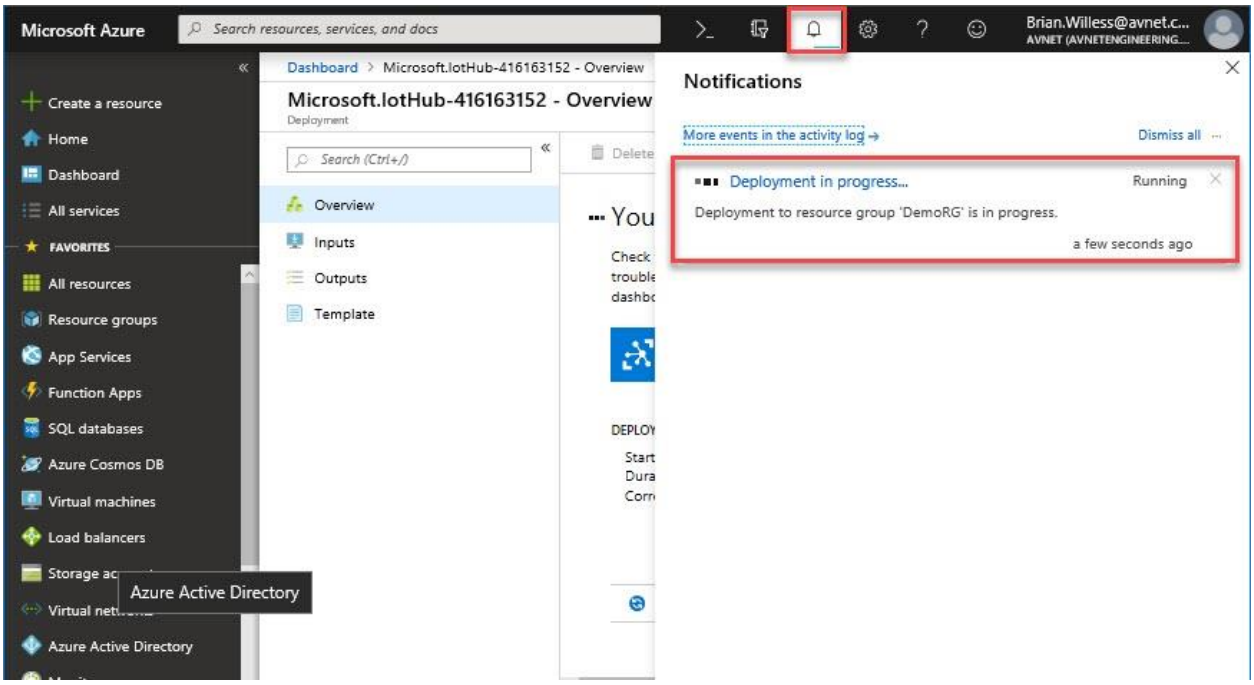
- In the IoT hub form fill in each entry
    - **Subscription:** Whatever your subscription is, it may be a “Free” or a “Pay-as-you-Go” subscription.
    - **Resource Group:** Click on the “Create new” link under the entry box and give your new Resource Group a name. For example “DemoRG”.
    - **Region:** Select the region closest to your physical location.
    - **IoT Hub Name:** Select a name for your IoT Hub. Note that the IoT Hub name must be unique across all of Azure. Your entry will be validated and if the name you used is not available, the form will display an error. Azure will generate a FQDN for your IoT Hub, so it must be unique.
- Click on the “Review + create” button



- Review the properties for your new IoT Hub. The “Pricing and scale tier” should be set to S1, the default. This tier will accommodate 400,000 data messages/day to/from your Azure Sphere device. After you’re happy with the properties, click on the “Create” button at the bottom of the form



- Azure will start to work on deploying your IoT Hub. This can take a few minutes. You can monitor the progress/status of your deployment by clicking on the bell icon in the header.



Create a Device Provisioning Service (DPS)

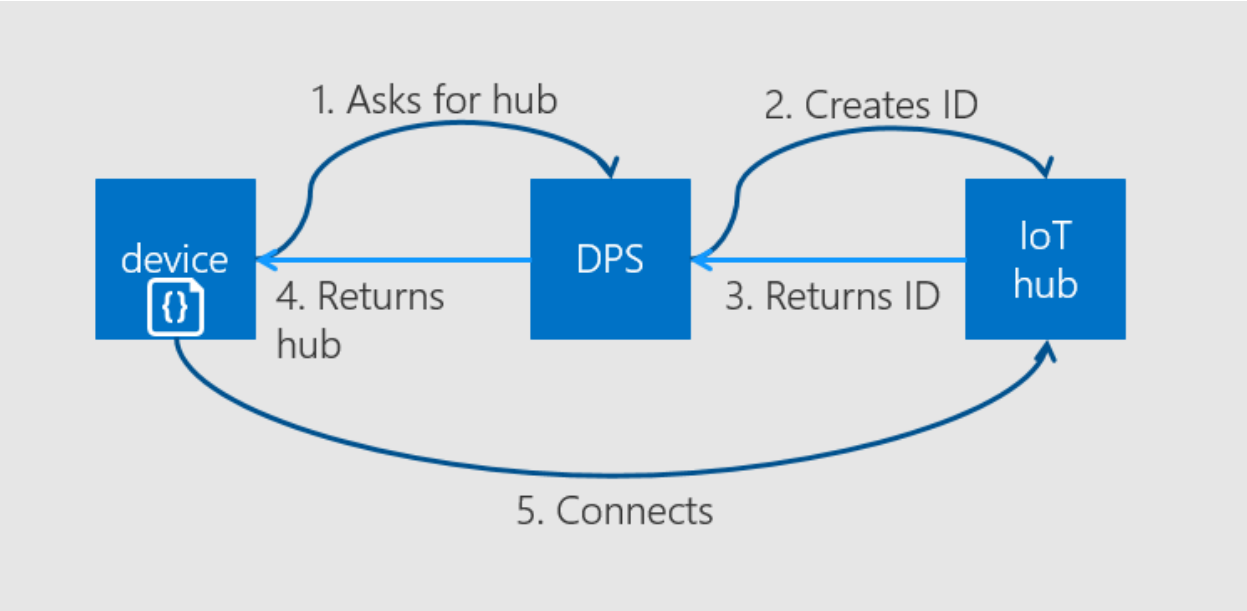
Now that we have an IoT Hub, we need to provision or add devices to our Hub. Devices must be provisioned to an IoT Hub; the IoT Hub will reject any connection attempts from un-provisioned devices.

When we're talking about IoT this usually implies that we'll have a very large number of devices. This allows us to collect large amounts of data that can be used to gain insights about our system so that we can make smart, data-driven, business decisions.

But how do we provision all these devices? One way is to manually add each device to an IoT Hub and use an IoT Hub connection string specific to that device. This works for a single device, but what about when you have 10, 100, or 100,000 devices. This approach would require some poor engineer to manually add 100 different devices to the IoT Hub, and would require 100 different application builds, each with its own specific connection string. It's easy to see this this is not a scalable approach.

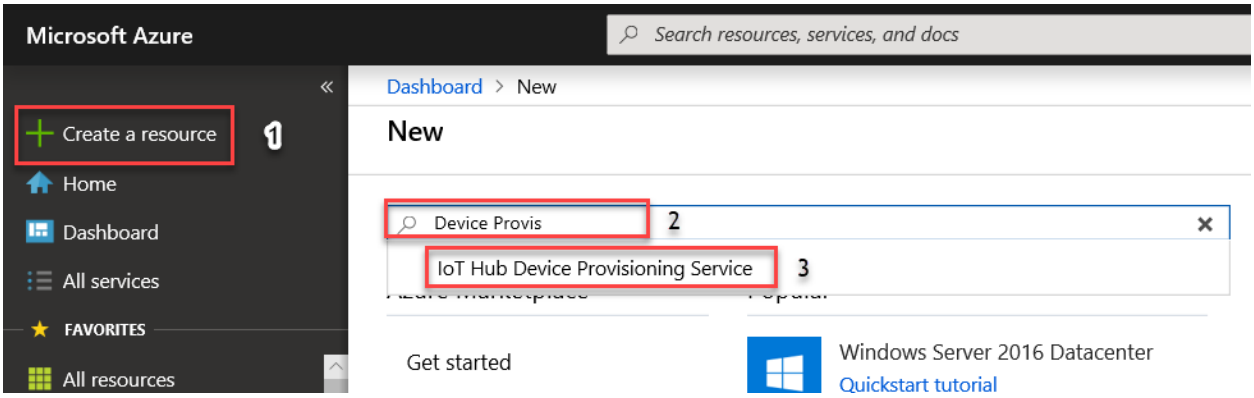
To make connecting 100, 100,000, or 1,000,000 devices to Azure easy, Microsoft provides a Device Provisioning Service (DPS). DPS allows large scale deployments without any manual provisioning steps. When you have 10 or 1,000,000 devices this is a great thing!

From the developer's point of view, I can create a single application build that can be deployed on all my devices. When my devices first connect to the Internet they will contact the global DPS server that will use some specific information in my application to provision my devices onto my IoT Hub(s). The diagram below illustrates how DPS works. After step #5 the device is provisioned and connected to the IoT Hub!

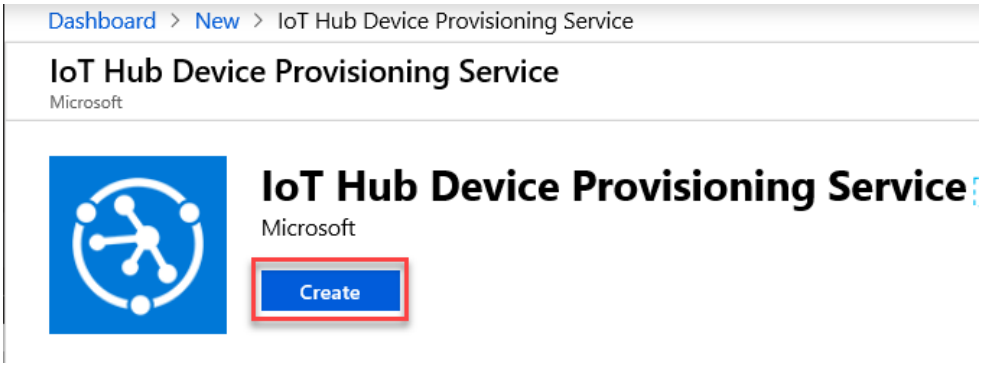


Create a new DPS

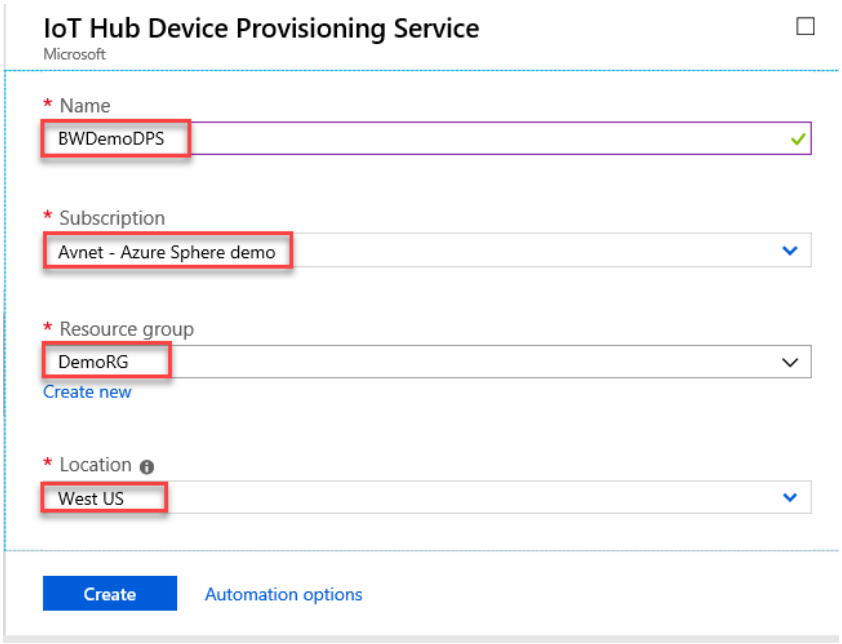
- In your Azure portal click on the “Create a resource” button
- Search the marketplace for “Device Provisioning Service”
- Select IoT Hub Device Provisioning Service



- Click Create



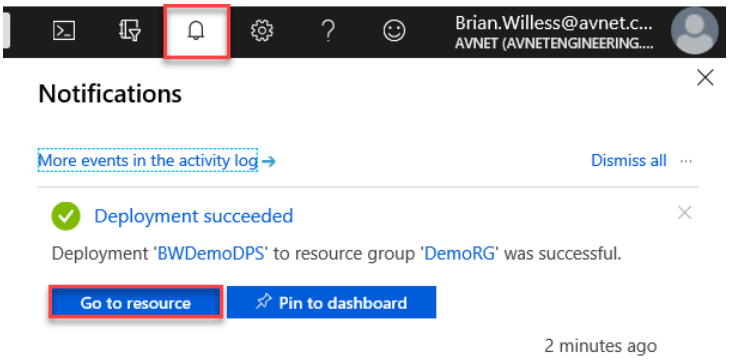
- In the **IoT Hub Device Provisioning Service** form fill in each entry
  - **Name:** Select a name for your DPS.
  - **Subscription:** Select your subscription, it may be a “Free” or a “Pay-as-you-Go” subscription.
  - **Resource Group:** Select the same resource group that you created when you created your IoT Hub
  - **Region:** Select the region closest to your physical location.
- Click on the “Create” button



- Wait for your DPS to be deployed

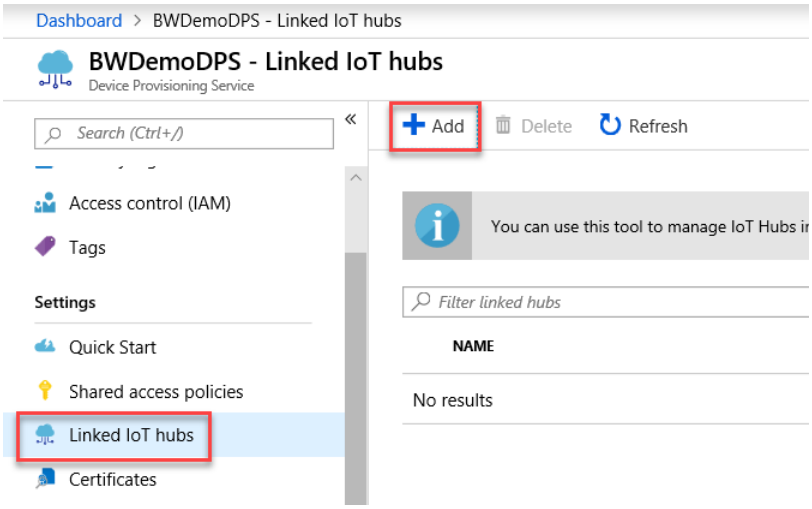
Next we need to configure our DPS. Find your new DPS resource. One way to find your new resource is from the notification icon at the top of the Azure Portal (the bell), click on this icon to see the resources you recently created.

- Click on the “Go to resource” link



Next we need to associate our DPS with our IoT Hub. This way when a device connects to the DPS, the DPS will know which IoT Hub to provision the device.

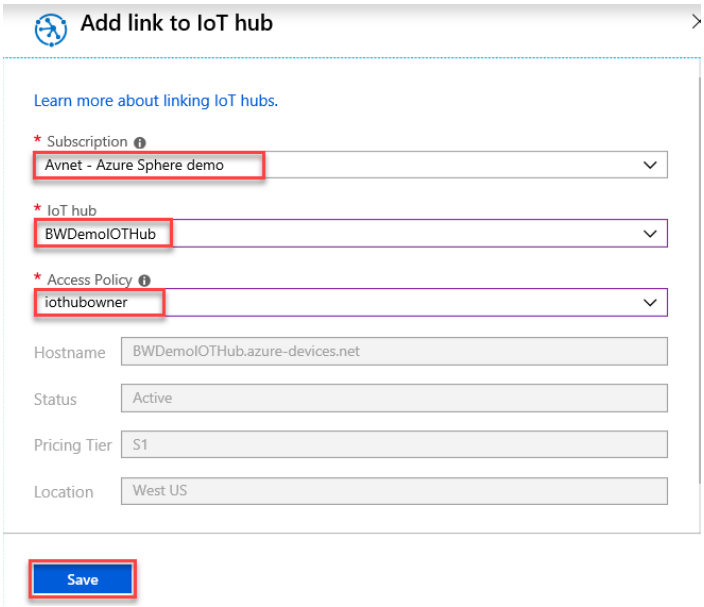
- From the DPS resource find the “Linked IoT hubs” blade (In Azure these configuration categories are called blades)
- Click on the “+ Add” link



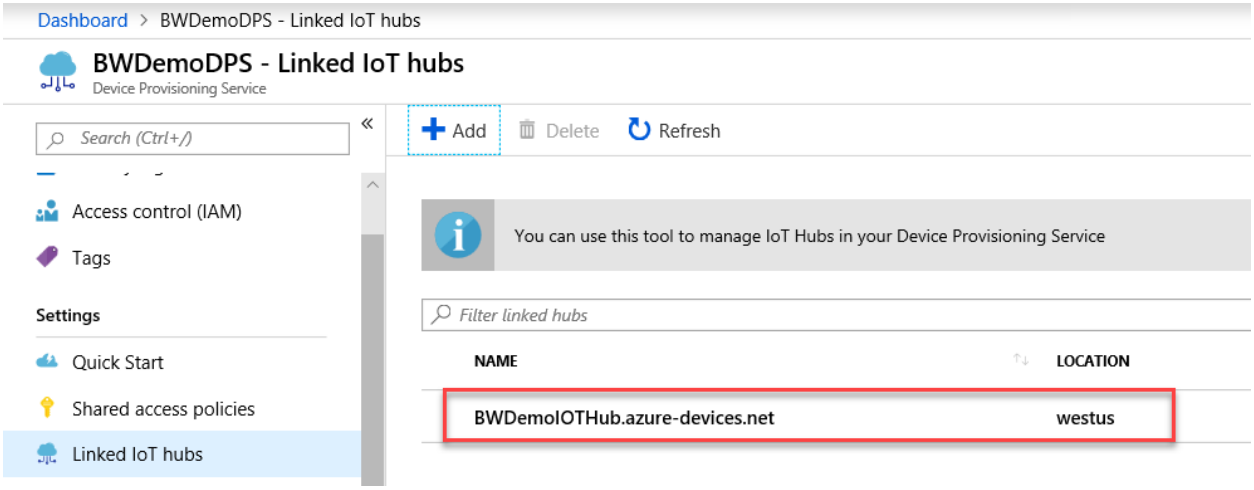
In the **Add link to IoT hub** form fill in each entry

- **Subscription:** Select your subscription, it may be a “Free” or a “Pay-as-you-Go” subscription.
- **IoT hub:** Select the IoT Hub we created earlier
- **Access Policy:** Select iothubowner from the drop down list

- Click on the “Save” button



- You will see your IoT Hub listed by its FQDN
- If you don't see your IoT Hub, click on the refresh button at the top of the form



Prove to DPS that we own the tenant

The next thing we need to do is to prove to the DPS service that we own the Azure Sphere tenant that our devices are claimed to. This is another slick security feature of the Azure Sphere system. After everything is setup, only devices in your tenant will be able to use your DPS to connect to your IoT Hub. That means that if someone where to get hold of your application and side load it onto their Azure Sphere device, that device would not be allowed to connect to your DPS or your IoT Hub. DPS will reject the connection based on an incorrect tenant certificate. Only devices claimed to your Azure Sphere Tenant will be allowed to connect to your DPS and IoT Hub because they will have the correct tenant certificate.

The steps to setup this trust relationship are listed below. This is a one-time setup task. Once this is all setup and configured, you'll only have to do this again if you setup a new DPS with a new IoT Hub.

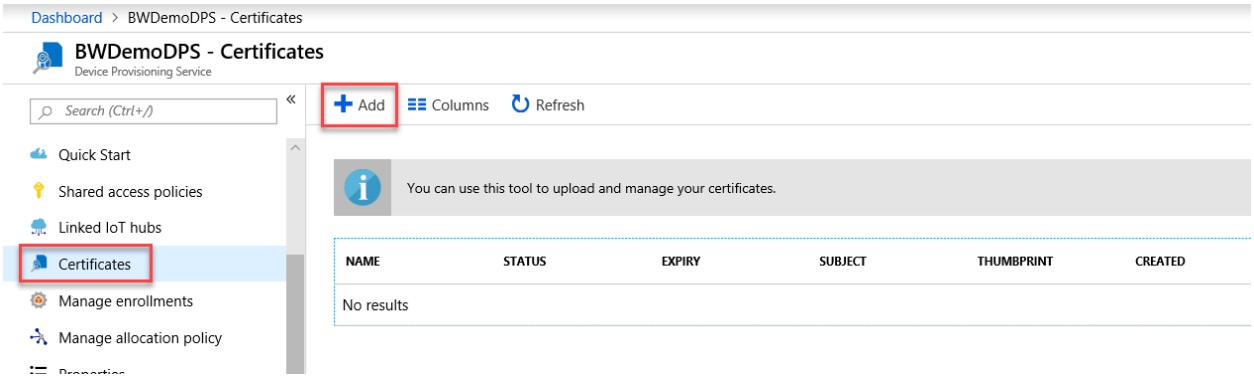
1. Download the authentication CA certificate for your Azure Sphere tenant from the Azure Sphere Security Service.
2. Upload the CA certificate to DPS to tell it that you own all devices whose certificates are signed by this CA. In return, the DPS presents a challenge code.
3. Generate and download a validation certificate from the Azure Sphere Security Service, which signs the challenge code. Upload the validation certificate to prove to DPS that you own the CA.
4. Create a device enrollment group, which will enroll any newly claimed Azure Sphere device whose certificate is signed by the validated tenant CA.

Download the authentication CA certificate for your Azure Sphere tenant from the Azure Sphere Security Service.

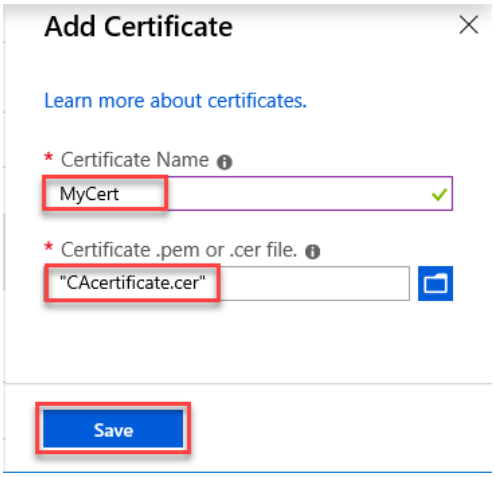
- Go back to your "Azure Sphere Developer Command Prompt Preview" application
    - Start → Azure Sphere → Azure Sphere Developer Command Prompt Preview
- Make sure you're logged into your tenant:
    - `azsphere login`
- Copy and paste in the command:
    - `azsphere tenant download-CA-certificate --output CAcertificate.cer`
    - Note the output file must have the .cer extension

Upload the CA certificate to DPS to tell it that you own all devices whose certificates are signed by this CA. In return, the DPS presents a challenge code.

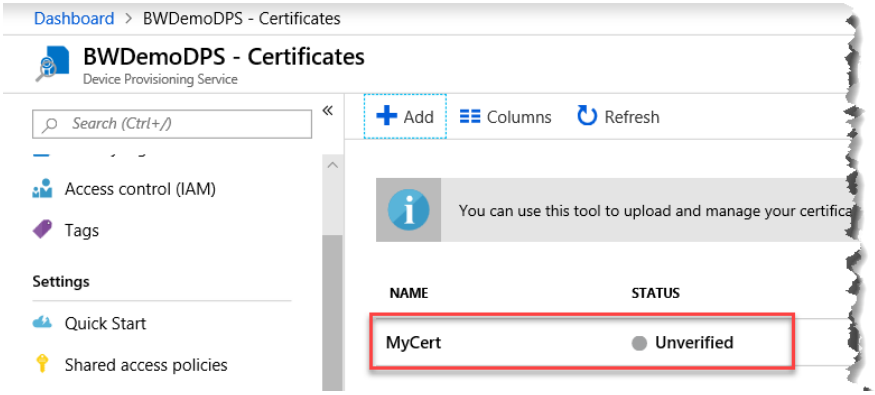
- Back in your Azure Portal navigate to the DPS that you created
- Open the Certificates blade from the list
- Click on the “+ Add” link at the top of the form



- In the **Add Certificate** form fill in each entry
  - **Certificate Name:** Create a name for your certificate
  - **Certificate *:** Browse to the certificate file we just downloaded
- Click on the “Save” button

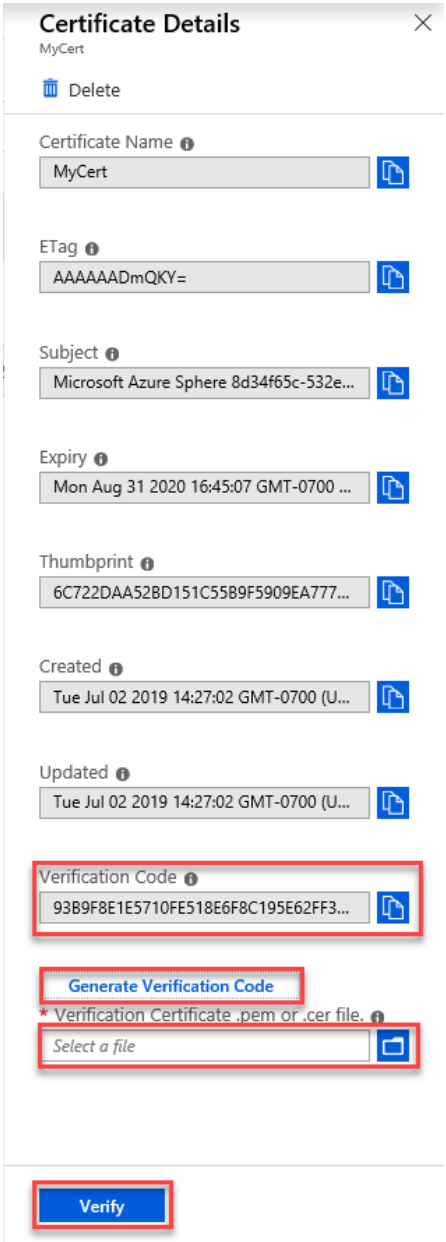


Your certificate will be added to the list and its state will be “Unverified.” Technically, we could have gained access to someone’s tenant ca. Just because we have this public certificate it does not prove that we own the tenant. Next we need to verify the certificate.



Generate and download a validation certificate from the Azure Sphere Security Service, which signs the challenge code. Upload the validation certificate to prove to DPS that you own the CA.

- Click on your certificate in the list, this brings up the Certificates Details form



- Return to the Azure Sphere Developer Command Prompt application

- Copy and paste the following command into the application, don't execute the command yet, we need to get the validation code first

    - azsphere tenant download-validation-certificate --output ValidationCertification.cer --verificationcode <code>

- Click on the "Generate Verification Code" link towards the bottom of the form, a Verification code is generated and displayed in the "Verification Code" box.

- Copy the verification code, there's a copy link to the right of the box

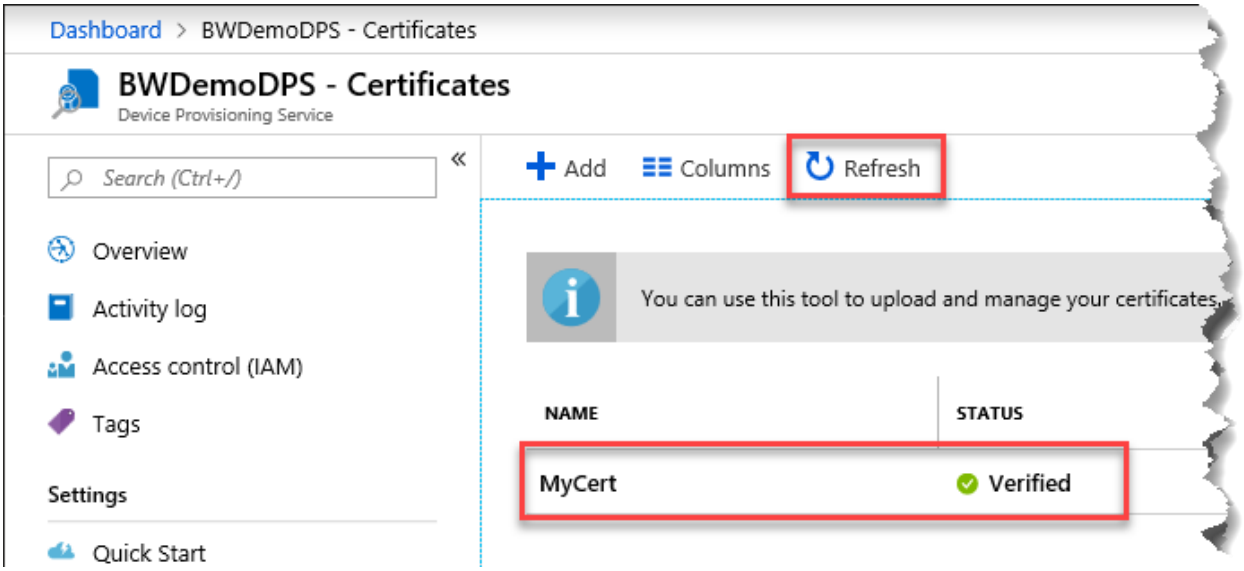
- Back in the command window, replace the <code> text with your verification code and execute the command

The Azure Sphere Security Service signs the validation certificate with the verification code to prove that you own the CA and downloads a Verification certificate.

- Back in your Azure portal, upload the new Verification Certificate by browsing to the file.

- Click the "Verify" link at the bottom of the form

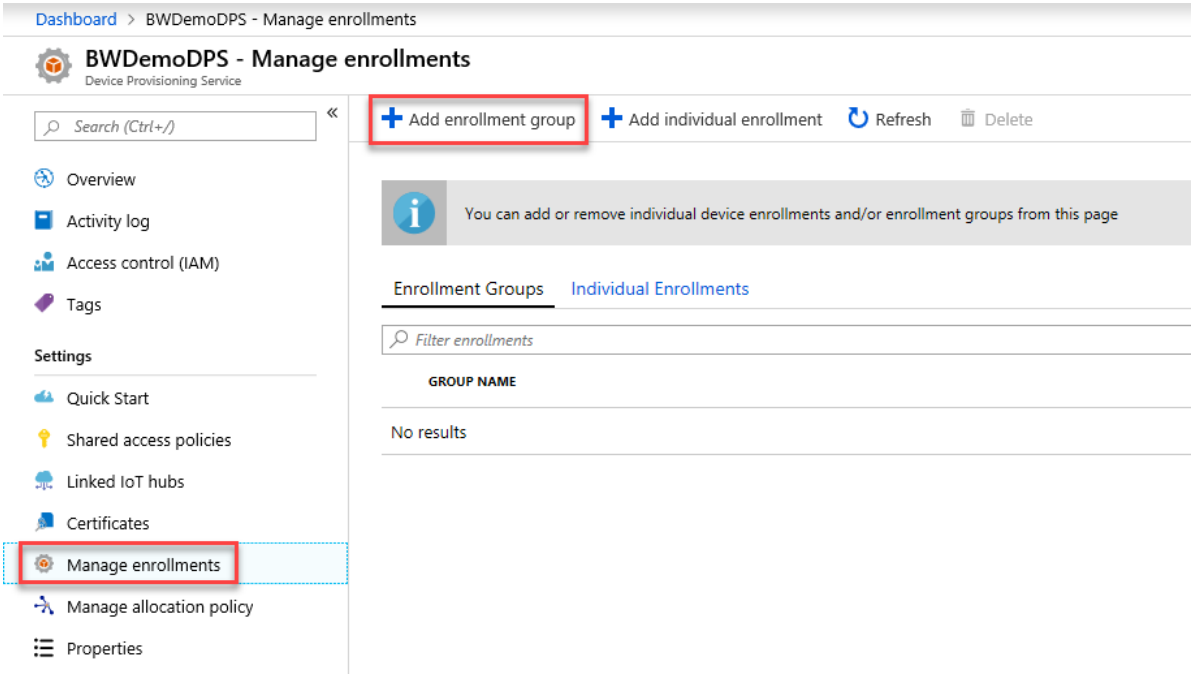
You should see that your certificate is now shown as Verified. If not, click on the “Refresh” link at the top of the form.



Create a device enrollment group, which will enroll any newly claimed Azure Sphere device whose certificate is signed by the validated tenant CA.

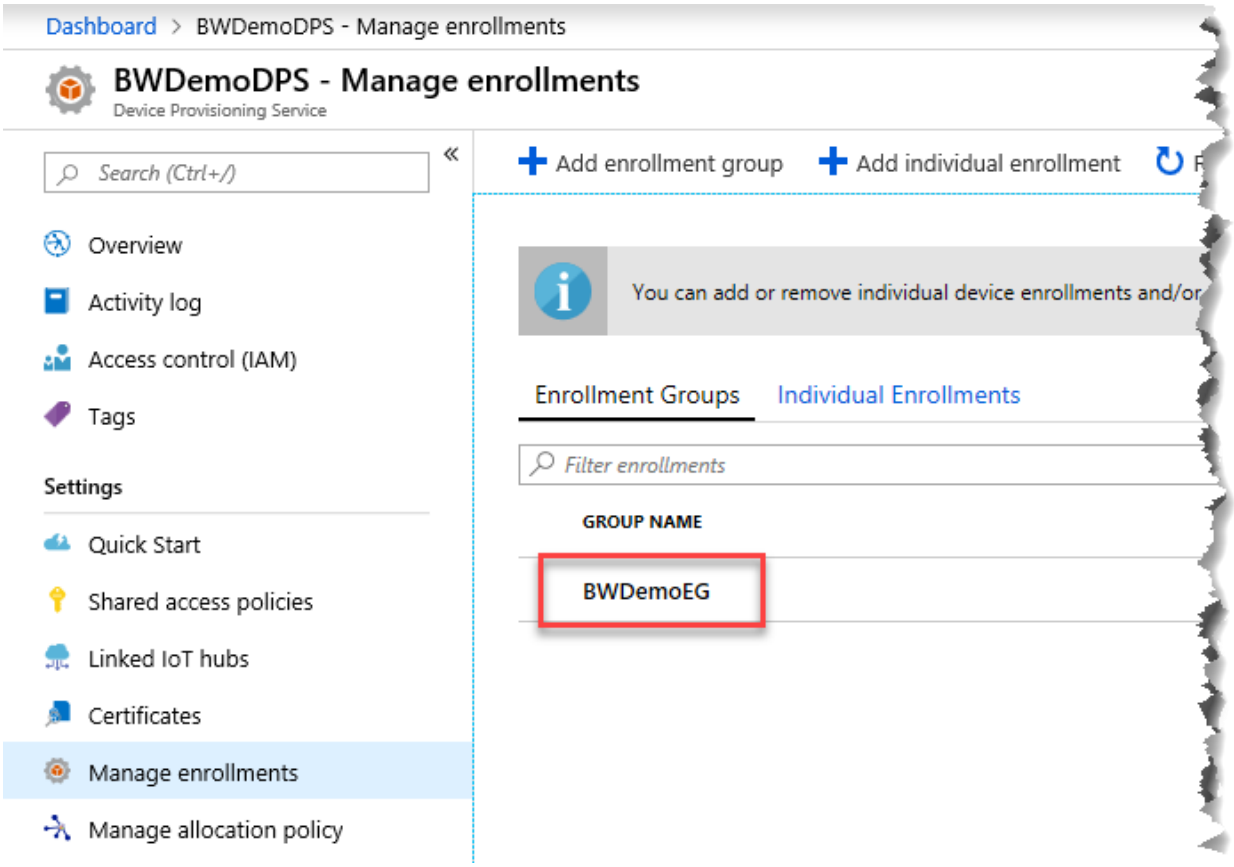
We're almost done!

- Back in your Azure Portal, navigate to your DPS resource
- Find and click on the "Manage enrollments" blade
- Click on the "Add enrollment group" link at the top of the form



- In the **Add Enrollment Group** form fill in each entry
  - **Group Name:** Create a name for your enrollment group
  - **Primary Certificate:** Select the certificate that we just uploaded and validated
  - Leave all the other fields at the default selections
- Click on the “Save” button at the top of the form

You should see your new Enrollment Group appear in the list

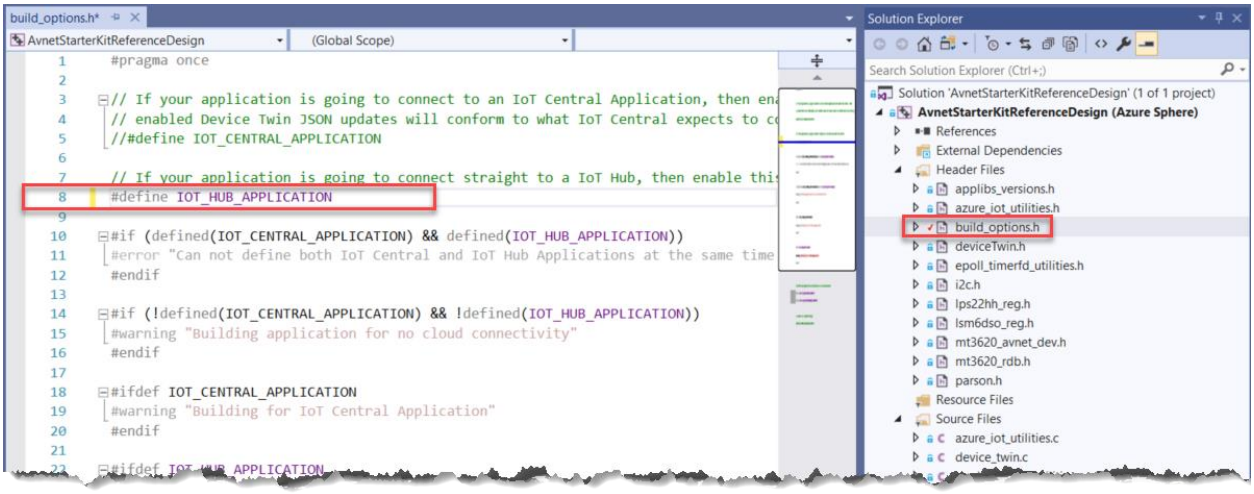


Configure the example application for the IoT Hub configuration

Now that we have the Azure side ready, let's go back to our application code and configure the application to connect to use our newly created DPS and IoT Hub.

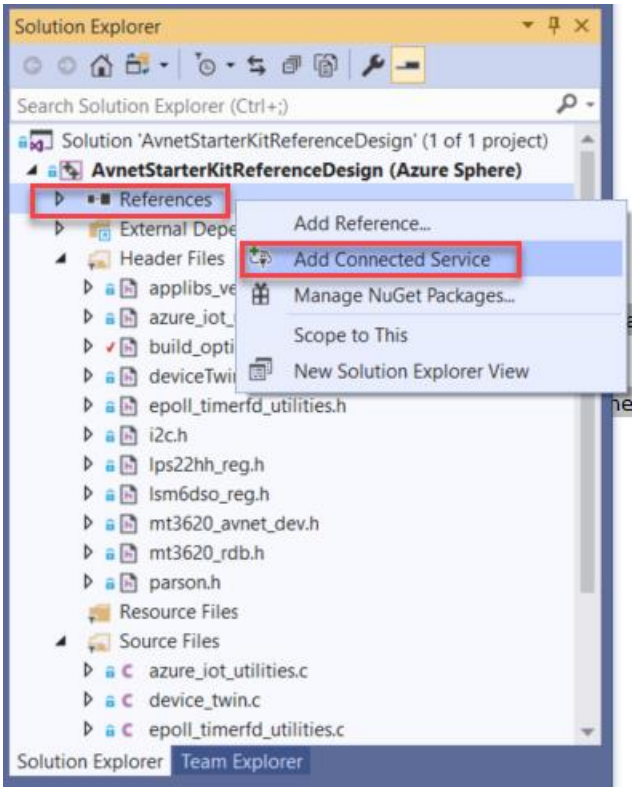
Modify the Azure Sphere source code

- Launch the Visual Studio application and open the "**AvnetStarterKitReferenceDesign**" project. Visual Studio keeps a list of recent projects, your project should be found in that list.
- Open the build_options.h file
- On line #8 remove the "//"s to enable the IOT_HUB_APPLICATION build option
- Confirm that line #5 is commented out

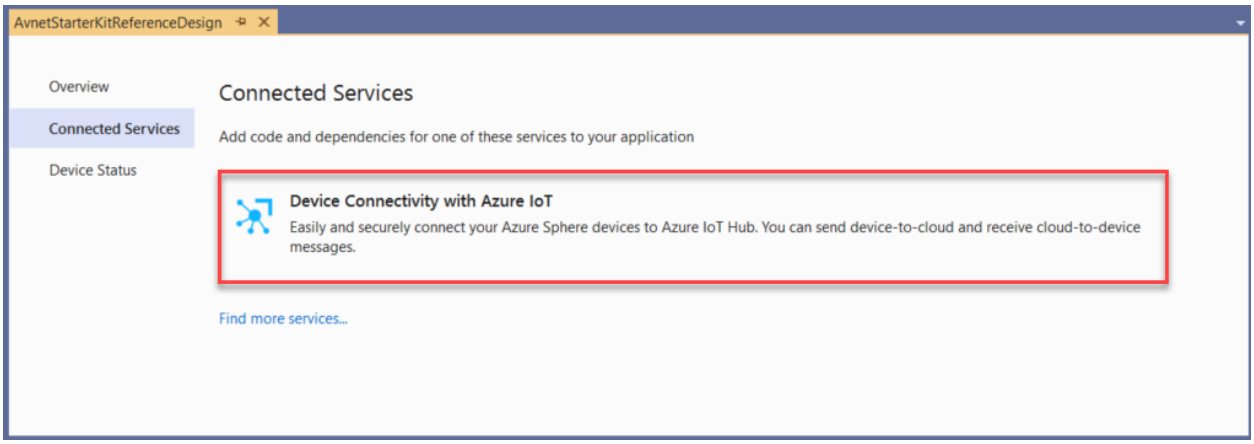


Next we need to add DPS and IoT Hub details to our project.

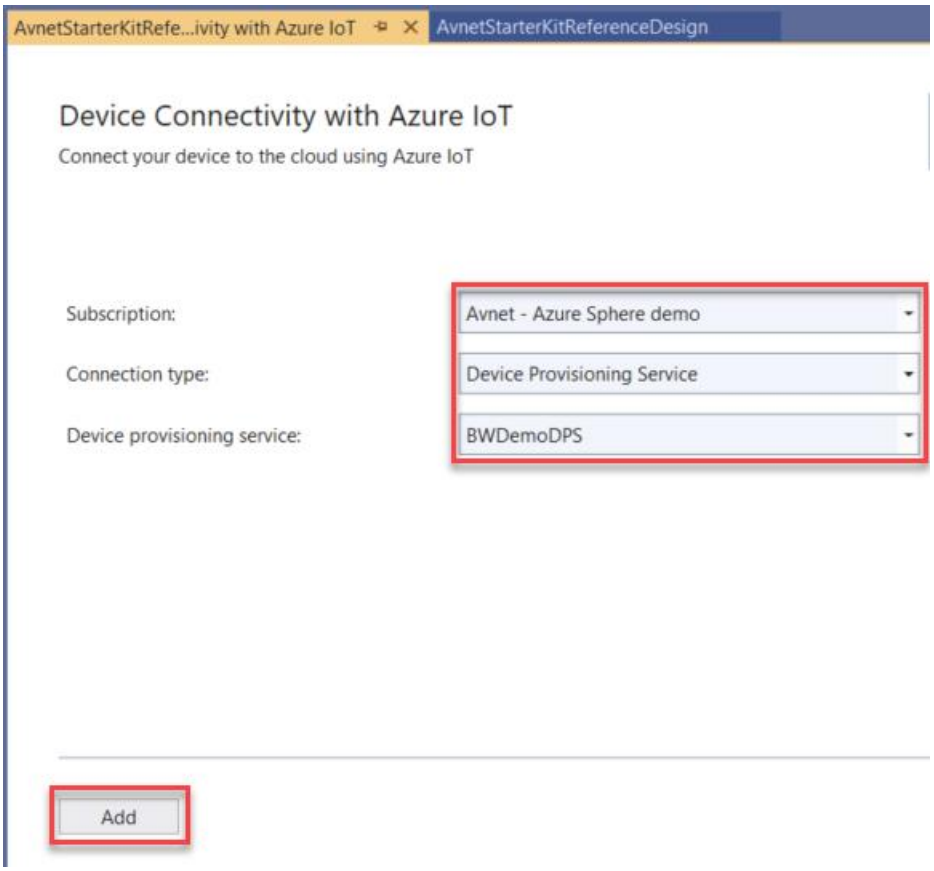
- In the Solution Explorer window, right click on “References”
- Select “Add Connected Service”



- Select the “Device Connectivity with Azure IoT” option



- You may be asked to login to your Azure account. If so, then log into your Azure account
    - **Subscription**: Select your subscription
    - **Connection type**: select “Device Provisioning Service”
    - **Device Provisioning Service**: select the DPS we just configured
- Click on the “Add” link at the bottom of the form, you may have to scroll down to see the Add link

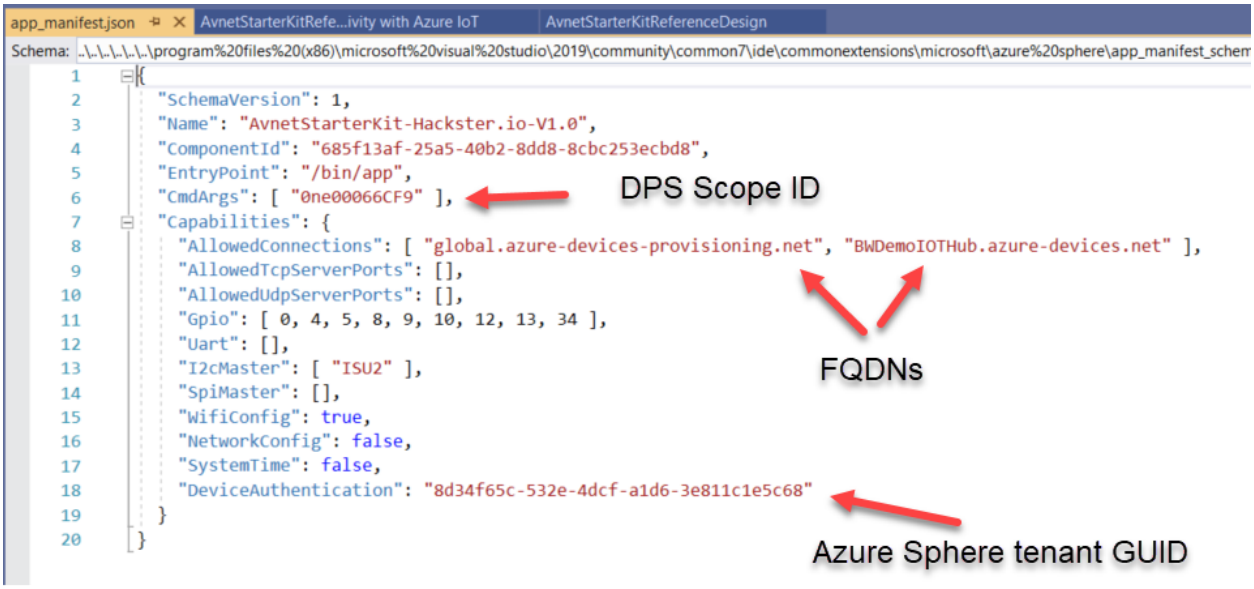


This service modified our project. Specifically it added two FQDNs, my Azure Sphere tenant ID and the scope ID for my DPS to the app_manifest.json file

```
Adding Device Connectivity with Azure IoT to the project.
The following hostnames have been added to the AllowedConnections attribute of app_manifest.json: global.azure-devices-provisioning.net, BWDemoIOTHub.azure-devices.net
The Azure Sphere tenant ID '8d34f65c-532e-4dcf-a1d6-3e811c1e5c68' has been added to the DeviceAuthentication attribute of app_manifest.json .
Azure Sphere Device Provisioning Service scope id:'0ne00066CF9'
Successfully added Device Connectivity with Azure IoT to the project.
```

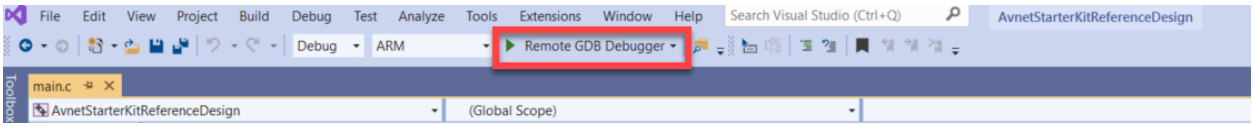
Below is a capture of my app_manifest.json file with the changes identified.

- **DPS Scope ID**: This is used when our application connects to the global DPS, this allows the global DPS to route our request to our DPS.
- **AllowedConnections**: The connected service feature added two FQDNs to this field. We discussed the "AllowedConnections" capability in Lecture 4. If our application needs to talk with any server, that servers IP address of FQDN needs to be listed here.
- **DeviceAuthentication:** This is the GUID for my Azure Sphere Tenant.



Now let's build and run our application.

- Make sure your device is connected to your PC
- Ensure your device has a Wi-Fi connection
    - azsphere device wifi show-status
- Click on the "Remote GDB Debugger" button at the top of the application. Your application will build, link, side-load, and run.



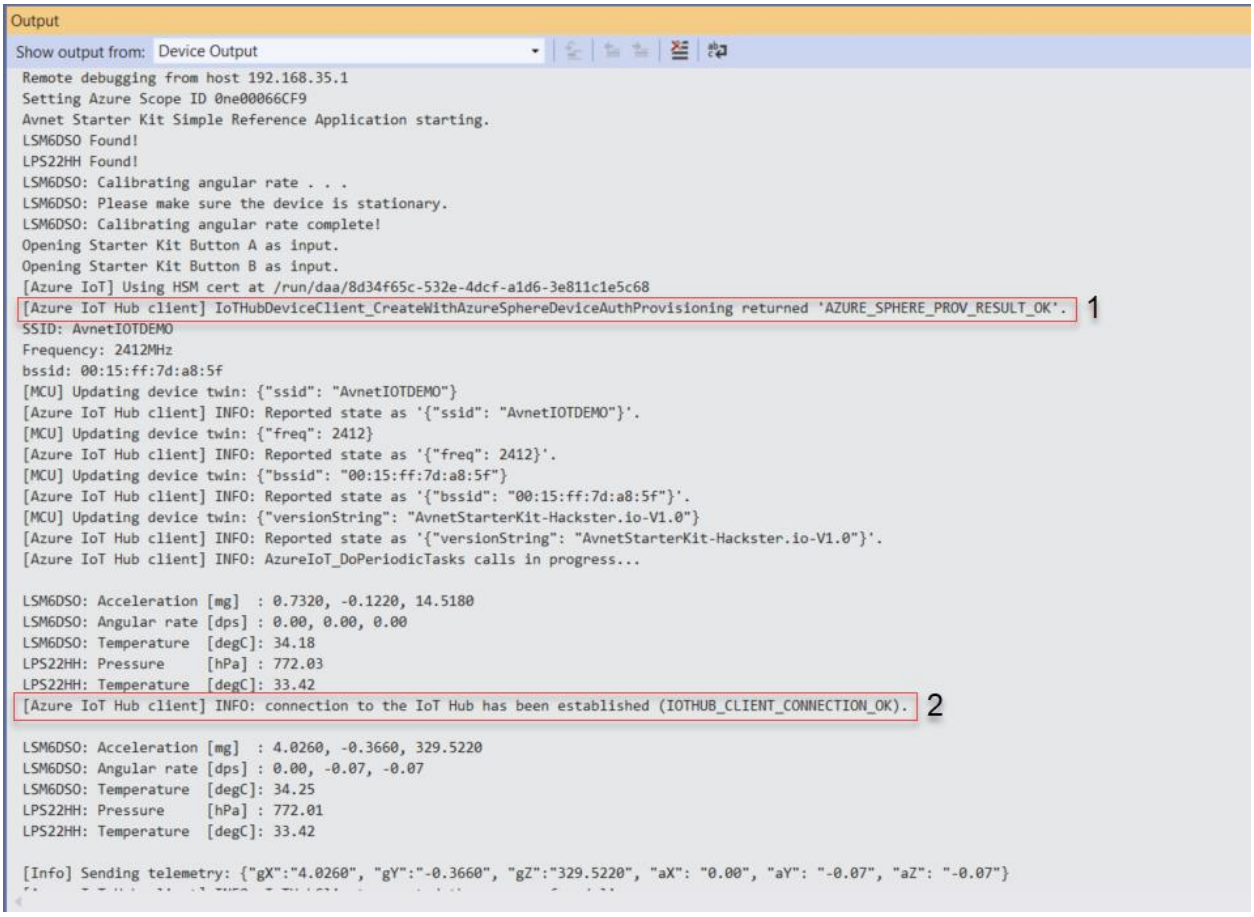
Your output should look similar to the screenshot below. There are two debug lines that I want to point out.

1: This debug shows that our device connected to our DPS and that the DPS successfully provisioned our device to our IoT Hub

2: This debug shows that our application has successfully connected to our IoT Hub

If you have errors . . .

- Confirm your device is connected to a Wi-Fi access point or hot spot that has internet connectivity



Code assignment

The assignment is to add and additional telemetry item to report the pressure reading from the LPS22HH sensor. The key for the {“key”: value} pair should be called “pressure.”

Hints:

- The pressure is read into the variable `pressure_hPa` in the i2c.c file around line #172
- You could modify the existing code that sends the telemetry data up
    - i2c.c file around line #200
- You could send up the pressure telemetry as a standalone {“key”: value} pair

What does success look like?

When the new pressure telemetry item is implemented, you’ll see the new telemetry item transmitted to the Azure IoT Hub. You’ll see the data in the Azure Sphere debug and after setting up Time Series Insights (the next section), you’ll also be able to see the data graphed in your TSI Environment.

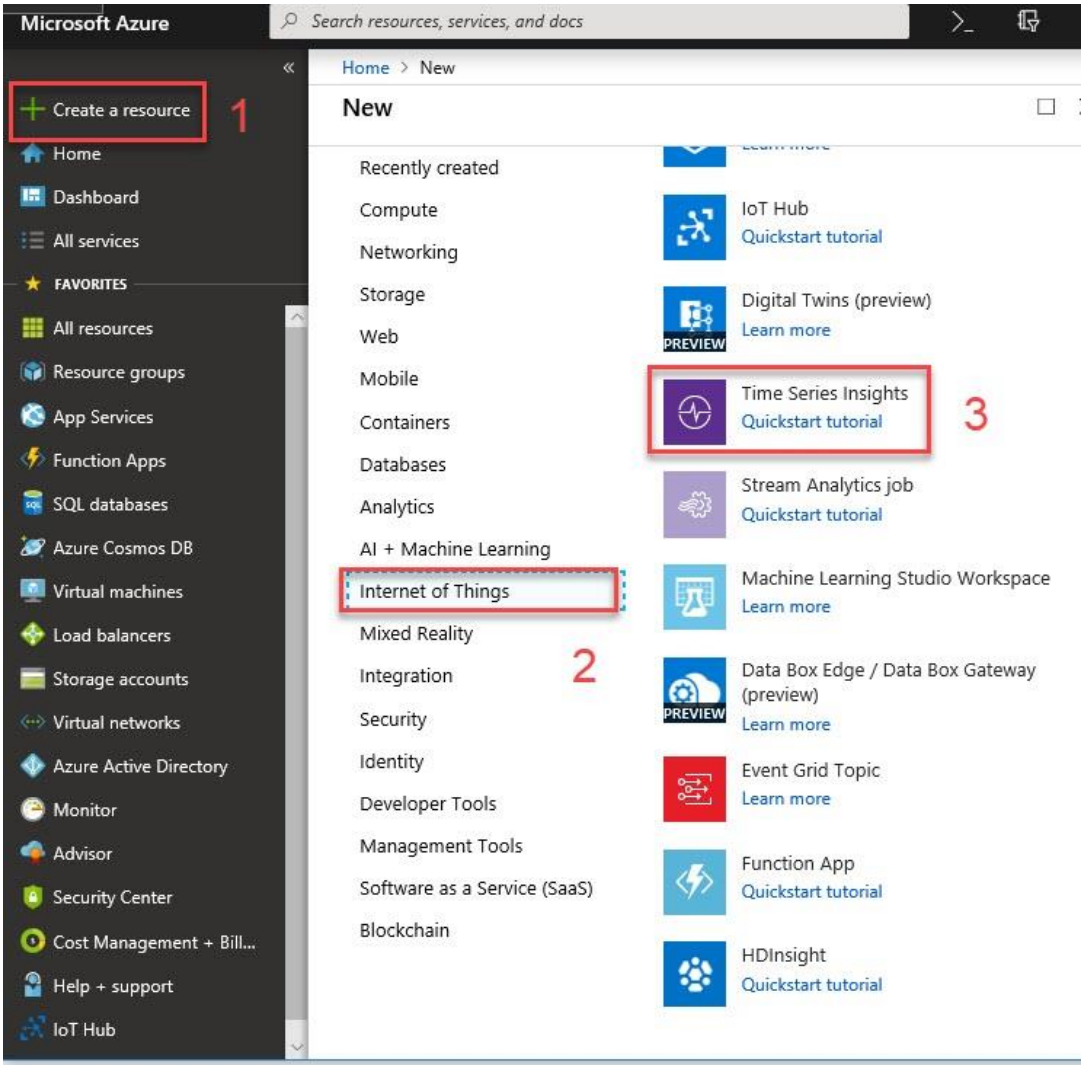
Create a Time Series Insights (TSI) Environment

Our application is streaming lots of telemetry data. What can we do in Azure to view this data? One answer is to setup a Time Series Insights (TSI) environment. TSI documentation is here. There are other services available in Azure to visualize your data, TSI is easy to setup and is a powerful tool.

> "Azure Time Series Insights provides powerful data exploration and telemetry tools to help you refine operational analysis."

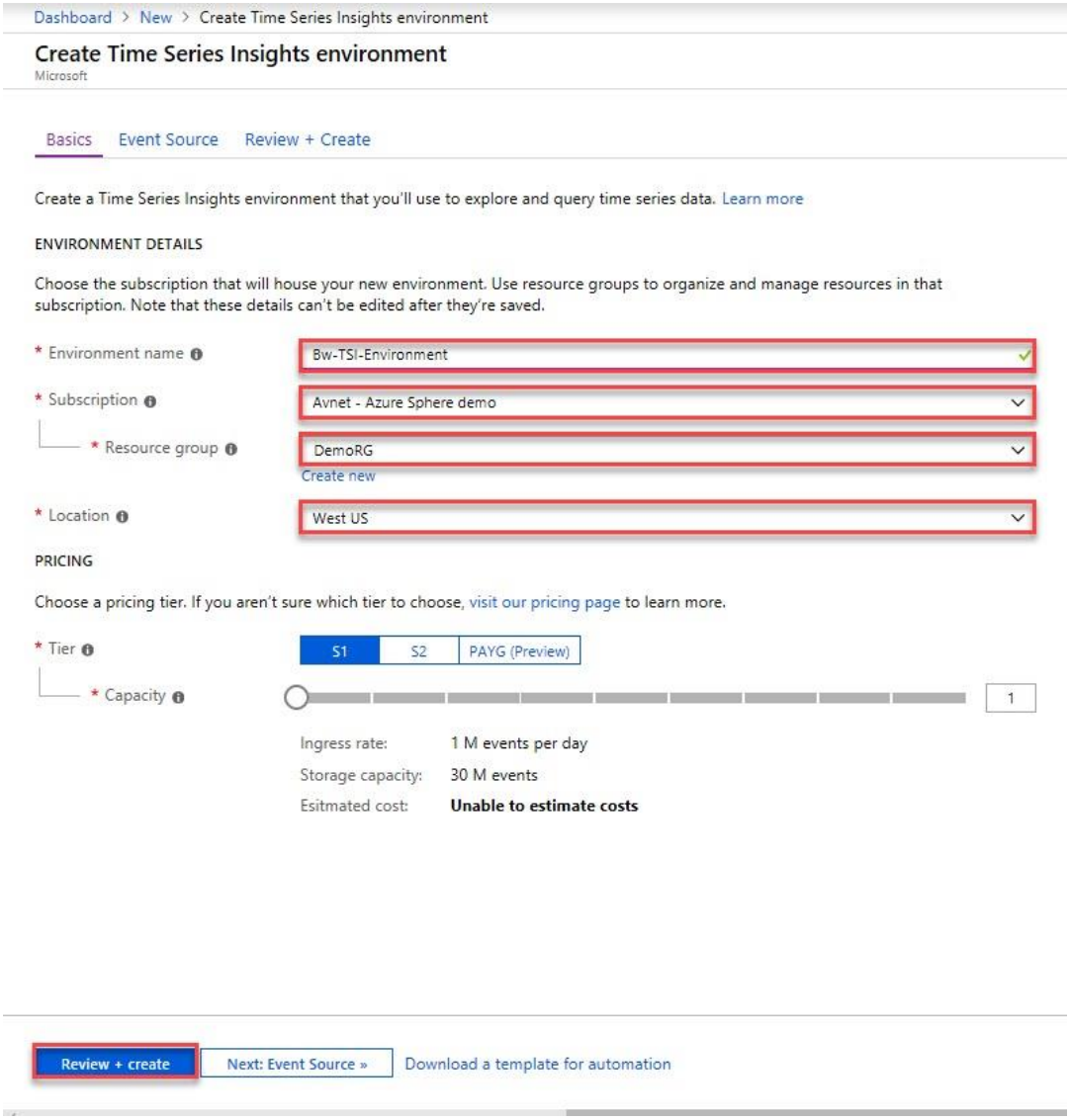
One note about the TSI resource. This resource is one of the more expensive Azure resources. I recommend deleting this resource when you've completed this lab.

- Login to your Azure account: https://portal.azure.com
- Click on the "+ Create a resource" link (1)
- Click on the "Internet of Things" category (2)
- Click on the "Time Series Insights" link (3)

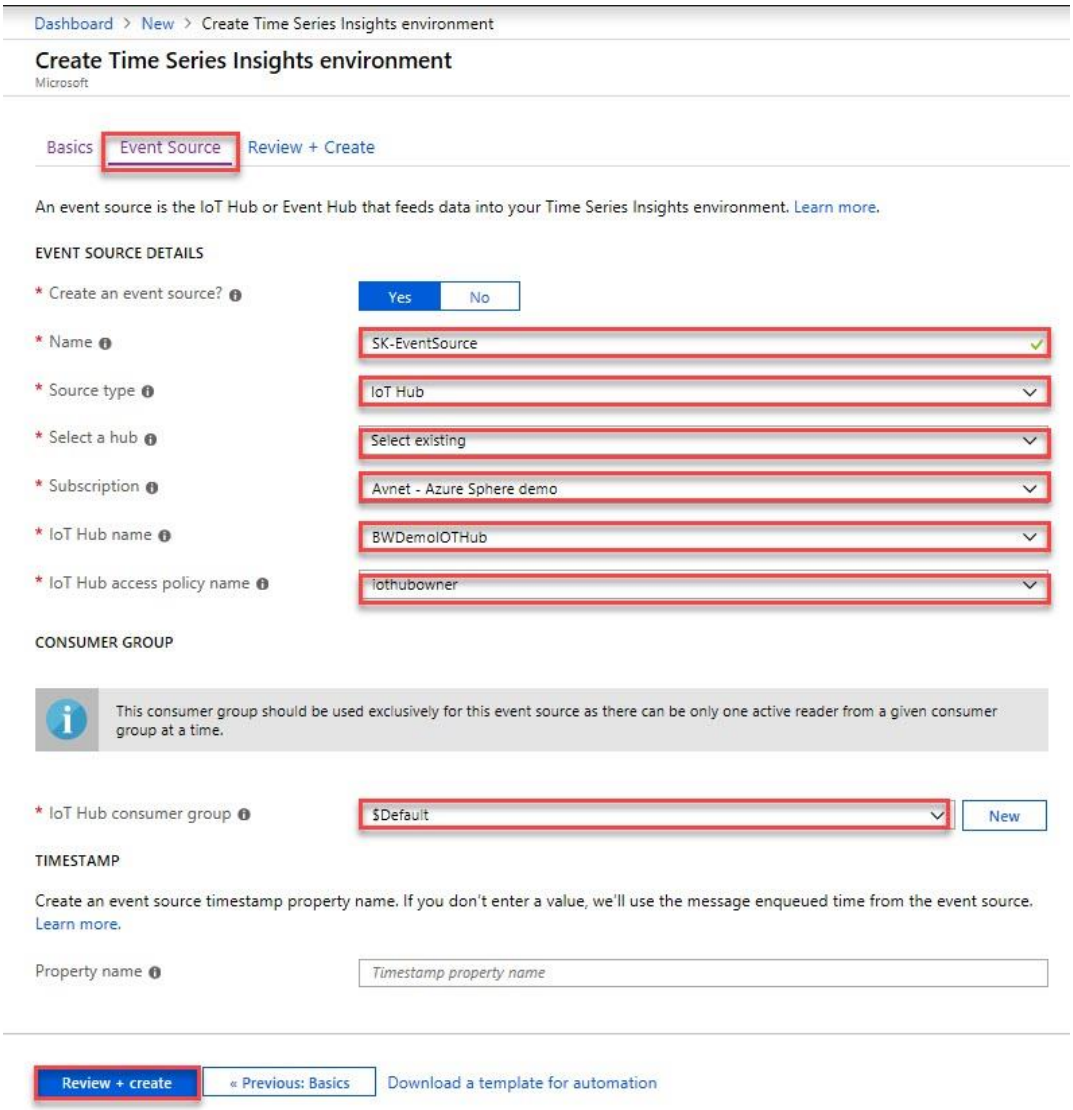


On the “Basics” Tab fill in the form

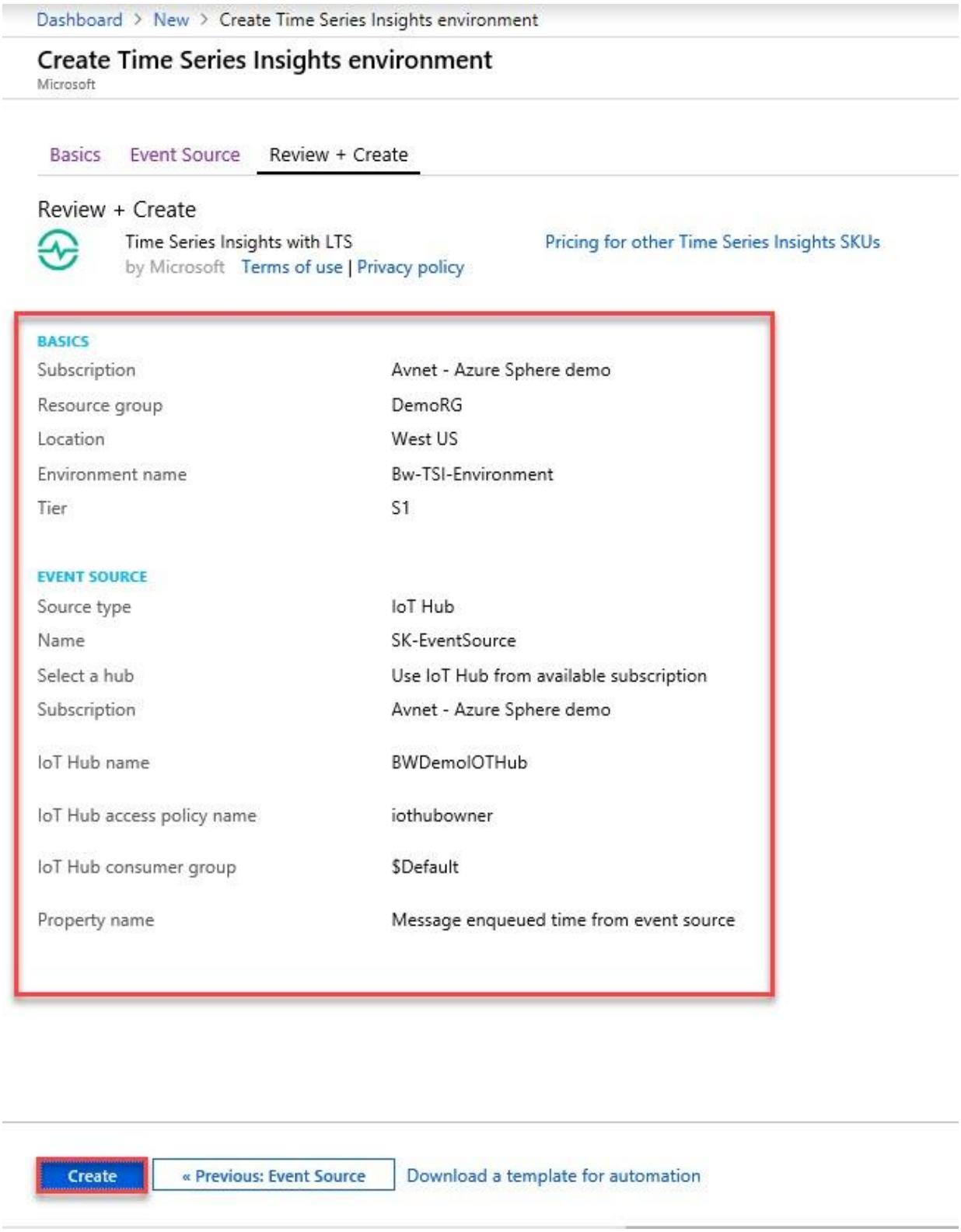
- **Environment Name**: Enter a name for your TSI environment
- **Subscription**: Select your Subscription
- **Resource group**: Select the same Resource Group you used for the IoT Hub
- **Location**: Select the Location closest to your physical location



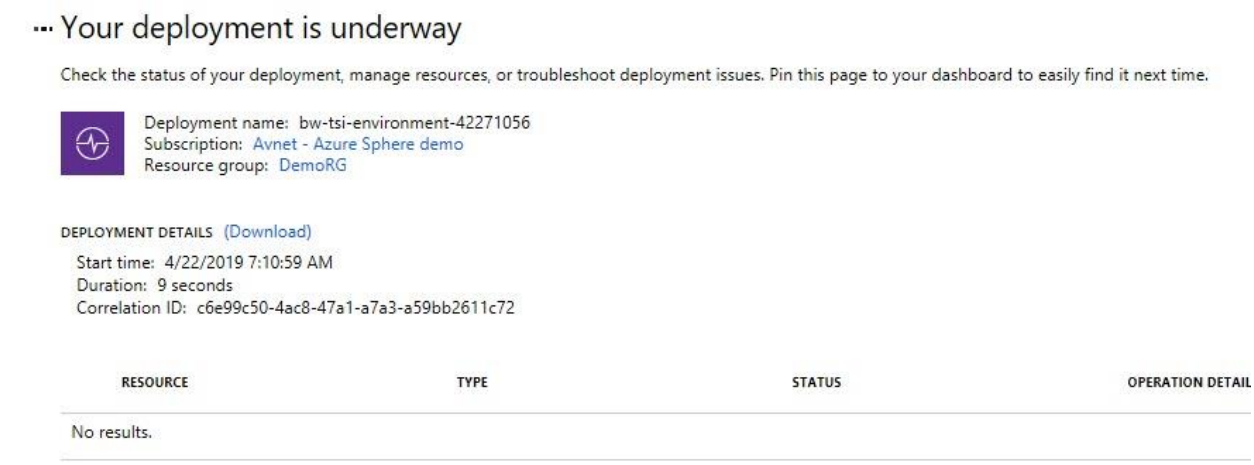
- Next click on the “Event Source” tab.
  - **Name**: Select a name for your event
  - **Source Type**: Select “IoT Hub”
  - **Select a Hub**: Select “Select existing”
  - **Subscription**: Select your subscription
  - **IoT Hub Name**: Select the name of your IoT Hub from the list
  - **IoT Hub access policy name**: Select “iothubowner”
  - **IoT Hub consumer group**: Select “$Default”
  - Click on “Review + create”



On the “Review + Create” screen, review your settings and if they look good, click on the “Create” button at the bottom of the form.

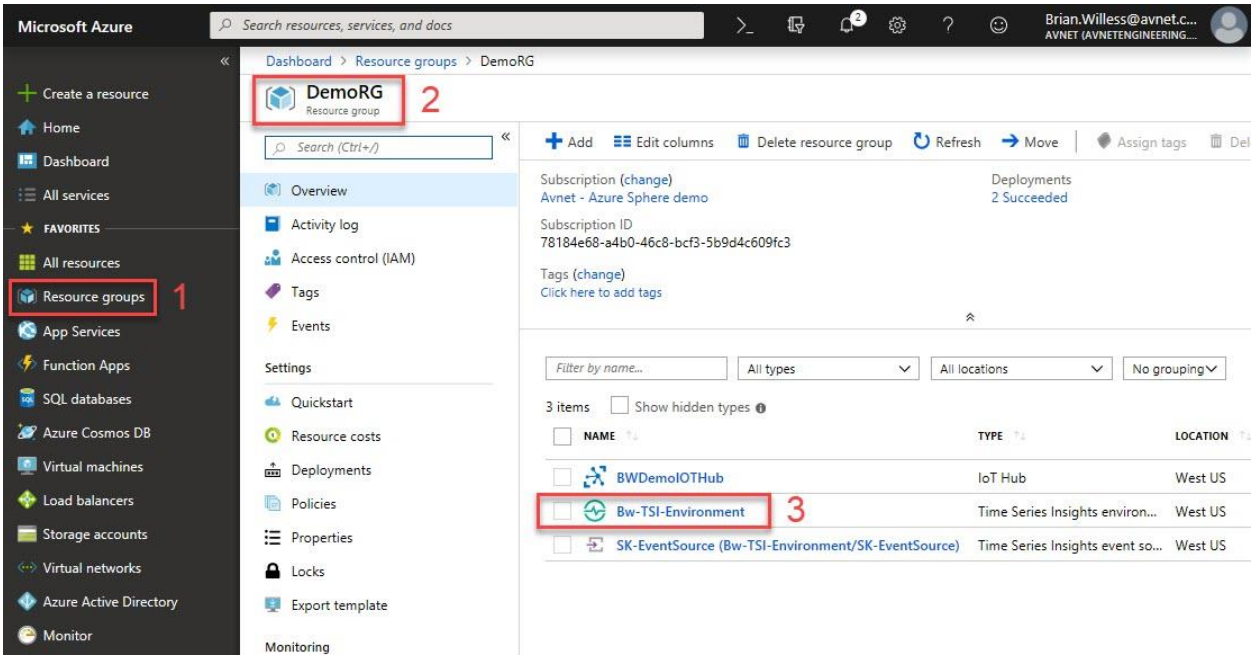


You'll see your TSI environment being provisioned:

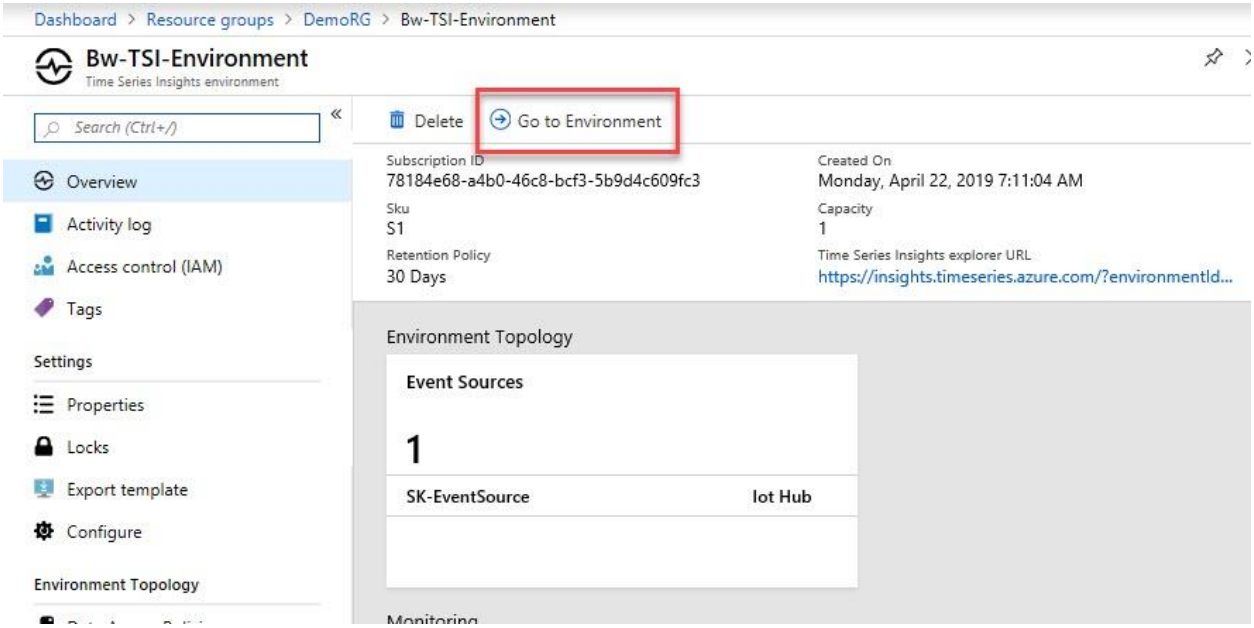


Once your deployment is complete (mine took 42 seconds), navigate to your new TSI resource.

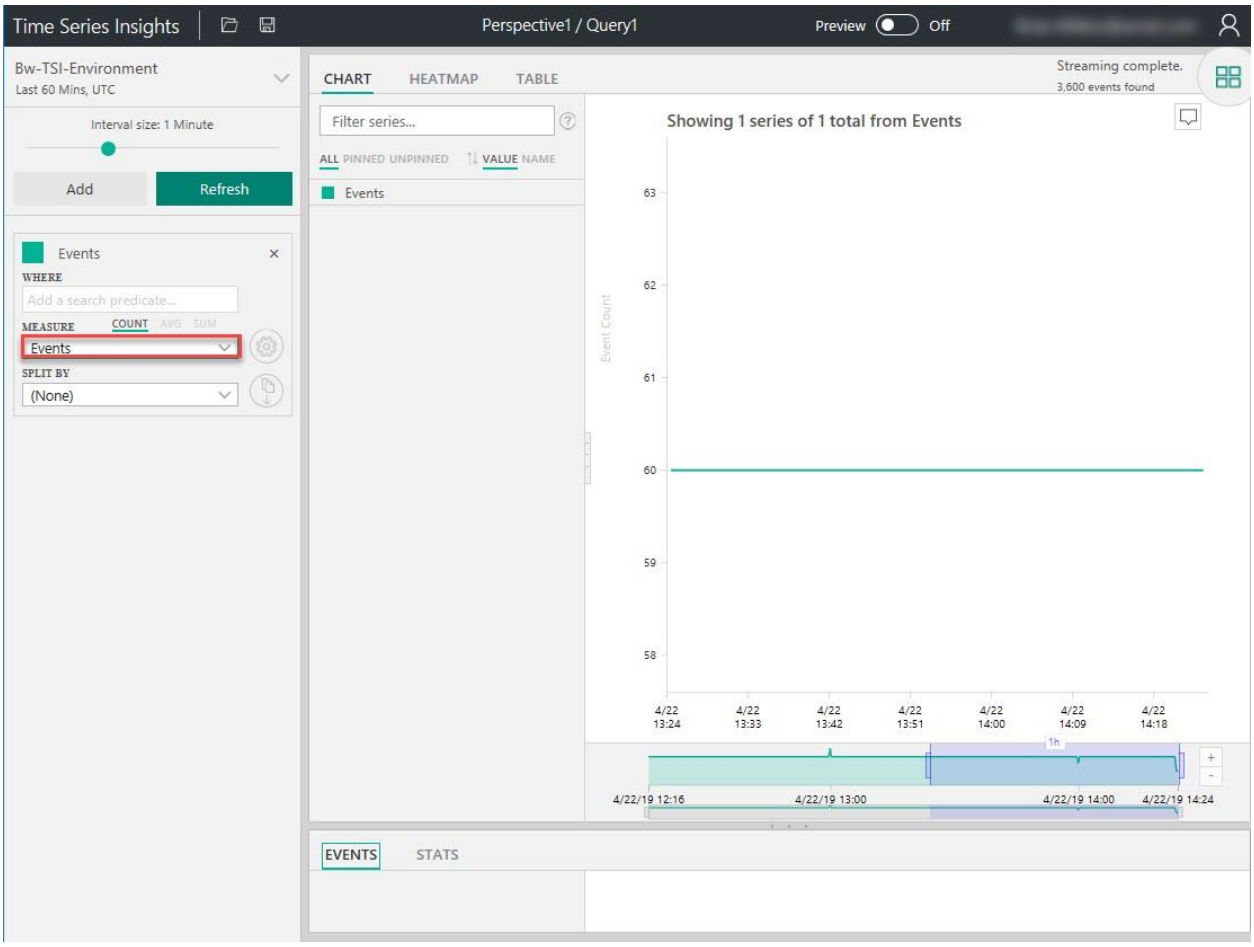
- From the left most column, click on "Resource Groups"
- Select your resource group
- Select your TSI Environment



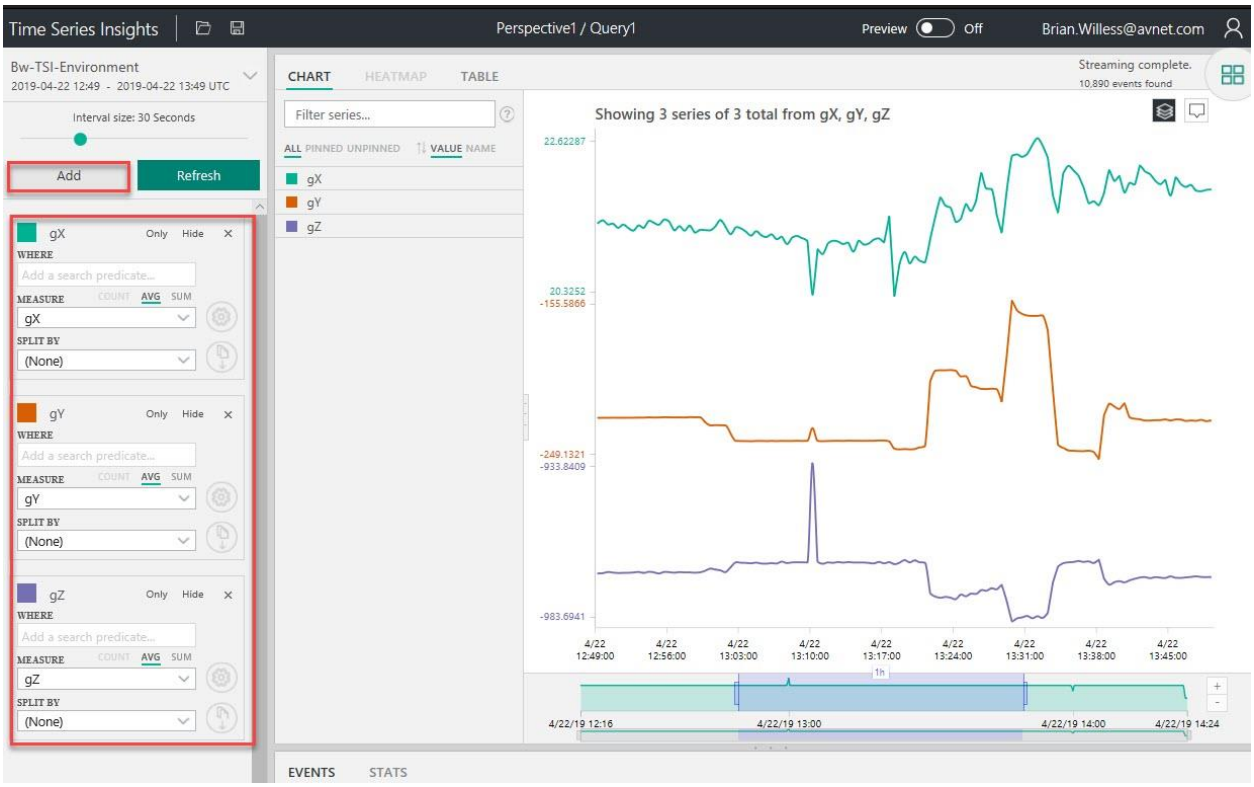
- Click on the “Go to Environment” link



The Environment will open, but you won’t see any data



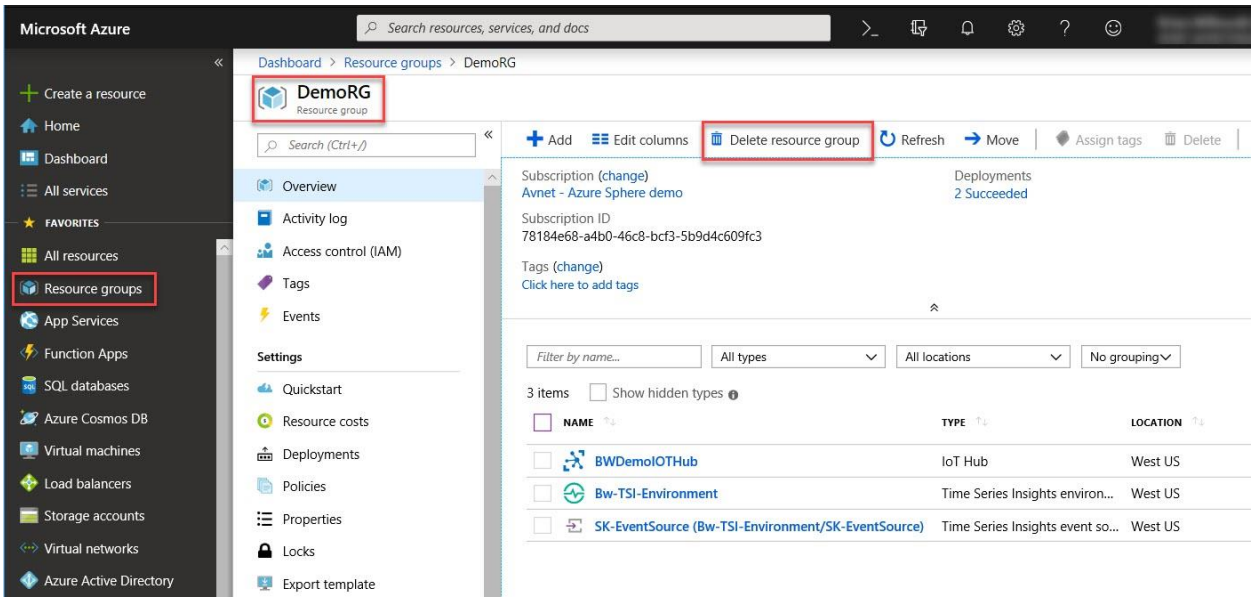
Select the “Events” pull down menu. You’ll see entries for all the different telemetry items the application sends up, select the “gX” entry. You can add additional measurements to the graph by clicking the “Add” button. The graphic below shows the gX, gY, and gZ data all plotted. I was moving my Starter Kit around on the different axis’s to generate this data.



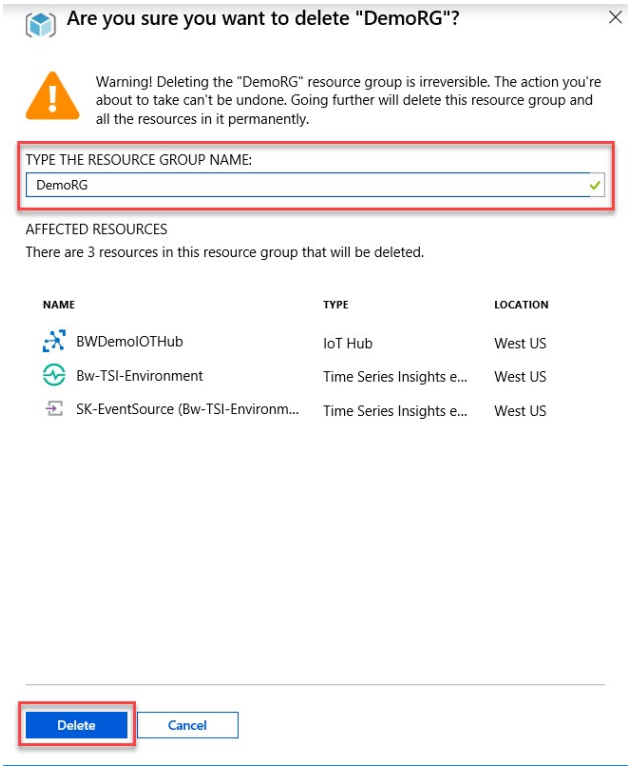
Clean up Azure Resources

When you're finished playing with the graph and the demo, you should delete the Azure resources. If you don't delete them, then you'll see monthly charges for the IoT Hub, and for the Time Series Insights resources. The quick and easy way to remove all these resources is to delete the Resource Group.

- Open the Azure Portal: https://portal.azure.com
- In the left most column, select "Resource Groups"
- Select your resource group
- At the top select "Delete resource group"



- Type the name of your resource group into the form
- Click on the "Delete" button at the bottom of the form.



Wrap Up

In this Lab we learned a lot about Azure and how to create the Azure resources required to connect IoT devices.

- How to create an IoT Hub
- How to create a Device Provisioning Service (DPS)
- How to configure the example application for the IoT Hub configuration and the Connected Service utility
- How to create a Time Series Insights (TSI) Environment

Revision History

Date	Version	Revision
1 July 19	01	Preliminary release