Renesas Synergy™ Platform

Synergy MQTT/TLS Azure Cloud Connectivity Solution

Introduction

This application note describes IoT Cloud connectivity solution in general and introduces you briefly to the IoT Cloud provider Microsoft Azure. It covers the Synergy MQTT/TLS module, its features, and operational flow sequence (Initialization/Data flow). The application example provided in the package uses Azure IoT Hub. This document shows first-time Microsoft Azure users in detailed steps how to configure the Azure IoT Hub platform to run this application example demonstration.

This application note enables you to effectively use the Synergy MQTT/TLS modules in your own design. Upon completion of this guide, you will be able to add the MQTT/TLS module to your own design, configure it correctly for the target application, and write code using the included application example code as a reference and efficient starting point. References to more detailed API descriptions, and other application projects that demonstrate more advanced uses of the module, are in the *Synergy Software Package (SSP) User's Manual* (see Next Steps section), and serve as valuable resources in creating more complex designs.

Currently, the Synergy MQTT/TLS Connectivity solution is implemented and tested using Microsoft Azure IoT on PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit. Support for other Synergy kits and IoT Cloud providers will be provided in upcoming releases.

Required Resources

To build and run the MQTT/TLS application example, you need:

Development tools & software

- e^2 studio ISDE v6.2.1 or IAR Embedded Workbench® for Renesas Synergy™ v8.23.1, available at www.renesas.com/synergy/tools-kits.
- Synergy Software Package (SSP) 1.5.3 (www.renesas.com/synergy/ssp) or Synergy Standalone Configurator (SSC) 6_2_1 (www.renesas.com/synergy/ssc)
- SEGGER J-link® USB driver (www.renesas.com/synergy/jlinksynergy)
- When migrating to future SSP versions, follow the corresponding SSP release note to establish the required development environment.

Hardware

- Renesas Synergy™ PK-S5D9 kit (www.renesas.com/synergy/pk-s5d9); AE-CLOUD1 kit (includes a Wi-Fi board (www.renesas.com/synergy/ae-cloud1); and, the AE-CLOUD2 kit (www.renesas.com/synergy/ae-cloud2), which includes a Pillar board, Wi-Fi board, BG96 Cellular shield, and a CAT-M1 SIM card.
- Renesas Synergy™ Application Example kit PMOD based Wi-Fi Module (www.renesas.com/synergy/ae-wifi1).
- PC running Windows® 7 or 10; the Tera Term console, or similar application, and an installed web browser (Google Chrome, Internet Explorer, Microsoft Edge, Mozilla Firefox, or Safari).
- Micro USB cables
- Ethernet cable

Prerequisites and Intended Audience

This application note assumes that you have some experience with the Renesas e^2 studio ISDE and Synergy Software Package (SSP). Before you perform the procedures in this application note, follow the procedure in the *SSP User Manual* to build and run the Blinky project. Doing so enables you to become familiar with the e^2 studio/IAR and the SSP, and validates that the debug connection to your board functions properly. In addition, this application note assumes you have some knowledge of MQTT/TLS and its communication protocols.

The intended audience are users who want to develop applications with MQTT/TLS modules using Renesas Synergy™ S5 or S7 MCU Series.

Contents

1. Introduction to Cloud Connectivity

1.1 Overview

Internet of Things (IoT) is a sprawling set of technologies described as connecting everyday objects, like sensors or smart-phones, to the World Wide Web. IoT devices are intelligently linked together to enable new forms of communication between things and people, and among things.

These devices, or things, connect to the network. Using sensors, they provide the information they gather from the environment or allow other systems to reach out and act on the world through actuators. In the process, IoT devices generate massive amounts of data, and cloud computing provides a pathway, enabling data to travel to its destination.

1.2 Major Components

The IoT Cloud Connectivity Solution includes the following major components:

1. Devices or Sensors
2. Gateway
3. IoT Cloud services
4. End user application/system

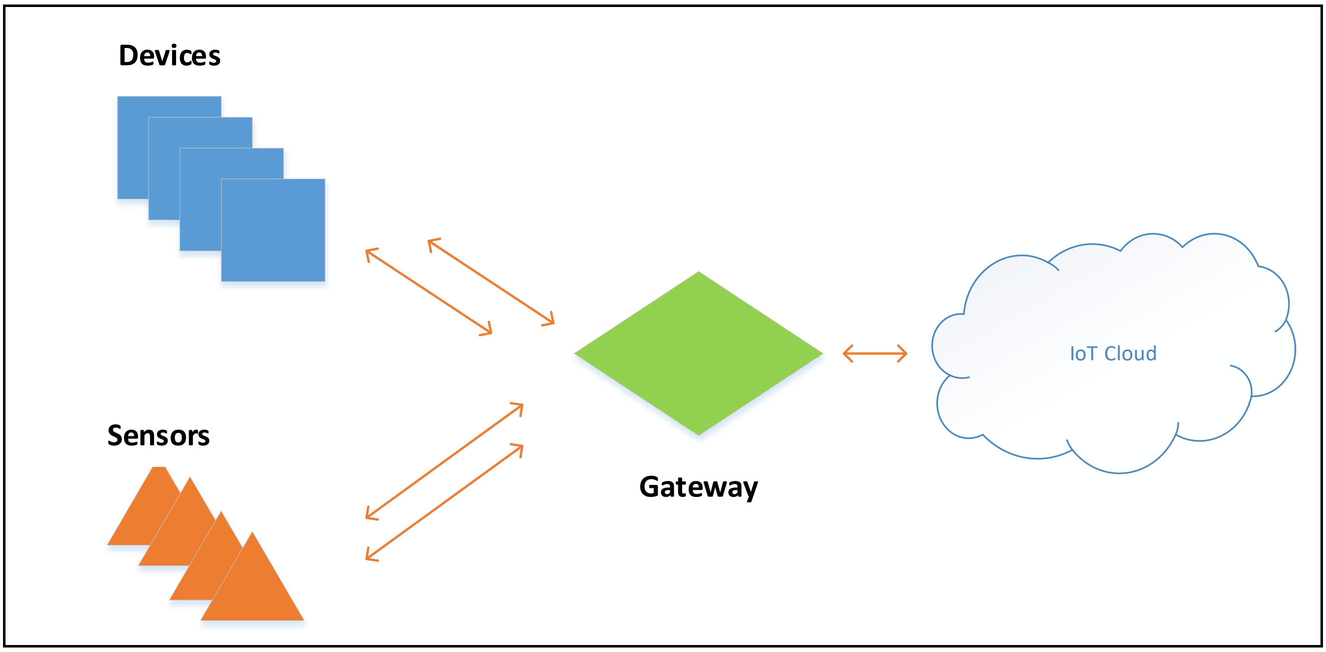


Figure 1. IoT Cloud Connectivity Architecture

Devices or Sensors

A device includes hardware and software that interacts directly with the world. Devices connect to a network to communicate with each other, or to centralized applications. Devices may connect to the Internet either directly or indirectly.

Gateway

A gateway enables devices that are not directly connected to the Internet to reach cloud services. The data from each device is sent to the Cloud Platform, where it is processed and combined with data from other devices, and potentially with other business-transactional data. Most of the common communication gateways support one or more communication technologies such as Wi-Fi, Ethernet, or cellular.

IoT Cloud

Many IoT devices produce lots of data. You need an efficient, scalable, affordable way to manage those devices, handle all that information, and make it work for you. When it comes to storing, processing, and analyzing data, especially big data, it is hard to surpass the cloud.

1.3 Cloud Provider Overview

1.3.1 Microsoft Azure IoT Solution

Microsoft's end-to-end IoT platform is a complete IoT offering so that enterprises can build and realize value from IoT solutions quickly and efficiently. Azure IoT solutions, including Azure IoT Suite and Azure IoT Hub, harness the power of the full cloud. Data and developer offerings for the enterprise offer hyperscale IoT services, rich data and analytics, and deep integration. Developers can begin building custom solutions using the IoT Hub, or quickly start with comprehensive preconfigured solutions available in the Azure IoT Suite (including the Azure IoT Hub).

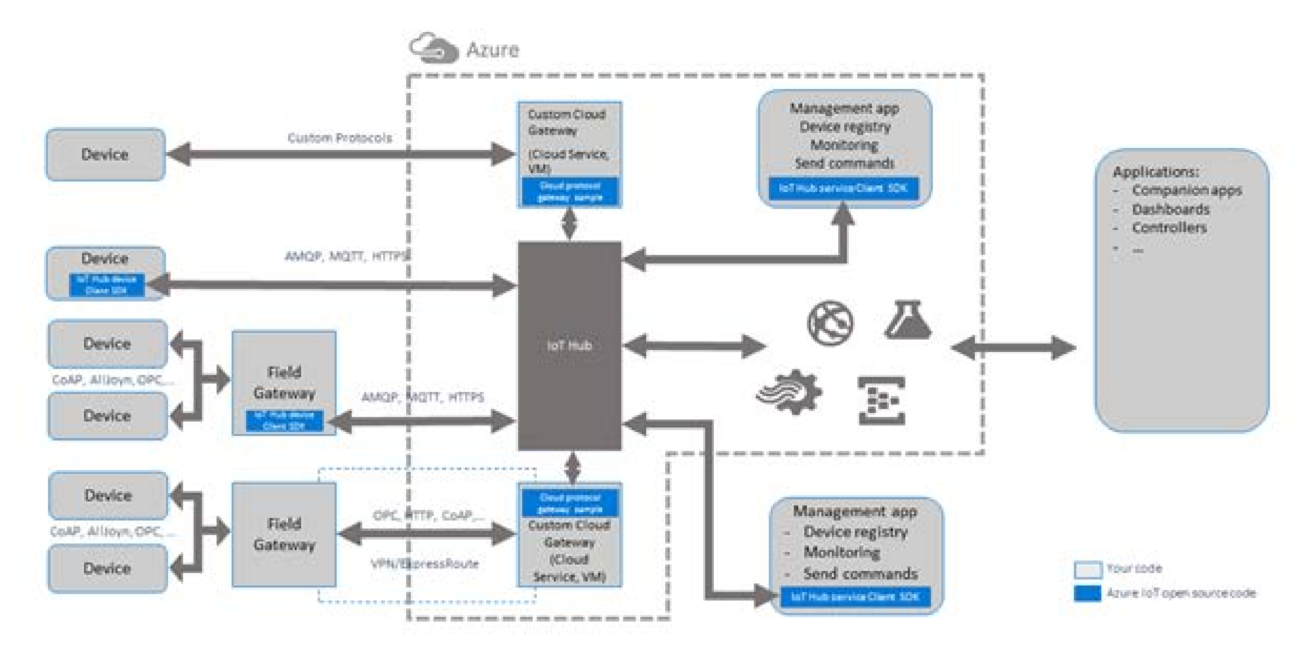


Figure 2. Microsoft Azure IoT Cloud Solution

IoT Hub: The IoT Hub provides an easy and secure way to connect, provision, and manage millions of IoT devices that send and receive billions of messages per month. IoT Hub is the bridge between your devices and their solutions in the Cloud, allowing them to store, analyze, and act on data in real time. The IoT Hub enables secure, reliable, two-way communication, from the device to the cloud and the cloud to the device, over open protocols, such as MQTT, HTTPS, and AMQPS that are already widely used in IoT.

Field Gateway: The Azure IoT protocol gateway is a framework for protocol adaptation that is designed for high-scale, bidirectional device communication with IoT Hub. The protocol gateway is a pass-through component that accepts device connections over a specific protocol. It bridges the traffic to IoT Hub over AMQP 1.0.

The Azure IoT protocol gateway includes an MQTT protocol adapter that enables you to customize the MQTT protocol behavior if necessary. Since IoT Hub provides built-in support for the MQTT v3.1.1 protocol, you should only consider using the MQTT protocol adapter if protocol customizations or specific requirements for additional functionality are required.

Custom Cloud Gateway: A custom cloud gateway enables protocol adaptation and/or some form of custom processing before reaching the cloud gateway communication endpoints. This can include the respective protocol implementation required by devices (or field gateways) while forwarding messages to the cloud gateway for further processing and transmitting command and control messages from the cloud gateway back to the devices.

1.3.1.1 Key Features

(1) Device Security

Security is a critical concern when deploying and managing IoT devices. IoT Hub offers the following security features:

- The communication path between devices and Azure IoT Hub, or between gateways and Azure IoT Hub, is secured using industry-standard Transport Layer Security (TLS) with Azure IoT Hub authenticated using X.509 standard.
- To protect devices from unsolicited inbound connections, Azure IoT Hub does not open any connection to the device. The device initiates all connections.
- Azure IoT Hub durably stores messages for devices and waits for the device to connect. These commands are stored for two days, enabling devices connecting sporadically due to power or connectivity concerns, to receive these commands. Azure IoT Hub maintains a per-device queue for each device.

(2) Per-device Key Authentication

The following diagram shows authentication in IoT Hub using security tokens.

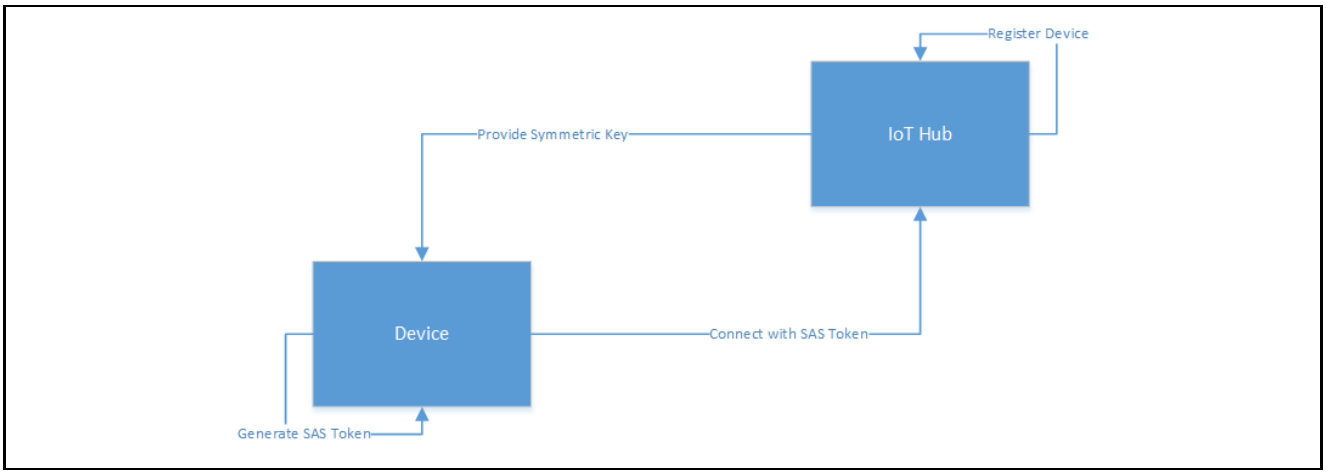


Figure 3. Authentication using Security Tokens

- The device prepares a shared access signature (SAS) token using the device endpoint, device id, and primary key (generated as part of the device add to the IoT Hub).
- When connecting to the IoT Hub, the device presents the SAS token as the password in the MQTT CONNECT message. The user name content is the combination of device endpoint, device name along with the additional Azure defined string.
- The IoT Hub verifies the SAS token and registers the device and connection gets established.
- IoT hub provides Symmetric key for Data encryption.
- The connection is closed when the SAS token expires.

1.4 MQTT Protocol Overview

MQTT stands for Message Queuing Telemetry Transport. MQTT is a Client Server publish-subscribe messaging transport protocol. It is an extremely light weight, open, simple messaging protocol, designed for constrained devices, as well as low-bandwidth, high-latency, or unreliable networks. These characteristics make it ideal for use in many situations, including constrained environments, such as communication in Machine to Machine (M2M) and IoT contexts, where a small code footprint is required, and/or network bandwidth is at a premium.

A MQTT client can publish information to other clients through a broker. A client, if interested in a topic, can subscribe to the topic through the broker. A broker is responsible for authentication, authorization of clients, as well as delivering published messages to any of its clients who subscribe to the topic. In this publisher/subscriber model, multiple clients may publish data with the same topic. A client will receive the messages published if the client subscribes to the same topic.

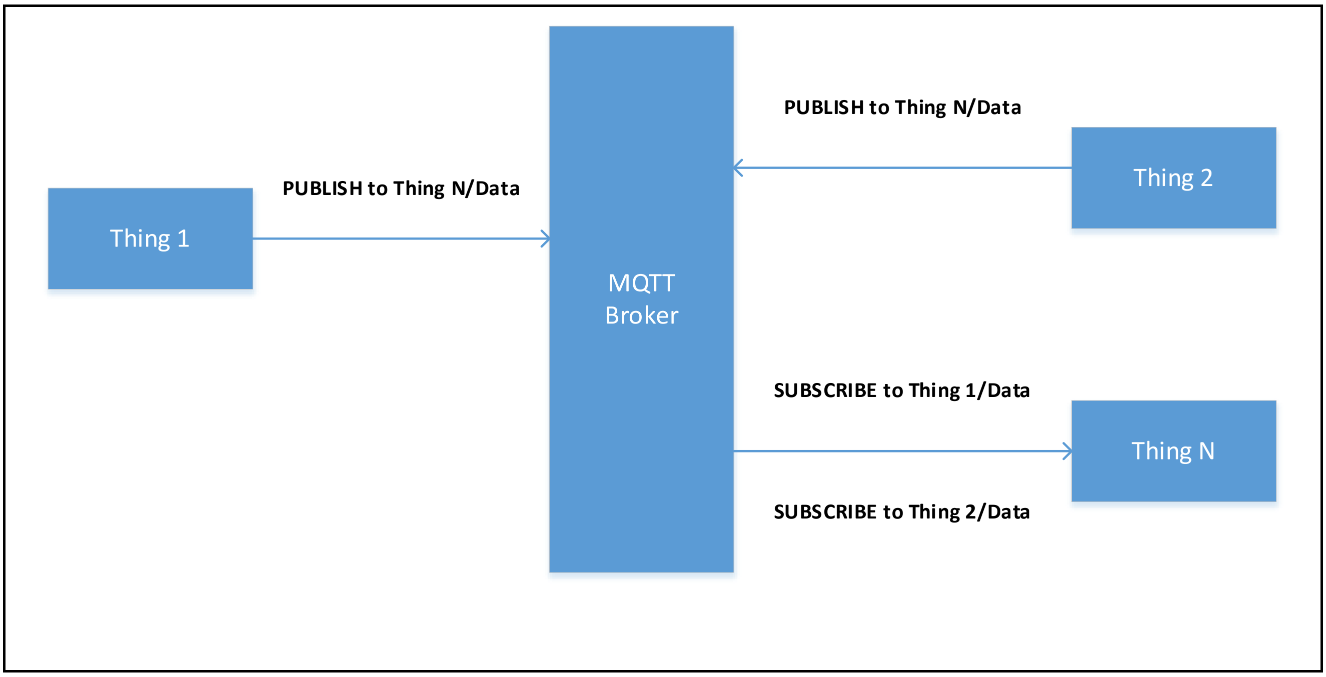


Figure 4. MQTT Client Publish/Subscribe Model

In this model, there is no direct connection between a publisher and the subscriber. To handle the challenges of a pub/sub system, the MQTT generally uses quality of service (QoS) levels. There are three QoS levels in MQTT:

- At most once (0)
- At least once (1)
- Exactly once (2)

At most once (0)

A message will not be acknowledged by the receiver or stored and redelivered by the sender.

At least once (1)

It is guaranteed that a message will be delivered at least once to the receiver. But the message can also be delivered more than once. The sender will store the message until it gets an acknowledgment in form of a PUBACK command message from the receiver.

Exactly once (2)

It guarantees that each message is received only once by the counterpart. It is the safest and the slowest QoS level. The guarantee is provided by two flows: there and back between sender and receiver.

1.5 TLS Protocol Overview

Transport Layer Security (TLS) protocol and its predecessor, Secure Sockets Layer (SSL), are cryptographic protocols that provide communications security over a computer network.

The TLS/SSL protocol provides privacy and reliability between two communicating applications. It has the following basic properties:

Encryption: The messages exchanged between communicating applications are encrypted to ensure that the connection is private. Symmetric cryptography mechanism such as AES (Advanced Encryption Standard) is used for data encryption.

Authentication: A mechanism to check the peer’s identity using certificates.

Integrity: A mechanism to detect message tampering and forgery ensures that connection is reliable. The Message Authentication Code (MAC), such as Secure Hash Algorithm (SHA), ensures message integrity.

TLS/SSL uses TCP to secure communication for application layer protocols, such as HTTP and MQTT.

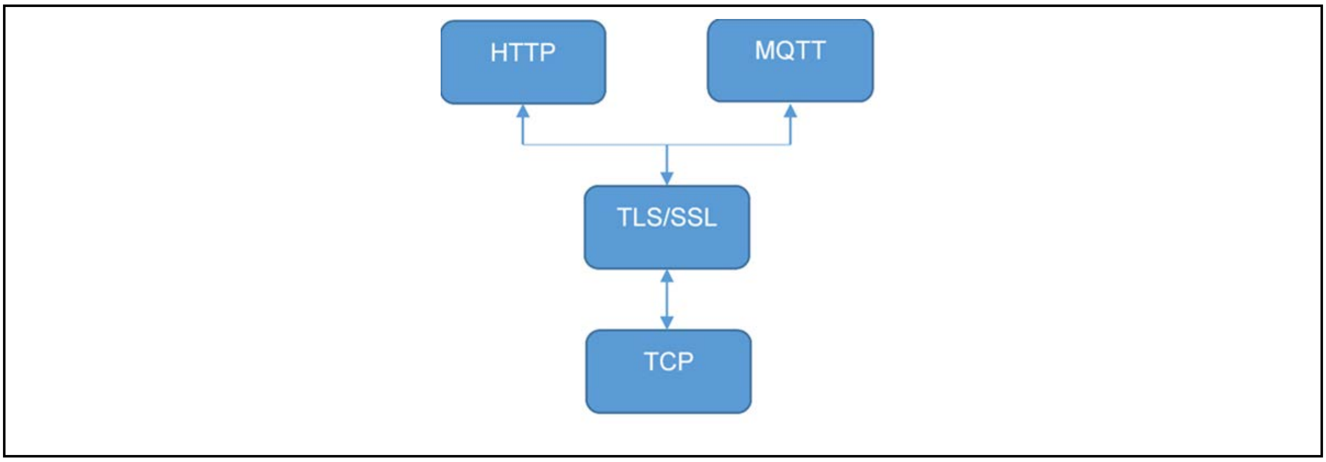


Figure 5. SSL/TLS Hierarchy

1.5.1 Device Certificates and Keys

Devices certificates, public and private keys, and the ways they can be generated, is discussed in this section.

1.5.1.1 Device Certificates

Security is a critical concern when deploying and managing IoT devices. In general, each of the IoT devices need an identity before they can communicate with the Cloud. Digital certificates are the most common method for authenticating a remote host in TLS. Essentially, a digital certificate is a document with specific formatting that provides identity information for a device.

TLS normally uses a format called X.509, a standard developed by the International Telecommunication Union (ITU), though other formats for certificates may apply if the TLS hosts can agree on the format to use. X.509 defines a specific format for certificates and various encoding that can be used to produce a digital document. Most X.509 certificates used with TLS are encoded using a variant of ASN.1, which is another telecommunication standard. Within ASN.1 there are various digital encodings, but the most common encoding for TLS certificates is the Distinguished Encoding Rules (DER) standard. DER is a simplified subset of the ASN.1 Basic Encoding Rules (BER) and designed to be unambiguous, making parsing easier.

Though DER-formatted binary certificates are used in the actual TLS protocol, they may be generated and stored in a number of different encodings, with file extensions such as .pem, .crt, and .p12. The most common of the alternative certificate encodings is Privacy-Enhanced Mail (PEM). The PEM format is a based-64 encoded version of the DER encoding.

Depending on your application, you may generate your own certificates, be provided certificates by a manufacturer or government organization, or purchase certificates from a commercial certificate authority.

1.5.1.2 Loading Certificates onto your Device

To use a digital certificate in your NetX™ Secure application, you must first convert your certificate into a binary DER format, and optionally, convert the associated private key into a binary format, typically, a PKCS#1-formatted, DER-encoded RSA key. Once converted, it is up to you how to load the certificate and the private key on to the device. Possible options include using a flash-based file system or generating a C array from the data (using a tool such as “xxd” from Linux® with the “-i” option) and compiling the certificate and key into your application as constant data.

Once your certificate is loaded on the device, you can use the TLS API to associate your certificate with a TLS session.

1.5.1.3 Generating Self-Signed Certificates

You may also choose to generate a self-signed certificate for testing purposes. The command to generate such a certificate is:

```
openssl req -x509 -newkey rsa:2048 -keyout private.key -out cert.pem -days 365 -
nodes -subj "/C=US/ST=Oregon/L=Portland/O=Company
Name/OU=Org/CN=www.example.com"
```

In this situation, a self-signed certificate for www.example.com is generated. The certificate and private key files are cert.pem and private.key. You may generate a certificate for localhost by replacing www.example.com for localhost. In that case, pass localhost as the first-argument to the installation script.

1.5.2 Device Security Recommendations

The following security recommendations are not enforced by Cloud IoT Core but will help you secure your devices and connections.

- The private key should be kept secret.
- Use TLS 1.2 when communicating with IoT Cloud and verify that the server certificate is valid using root certificate authorities.
- Each device should have a unique public/private key pair. If multiple devices share a single key and one of those devices is compromised, an attacker could impersonate all the devices that have been configured with that one key.
- Keep the public key secure when registering it with Cloud IoT Core. If an attacker can tamper with the public key and trick the provisioner into swapping the public key and registering the wrong public key, the attacker will subsequently be able to authenticate on behalf of the device.
- The key pair is used to authenticate the device to Cloud IoT Core and should not be used for other purposed or protocols.
- Depending on the device's ability to store keys securely, key pairs should be rotated periodically. When practical, all keys should be discarded when the device is reset.
- If your device runs an operating system, make sure you have a way to securely update it. Android Things provides a service for secure updates. For devices that don't have an operating system, ensure that you can securely update the device's software if security vulnerabilities are discovered after deployment.

2. Synergy MQTT/TLS Cloud Solution

2.1 MQTT Client Overview

The NetX Duo MQTT Client module provides high-level APIs for a Message Queuing Telemetry Transport (MQTT) protocol-based client. The MQTT protocol works on top of TCP/IP and therefore the MQTT client is implemented on top of NetX Duo IP and NetX Duo Packet pool. NetX Duo IP attaches itself to the appropriate link layer frameworks, such as Ethernet, Wi-Fi, or cellular.

The NetX Duo MQTT client module can be used in normal or in secure mode. In normal mode, the communication between the MQTT client and broker is not secure. In secure mode, the communication between the MQTT client and broker is secured using the TLS protocol.

2.2 Design Considerations

- By default, the MQTT client does not use TLS; communication is not secure between a MQTT client and broker.
- The Synergy MQTT client does not add the NetX Duo TLS session block. It only adds NetX Duo TLS common block. This block defines/controls the common properties of NetX secure.
- It is the responsibility of the user/application code to create the TLS session, configure the security parameters, and load the relevant certificates manually under the TLS setup callback provided by `nxd_mqtt_client_secure_connect ()` API.

2.2.1 Supported Features

NetX Duo MQTT Client supports the following features:

- Compliant with OASIS MQTT Version 3.1.1 Oct 29th, 2014. The specification can be found at http://mqtt.org/.
- Provides an option to enable/disable TLS for secure communication using NetX Secure in SSP.
- Supports QoS and provides the ability to choose the levels that can be selected while publishing the message.
- Internally buffers and maintains the queue of received messages.
- Provides a mechanism to register callback when a new message is received.
- Provides a mechanism to register callback when connection with the broker is terminated.

2.2.2 Operational Flow Sequence

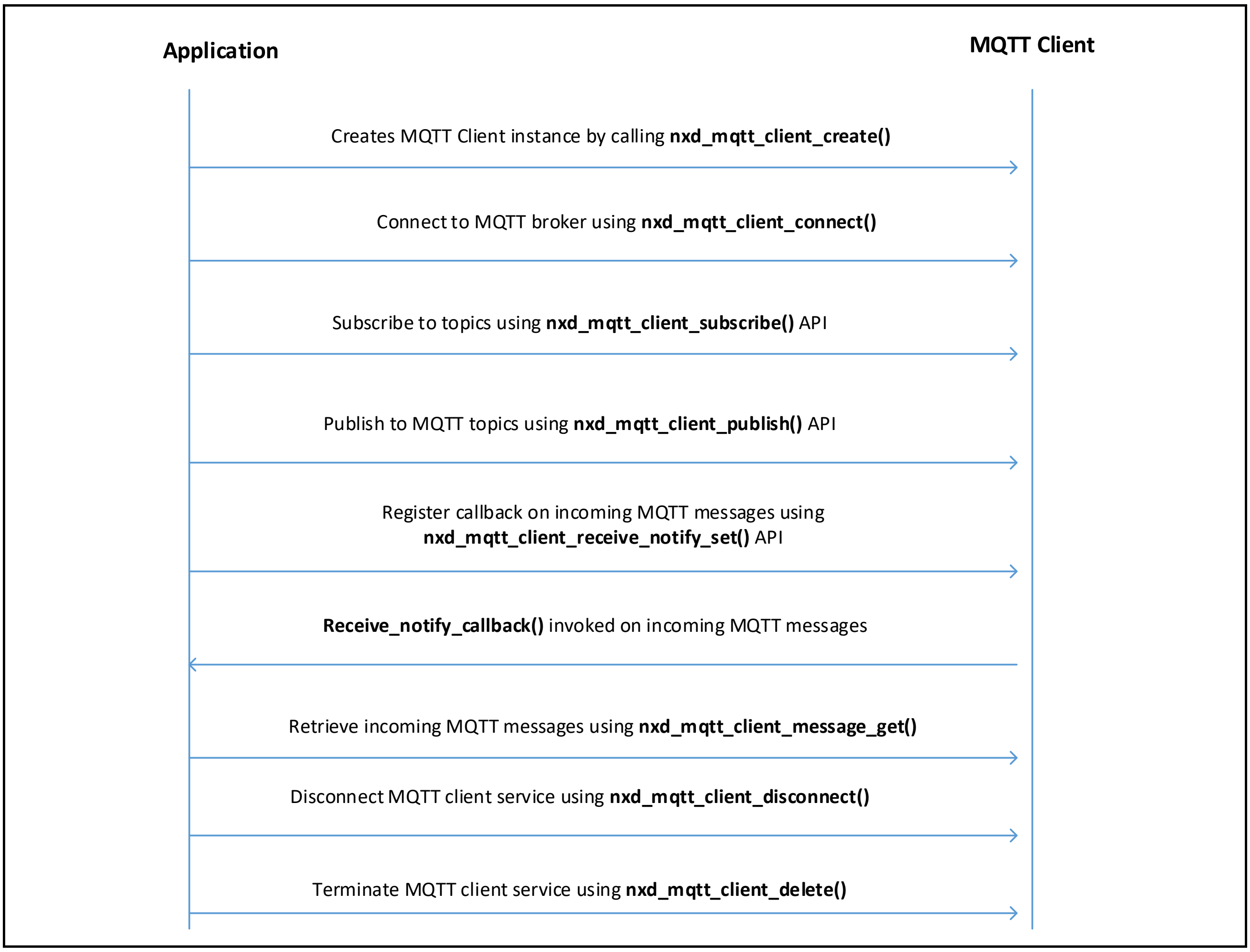

Application
MQTT Client
Creates MQTT Client instance by calling **nxd_mqtt_client_create()**
Connect to MQTT broker using **nxd_mqtt_client_connect()**
Subscribe to topics using **nxd_mqtt_client_subscribe()** API
Publish to MQTT topics using **nxd_mqtt_client_publish()** API
Register callback on incoming MQTT messages using **nxd_mqtt_client_receive_notify_set()** API
Receive_notify_callback() invoked on incoming MQTT messages
Retrieve incoming MQTT messages using **nxd_mqtt_client_message_get()**
Disconnect MQTT client service using **nxd_mqtt_client_disconnect()**
Terminate MQTT client service using **nxd_mqtt_client_delete()**

Figure 6. Synergy MQTT Client Flow Sequence

2.3 TLS Session Overview

The NetX Duo TLS session module provides high-level APIs for the TLS protocol-based client. It uses services provided by the Synergy Crypto Engine (SCE) to carry out hardware-accelerated encryption and decryption.

The NetX Duo TLS Session module is based on Express Logic's NetX Secure which implements the Secure Socket Layer (SSL) and its replacement, TLS protocol, as described in RFC 2246 (version 1.0) and 5246 (version 1.2). NetX Secure also includes routines for the basic X.509 (RFC 5280) format. NetX Secure is intended for applications using ThreadX RTOS in the project.

2.3.1 Design Considerations

- NetX Secure TLS performs only basic path validation on incoming server certificates.
  Once the basic path validation is complete, TLS then invokes the certificate verification callback supplied by the application.
- It is the responsibility of the application to perform any additional validation of the certificate.
  To help with the additional validation, NetX Secure provides X.509 routines for common validation operations, including DNS validation and Certificate Revocation List checking.
- Software-based cryptography is processor-intensive.
  NetX Secure software-based cryptographic routines have been optimized for performance, but depending on the power of the target processor, performance may result in very long operations. When hardware-based cryptography is available, it should be used for optimal performance of the NetX secure TLS.
- Due to the nature of embedded devices, some applications may not have the resources to support the maximum TLS record size of 16 KB.
  NetX Secure can handle 16 KB records on devices with sufficient resources.

2.3.2 Supported Features

- Support for RFC 2246 The TLS Protocol Version 1.0
- Support for RFC 5246 The Transport Layer Security (TLS) Protocol Version 1.2
- Support for RFC 5280 X.509 PKI Certificates (v3)
- Support for RFC 3268 Advanced Encryption Standard (AES) Cipher suites for Transport Layer Security (TLS)
- RFC 3447 Public-Key Cryptography Standards (PKCS) #1: RSA Cryptography Specifications Version 2.1
- RFC 2104 HMAC: Keyed-Hashing for Message Authentication
- RFC 6234 US Secure Hash Algorithms (SHA and SHA-based HMAC and HKDF)
- RFC 4279 Pre-Shared Key Cipher suites for TLS

2.3.3 Operational Flow Sequence

This section describes the TLS handshake operational sequence.

2.3.3.1 TLS Handshake

The following figure shows a typical TLS handshake between the TLS Server and Client.

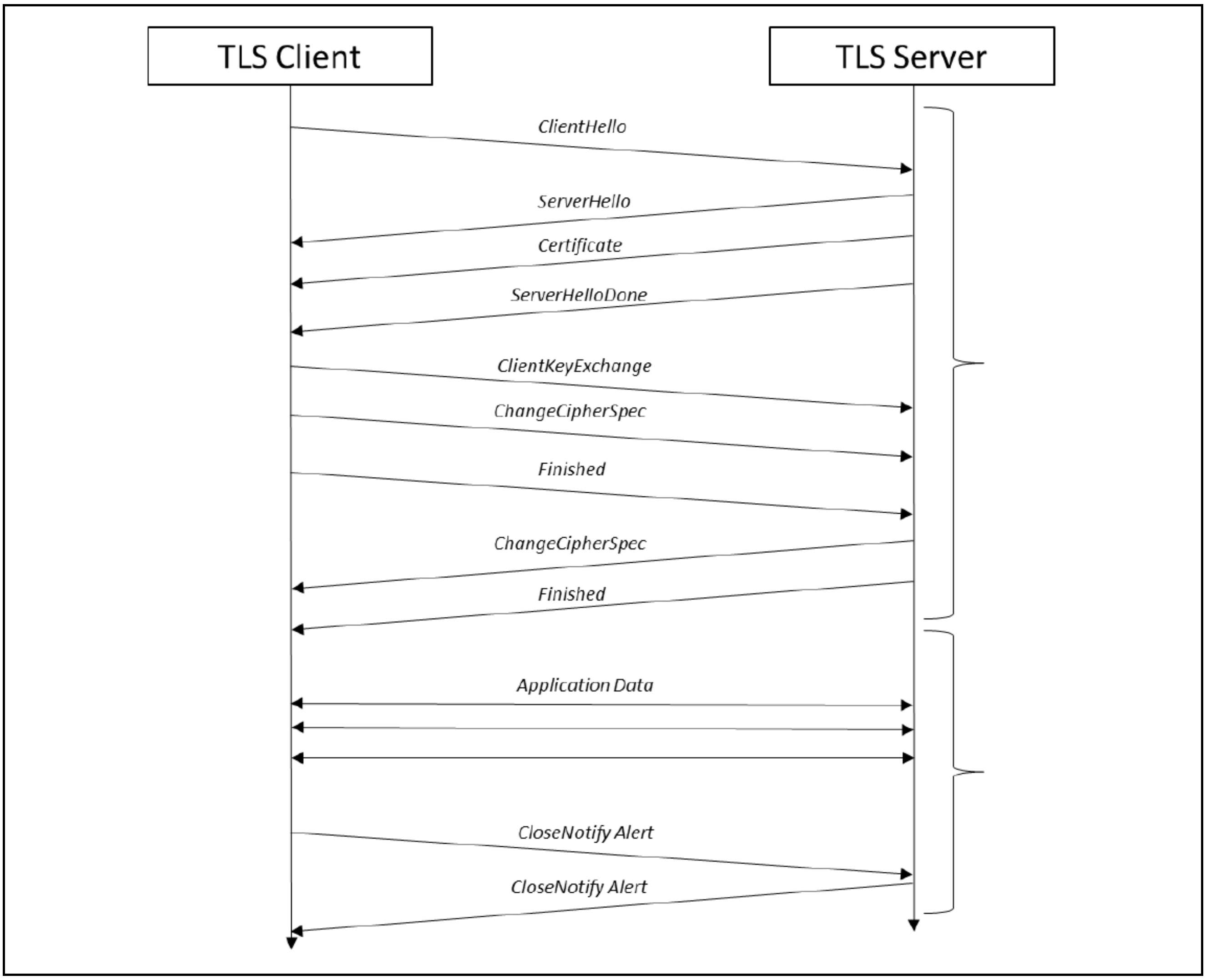


Figure 7. TLS Handshake

- A TLS handshake begins when the TLS client sends a **ClientHello** message to a TLS server, indicating its desire to start a TLS session.
- The message contains information about the encryption that the client would like to use for the session, along with information used to generate the session keys.
- The TLS server responds to the **ClientHello** with a **ServerHello** message, indicating a selection from the encryption options provided by the client.

- It is followed by a Certificate message, in which the server provides a digital certificate to authenticate its identity to the client.
- Finally, the server sends a **ServerHelloDone** message to indicate it has no more messages to send.
- Once Client has received all the server's messages, it has enough information to generate the session keys. TLS does this by creating a shared bit of random data called the Pre-Master Secret, which is a fixed size and is used as a seed to generate all the keys needed once encryption is enabled.
- The Pre-Master Secret is encrypted using the public key algorithm (such as RSA) specified in the Hello messages and the public key provided by the server in its certificate.
- The encrypted Pre-Master Secret is sent to the server in the **clientKeyExchange** message. The server, upon receiving the **ClientKeyExchange** message, decrypts the Pre-Master Secret using its private key and proceeds to generate the session keys in parallel with the TLS client.
- Once the session keys are generated, all further messages can be encrypted using the private-key algorithm (such as AES) selected in the Hello messages. One final un-encrypted message called **ChangeCipherSpec** is sent by both the client and server to indicate that all further messages will be encrypted.
- The first encrypted message sent by both the client and server is also the final TLS handshake message, called **Finished**. This message contains a hash of all the handshake messages received and sent. This hash is used to verify that none of the messages in the handshake have been tampered with or corrupted.
- Now the application begins sending and receiving data. All data — sent by either side — is first hashed using the hash algorithm chosen in the Hello messages, and then encrypted using the chosen private-key algorithm with the generated session keys.
- Finally, a TLS session can only be successfully ended if either the Client or Server chooses to do so. Both the client and server must send and process a **CloseNotify** alert for a successful session shutdown.

2.3.3.2 Initialization Flow Sequence

A typical TLS session initialization flow sequence is given as follows.

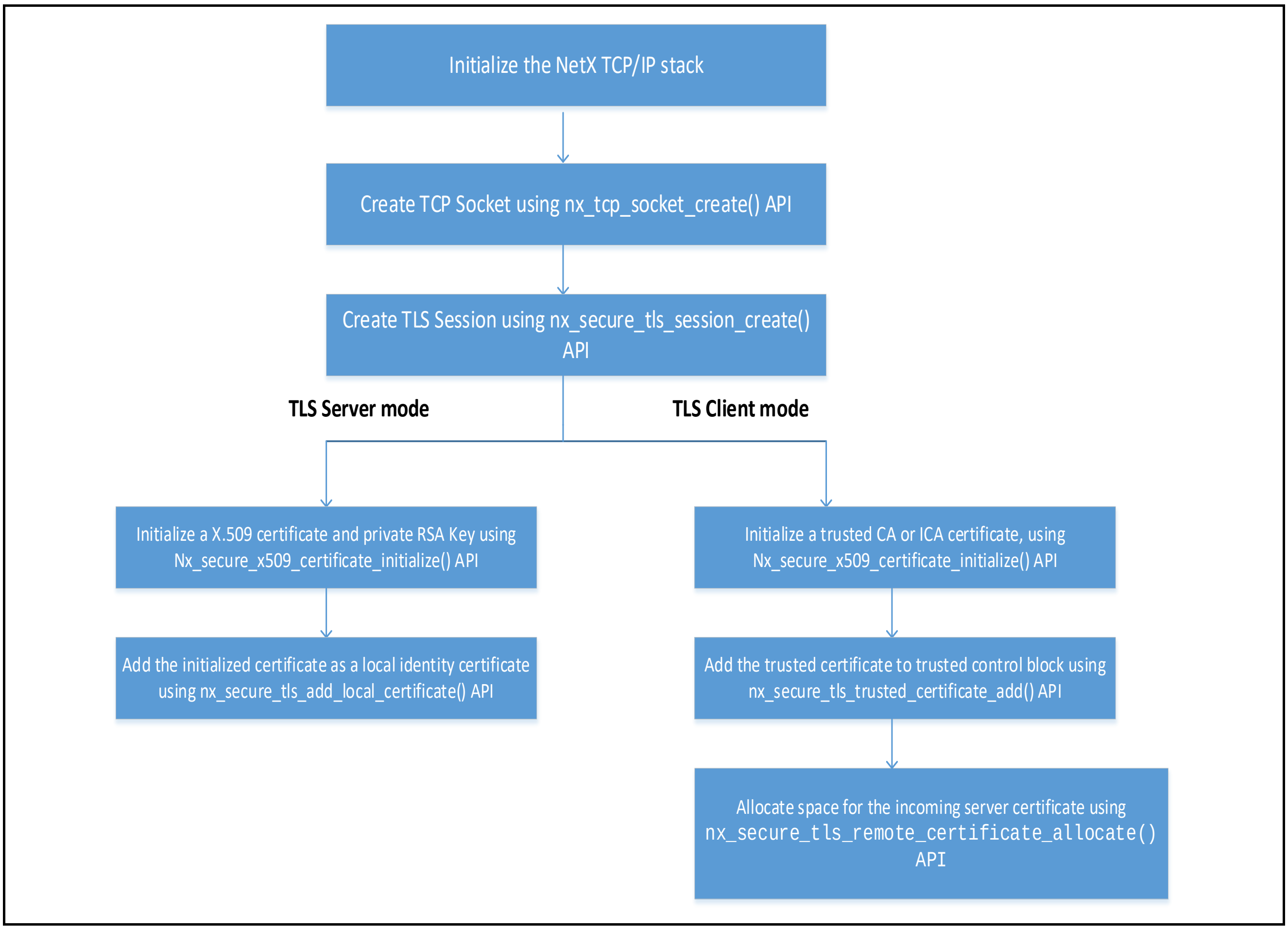

Initialize the NetX TCP/IP stack
Create TCP Socket using nx_tcp_socket_create() API
Create TLS Session using nx_secure_tls_session_create() API
TLS Server mode
TLS Client mode
Initialize a X.509 certificate and private RSA Key using Nx_secure_x509_certificate_initialize() API
Add the initialized certificate as a local identity certificate using nx_secure_tls_add_local_certificate() API
Initialize a trusted CA or ICA certificate, using Nx_secure_x509_certificate_initialize() API
Add the trusted certificate to trusted control block using nx_secure_tls_trusted_certificate_add() API
Allocate space for the incoming server certificate using nx_secure_tls_remote_certificate_allocate() API

Figure 8. Synergy TLS Session Initialization

2.3.3.3 Data Communication Flow Sequence

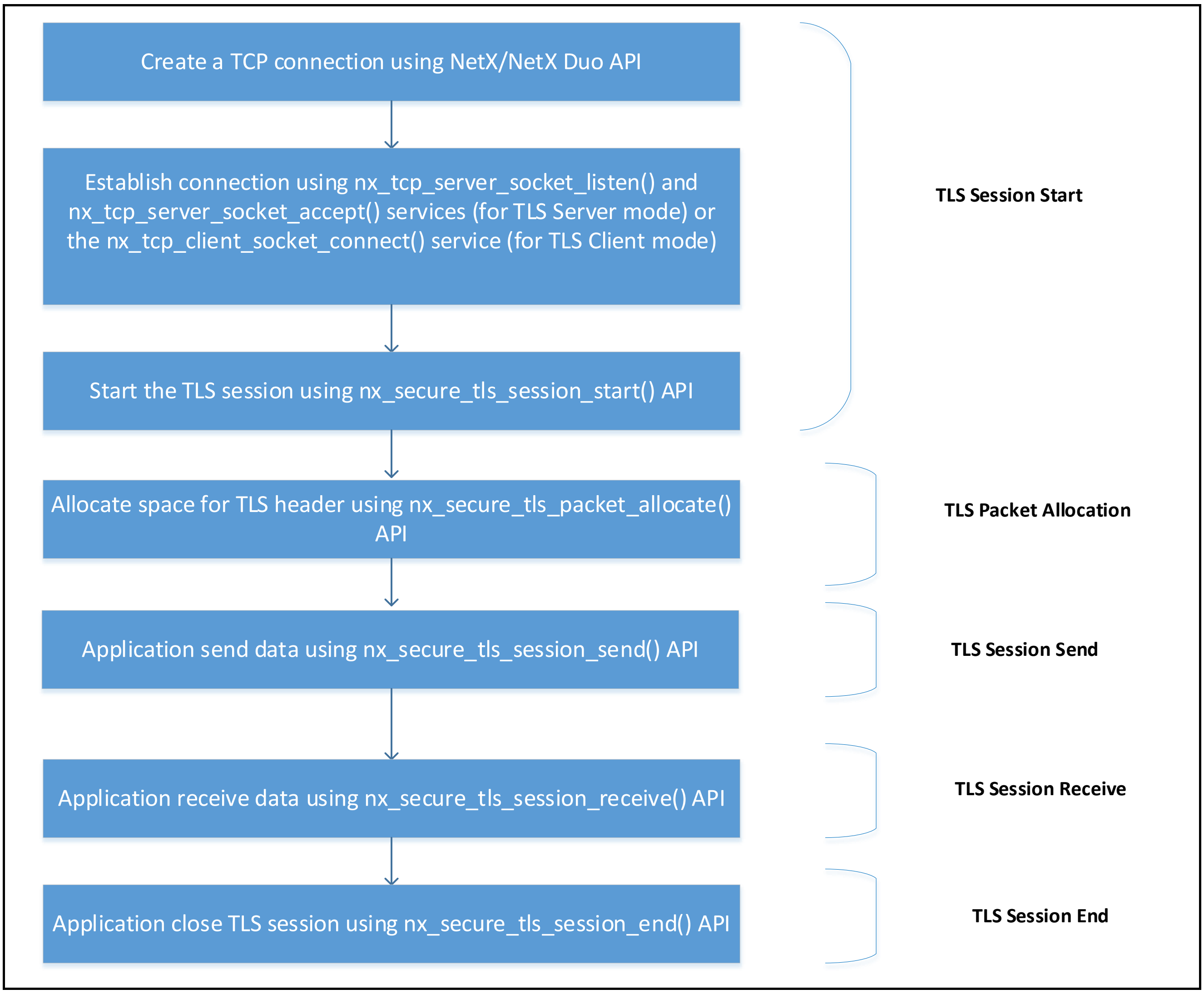

Create a TCP connection using NetX/NetX Duo API
Establish connection using nx_tcp_server_socket_listen() and nx_tcp_server_socket_accept() services (for TLS Server mode) or the nx_tcp_client_socket_connect() service (for TLS Client mode)
Start the TLS session using nx_secure_tls_session_start() API
TLS Session Start
Allocate space for TLS header using nx_secure_tls_packet_allocate() API
TLS Packet Allocation
Application send data using nx_secure_tls_session_send() API
TLS Session Send
Application receive data using nx_secure_tls_session_receive() API
TLS Session Receive
Application close TLS session using nx_secure_tls_session_end() API
TLS Session End

Figure 9. Synergy TLS Session Data Flow Sequence

3. MQTT/TLS Application Example

3.1 Application Overview

This example application project demonstrates the Renesas Synergy™ IoT Cloud Connectivity solution using the onboard Synergy MQTT/TLS modules. For demonstration purposes, this application uses Microsoft Azure as the cloud provider. Ethernet or Wi-Fi or Cellular (supported only on AE-CLOUD2 kit) is used as primary communication interface between the Device and Azure IoT Hub.

In this example, the PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit acts as MQTT node/Device, connects to the Azure IoT Hub, periodically reads its die temperature (in case of PK-S5D9 kit) or on-board sensors (in case of AE-CLOUD2/AE-CLOUD1 kit) values and publishes it to the Azure IoT Hub. It also subscribes to its User LED state MQTT topic. You can turn ON/OFF the User LEDs by publishing the LED state remotely. This application reads the updated LED state and turns ON/OFF the User LEDs.

3.2 Software Architecture Overview

The following figure shows the software architecture for the Synergy Cloud Connectivity Application Example Project.

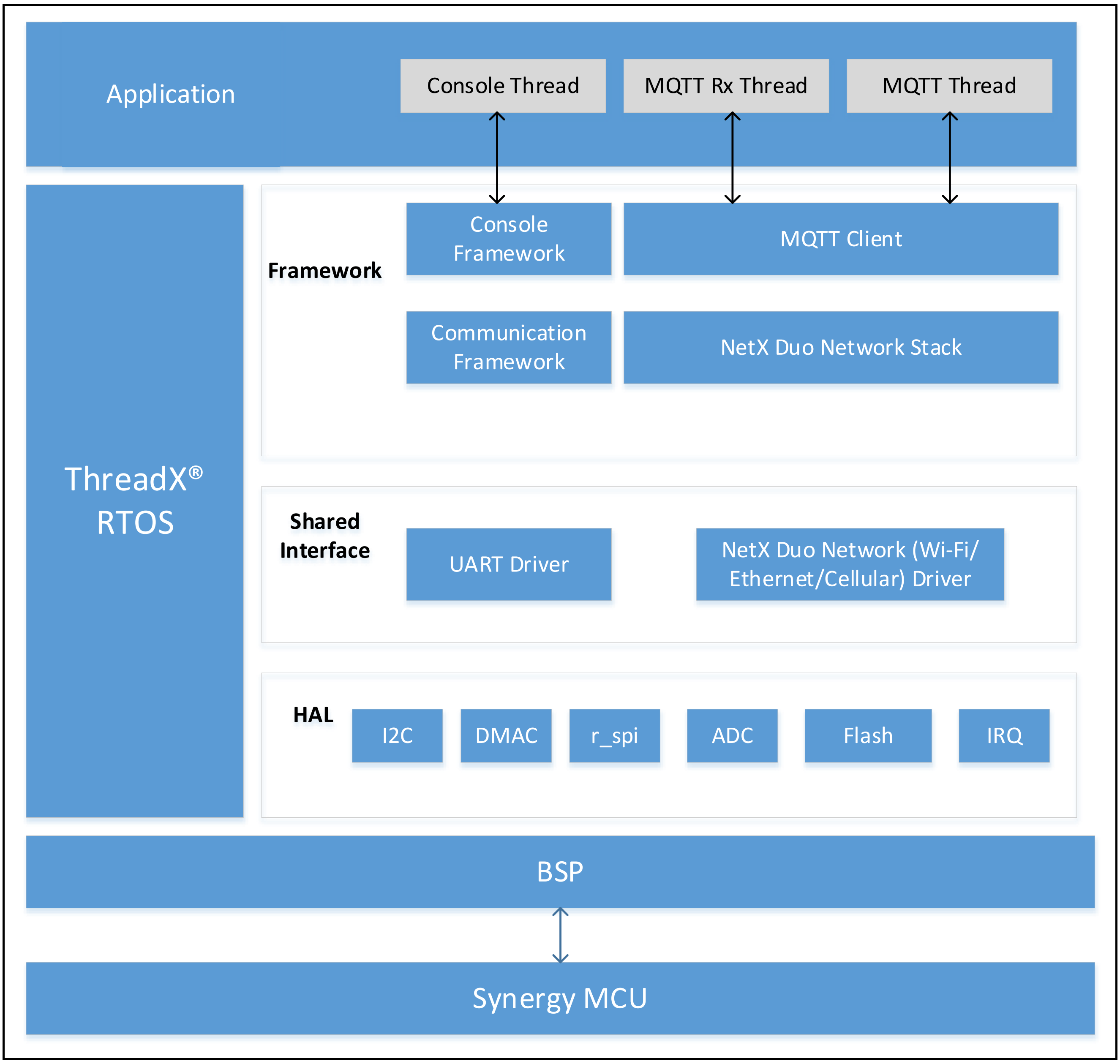


Figure 10. Synergy Cloud Connectivity Application Software Architecture

The main software components of this application are:

- MQTT Client
- NetX Duo IP Stack and its underlying driver components for Ethernet and Wi-Fi
- Console Framework

This application contains the following application threads:

- Console Thread
- MQTT Thread
- MQTT Rx Thread

3.2.1 Console Thread

This thread handles the function related to the Command Line Interface (CLI). It uses the console framework, which in-turn uses the communication framework and its underlying USBX CDC device module components.

This thread reads the user inputs and stores them in the internal data flash. The stored information is read later by the MQTT Thread when it tries to run the Synergy Cloud connectivity demo.

This thread presents you with the following CLI command options.

- **`cwiz`**
- **`Demo start/stop`**

`cwiz` command option

Using this command option, you can select the following configurations:

1. Network interface such as Ethernet, Wi-Fi and its associated IP mode (DHCP/Static).
2. IoT cloud selection (Azure).
3. Dump the existing configuration from flash.
4. Exit the menu.

Demo start/stop command option

Using this command option, you can run/stop the Synergy Cloud Connectivity Demonstration.

3.2.2 MQTT Thread

This is the main control thread which thread handles the following major functions:

1. Initialize communication interface (Ethernet/Wi-Fi/Cellular).
2. Initialize IoT Cloud interface.
3. Read sensor data and publish the data periodically on MQTT topics.
4. Update the user LED state based on the type of MQTT message received.

On wakeup, this thread periodically checks (every 5 seconds) for user input event flag state set once you enter the demonstration start/stop command on the CLI. If the demonstration start command is issued from the CLI, this thread will read the pre-configured user information from internal flash and checks its validity. If the content is valid, it then starts the Synergy Cloud connectivity demonstration. If a demo stop command is issued, it de-initializes the IoT cloud interface.

3.2.3 MQTT Rx Thread

This thread handles the incoming MQTT messages from the MQTT broker. On receiving the new MQTT message, the user callback `receive_notify_callback()`will be invoked by the MQTT thread. This callback in turn sets the semaphore on which the MQTT Rx Thread is polling periodically.

On receiving the new MQTT message, it uses the `nxd_mqtt_client_message_get()` API to read the message, parse it, and act on it based on the type of the message received.

3.3 IoT Cloud Configuration (Azure)

3.3.1 Azure Web Portal Signup

Microsoft Azure offers a free trial account (12 months) for each user. It is expected you have created an account on the Azure Cloud service before continuing to the next section.

To create an Azure account, open to the following link in your web browser: https://azure.microsoft.com/en-us/account/, fill in the required details and create a free user account.

Note: For identity verification, the user interface prompts you to add for the credit card information. The credit card will not be charged during the free trial period unless you upgrade. After inputting the details and accepting the agreement signup free Trial account is created.

Note: While creating the Azure Web account and IoT Hub, the snapshots may look slightly different from what is shown in the document and users need to navigation in the Azure environment to find corresponding attribute while working on this project.

3.3.2 Creating an IoT Hub on Azure Portal

1. From the **Microsoft Azure Portal**, click on the **All services**. Go to the **Internet of Things** sub section and select the **IoT Hub**. The snapshot of the accessing the IoT Hub is shown in the following figure.

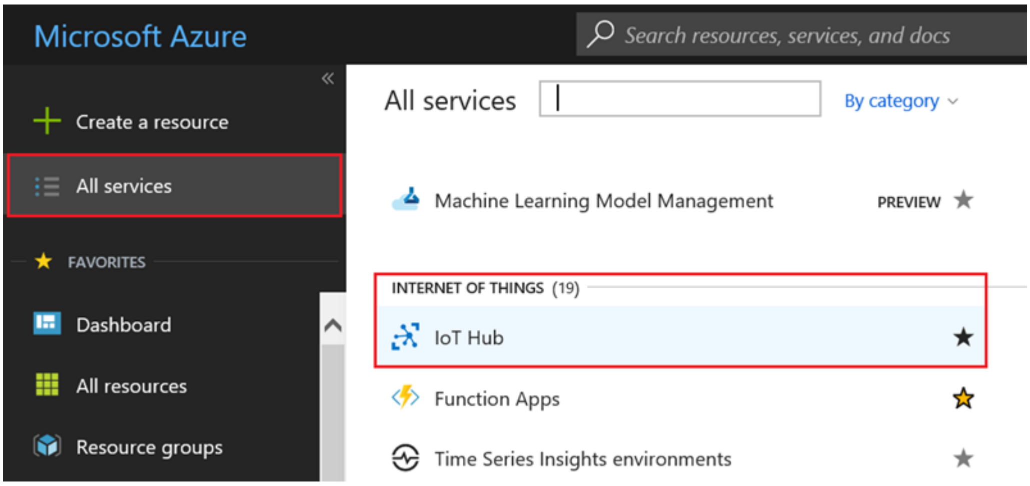
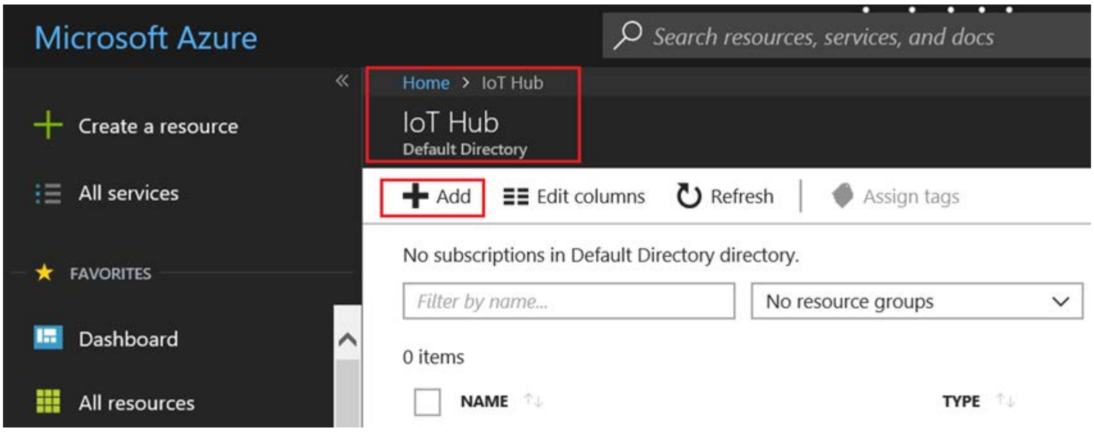


Figure 11. IoT Hub on Azure

2. **Add** and create the IoT Hub by inputting the **Desired IoT Hub name**, **Region**, **Resource Group** and **Subscription**. For the first-time user, it opens a window called **Create a free account**. Create a free account by clicking **Start free.**



No subscriptions in Default Directory directory.

0 items

Figure 12. Creating IoT Hub with Desired Name

3. **Choose the name of the IoT hub**: To create an IoT hub, you must name the IoT hub. This name must be unique across all IoT hubs. To fill out the form shown in Figure 13, refer to the following information:

Choose the pricing tier: S1- Standard

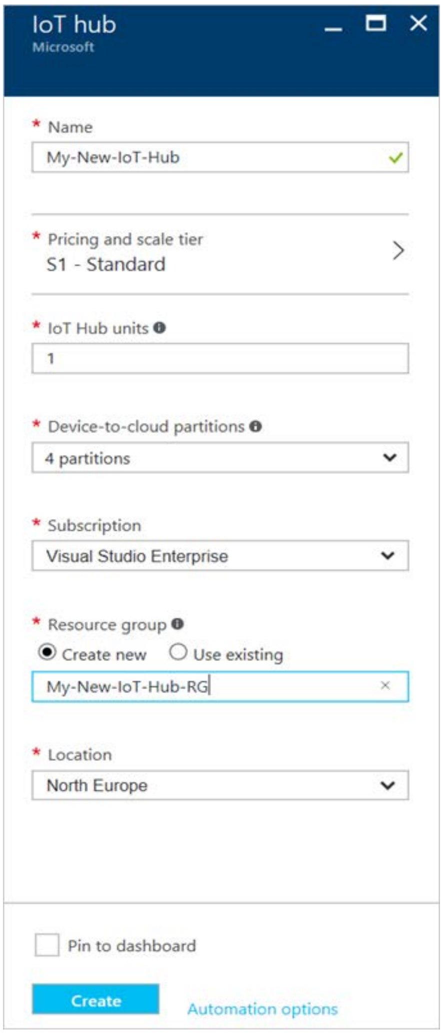
IoT Hub Units: 1 (Default)

Device to Cloud Partitions: 4 Partitions

Subscription: Visual Studio Enterprise

Resource Group: Create new

Location: West US (or as Desired per your location).



IoT hub
Microsoft

* Name
My-New-IoT-Hub

* Pricing and scale tier
S1 - Standard

* IoT Hub units
1

* Device-to-cloud partitions
4 partitions

* Subscription
Visual Studio Enterprise

* Resource group
● Create new ○ Use existing
My-New-IoT-Hub-RG

* Location
North Europe

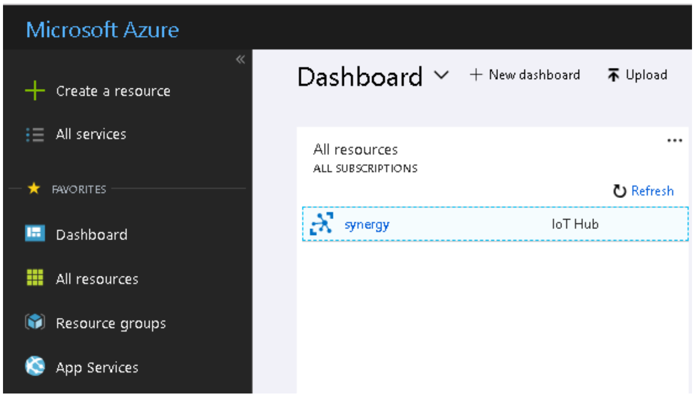
□ Pin to dashboard

Figure 13. Selecting the Azure IoT Hub Subscription

Note: It will take few seconds to create the IoT Hub on the Azure portal.

3.3.3 Creating a Device on Azure IoT Hub

Select and open the Azure IoT Hub, use the following steps to create the device on the IoT Hub.



All resources
ALL SUBSCRIPTIONS

synergy	IoT Hub

Figure 14. Sample Snapshot of the Created IoT Hub

1. Click **IoT Devices** under the **Explorers**; this opens a new blade as shown in Figure 16**.** On the blade for **IoT devices**, click the "+ **Add"** button to add the new device to your IoT Hub. When **Add Device** is clicked, it opens a new blade to enter the device credentials, such as **Device ID**, **Authentication Type**.

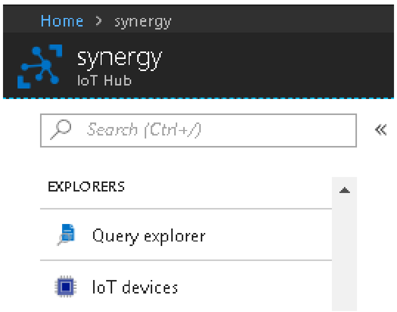
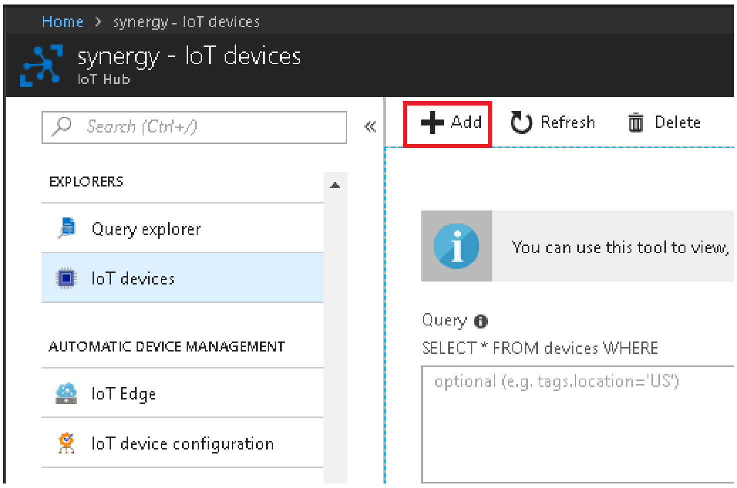


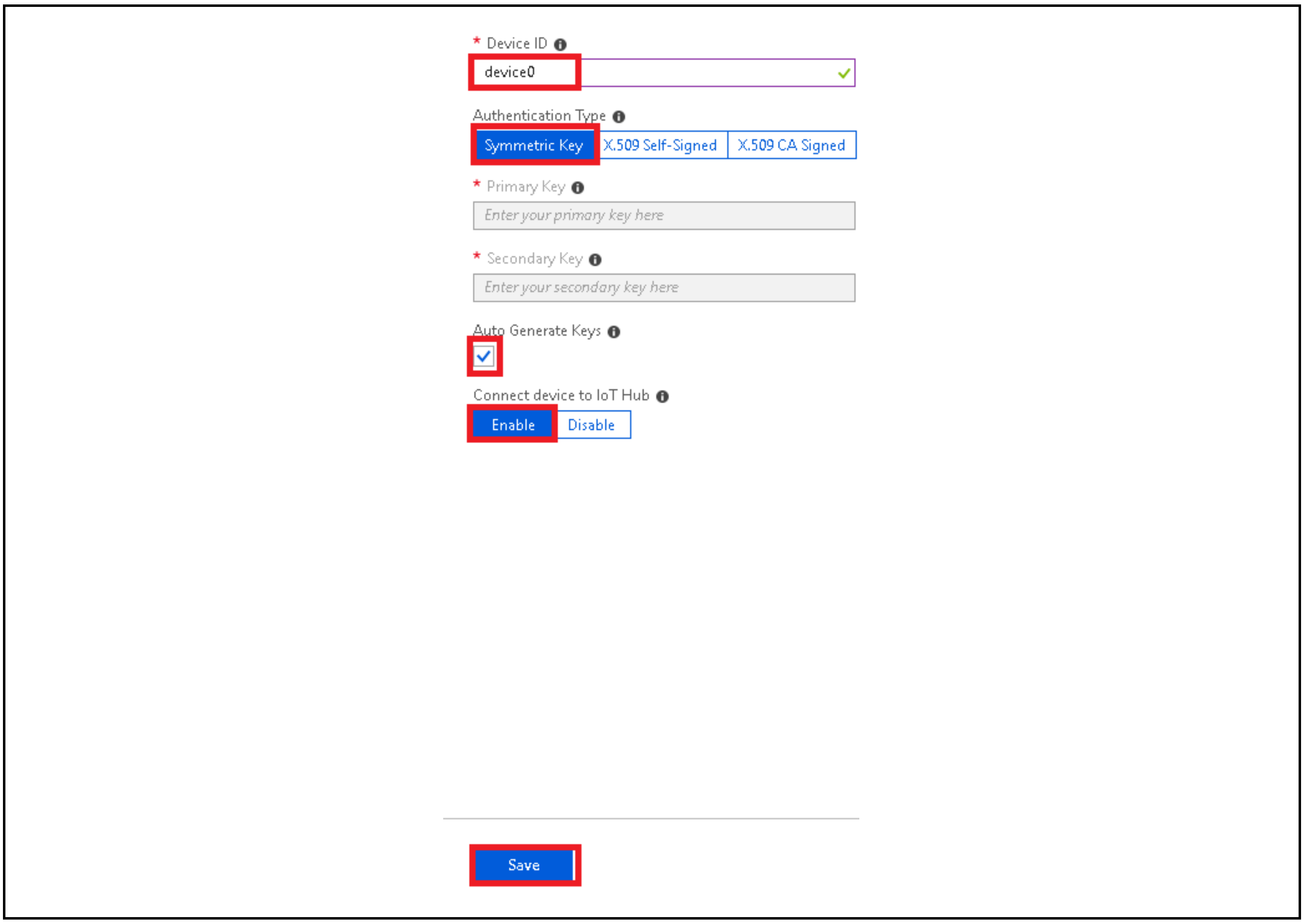
Figure 15. Adding Devices to IoT Hub



Home > synergy - IoT devices
synergy - IoT devices
IoT Hub
Search (Ctrl+/)
«
Add
Refresh
Delete
EXPLORERS
Query explorer
IoT devices
AUTOMATIC DEVICE MANAGEMENT
IoT Edge
IoT device configuration
You can use this tool to view,
Query
SELECT * FROM devices WHERE
optional (e.g. tags.location='US')

Figure 16. Device Added to IoT Hub

2. For the Application project, as part of this app, note "**Symmetric Key Authentication Type"** is used. After inputting and selecting desired settings shown in the following figure, click **Save**. This will create the device on the IoT Hub. The snapshot of the created device on the IoT Hub is shown in the Figure 18.



* Device ID: device0

Authentication Type: [✓ Symmetric Key] X.509 Self-Signed X.509 CA Signed

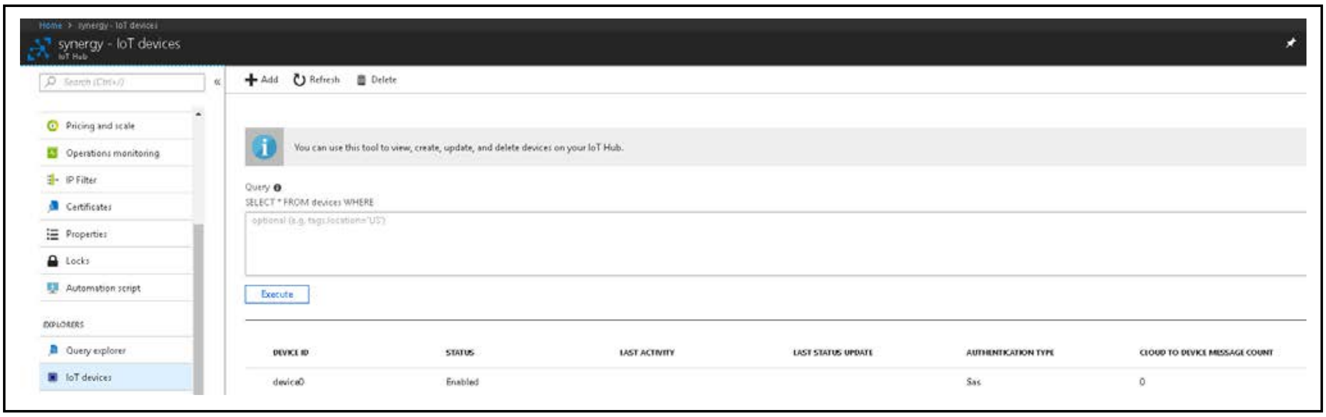
* Primary Key: Enter your primary key here

* Secondary Key: Enter your secondary key here

Auto Generate Keys: ☑

Connect device to IoT Hub: [✓ Enable] Disable

Figure 17. Device Configuration



Home > synergy - IoT devices

synergy - IoT devices
IoT Hub

You can use this tool to view, create, update, and delete devices on your IoT Hub.

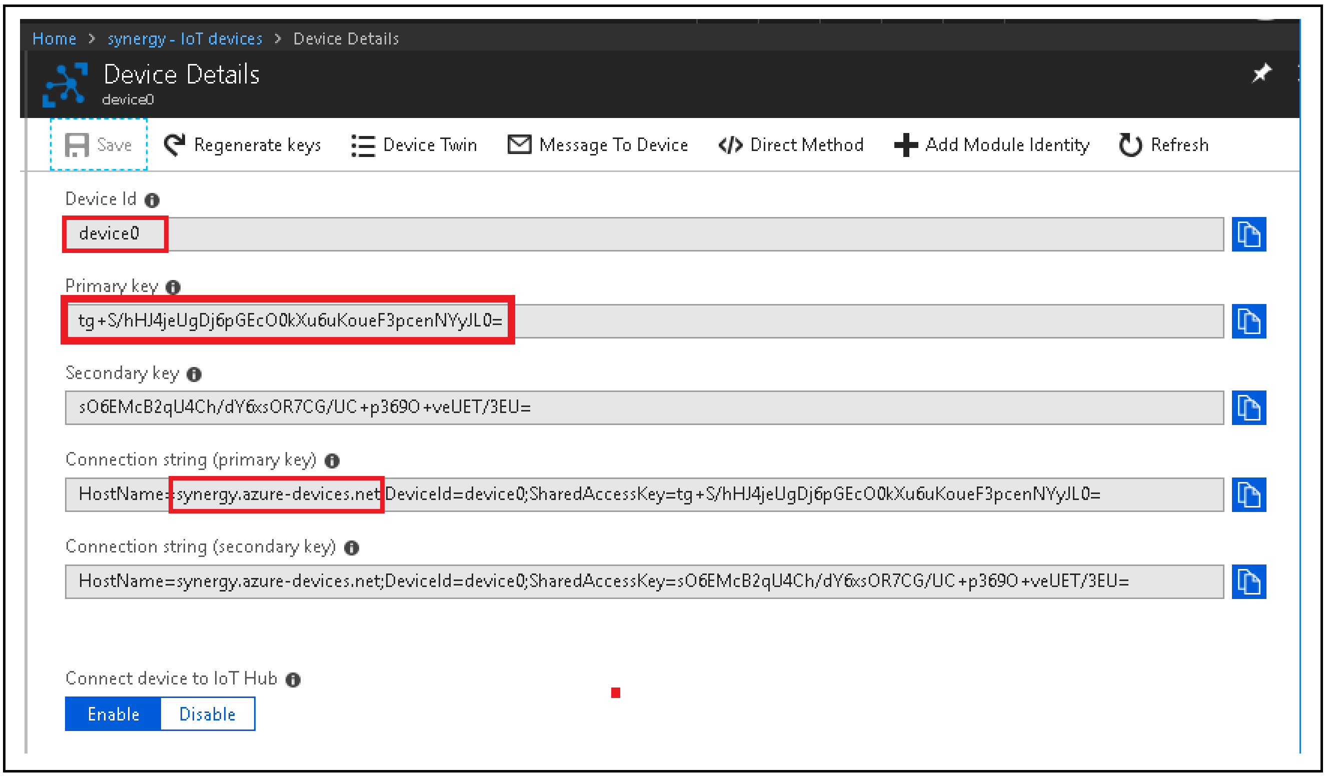
Query
SELECT * FROM devices WHERE
optional (e.g. tags.location='US')

DEVICE ID	STATUS	LAST ACTIVITY	LAST STATUS UPDATE	AUTHENTICATION TYPE	CLOUD TO DEVICE MESSAGE COUNT
device0	Enabled			Sas	0

Figure 18. Snapshot of the Created Device

3. Double-click the **device**(device0) to open a new blade as shown in the following figure, which displays the Device details such as, **Device ID**, **Primary and Secondary symmetric shared access Key**, **Primary and Secondary connection string**.

Note: The Primary Key and the Hostname info from the connection string are used when running the application on the device side. When configuring the device using command line interface, these details will be used. Details are in section 4.4.1.2.



Device Id: device0

Primary key: tg+S/hHJ4jeUgDj6pGEcO0kXu6uKoueF3pcenNYyJL0=

Secondary key: sO6EMcB2qU4Ch/dY6xsOR7CG/UC+p369O+veUET/3EU=

Connection string (primary key): HostName=synergy.azure-devices.net;DeviceId=device0;SharedAccessKey=tg+S/hHJ4jeUgDj6pGEcO0kXu6uKoueF3pcenNYyJL0=

Connection string (secondary key): HostName=synergy.azure-devices.net;DeviceId=device0;SharedAccessKey=sO6EMcB2qU4Ch/dY6xsOR7CG/UC+p369O+veUET/3EU=

Connect device to IoT Hub: Enable Disable

Figure 19. Device Details

This completes the creation and configuration of the device on the IoT Hub.

4. Running the MQTT/TLS Application

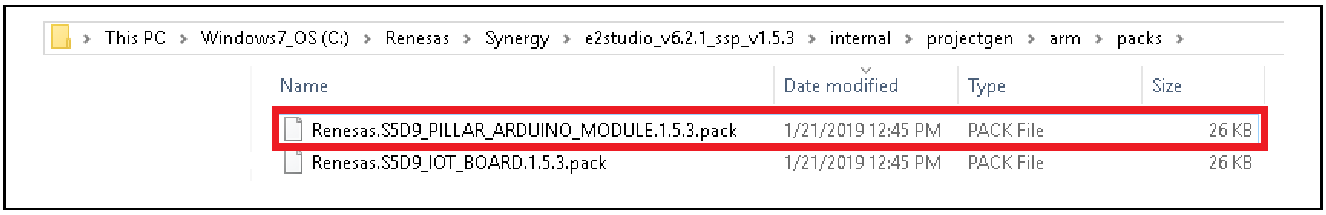
4.1 Importing, Building, and Loading the Project

See the *Renesas Synergy™ Project Import Guide* (r11an0023eu0121-synergy-ssp-import-guide.pdf), included in this package, for instructions to import the project into e^2 studio, build, and run the project.

4.2 Manually Adding the Board Support Package for AE-CLOUD2/AE-CLOUD1

4.2.1 AE-CLOUD2 Kit

1. From the project bundle, locate the BSP file, `Renesas.S5D9_PILLAR_ARDUINO_MODULE.1.5.3.pack`.
2. **e^2 studio users**: Copy the file shown in the figure below to the following location: `C:\Renesas\Synergy\e2studio_v6.2.1_ssp_v1.5.3\internal\projectgen\arm\packs`.

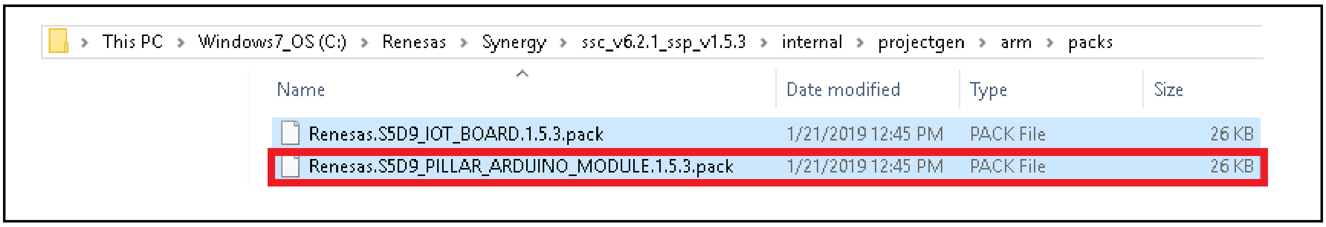


This PC > Windows7_OS (C:) > Renesas > Synergy > e2studio_v6.2.1_ssp_v1.5.3 > internal > projectgen > arm > packs >

Name	Date modified	Type	Size
Renesas.S5D9_PILLAR_ARDUINO_MODULE.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB
Renesas.S5D9_IOT_BOARD.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB

Figure 20. Load BSP Pack for AE-CLOUD2 Kit

3. **IAR users**: Copy the file shown in the figure below to the following location: `C:\Renesas\Synergy\ssc_v6.2.1_ssp_v1.5.3\internal\projectgen\arm\packs`.



This PC > Windows7_OS (C:) > Renesas > Synergy > ssc_v6.2.1_ssp_v1.5.3 > internal > projectgen > arm > packs

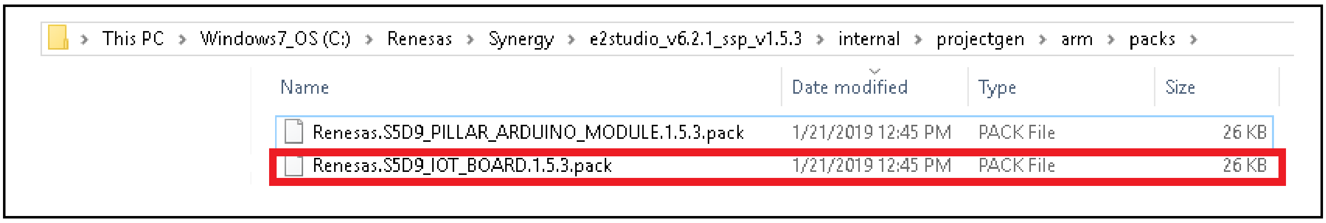
Name	Date modified	Type	Size
Renesas.S5D9_IOT_BOARD.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB
Renesas.S5D9_PILLAR_ARDUINO_MODULE.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB

Figure 21. Load BSP Pack for AE-CLOUD2 Kit

Note: If e^2 studio, or the SSC, is installed in any other location, provide the same path information to copy the pack.

4.2.2 AE-CLOUD1 Kit

1. From the project bundle, locate the BSP file, `Renesas.S5D9_IOT_BOARD.1.5.3.pack`.
2. **e^2 studio users**: Copy the file shown in the figure below to the following location: `C:\Renesas\Synergy\e2studio_v6.2.1_ssp_v1.5.3\internal\projectgen\arm\packs`.

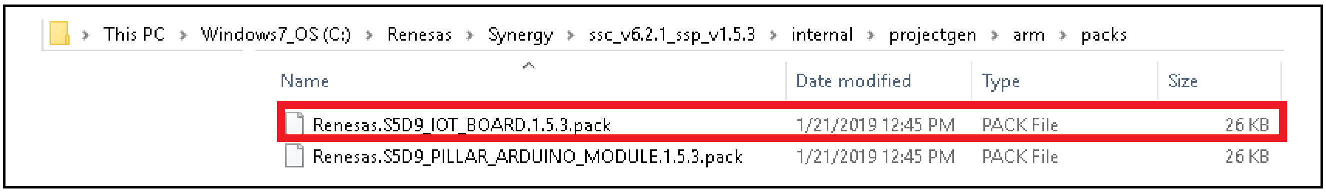


This PC > Windows7_OS (C:) > Renesas > Synergy > e2studio_v6.2.1_ssp_v1.5.3 > internal > projectgen > arm > packs >

Name	Date modified	Type	Size
Renesas.S5D9_PILLAR_ARDUINO_MODULE.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB
Renesas.S5D9_IOT_BOARD.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB

Figure 22. Load BSP Pack for AE-CLOUD1 Kit

3. **IAR users**: Copy the file shown in the figure below to the following location: `C:\Renesas\Synergy\ssc_v6.2.1_ssp_v1.5.3\internal\projectgen\arm\packs`.



This PC > Windows7_OS (C:) > Renesas > Synergy > ssc_v6.2.1_ssp_v1.5.3 > internal > projectgen > arm > packs

Name	Date modified	Type	Size
Renesas.S5D9_IOT_BOARD.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB
Renesas.S5D9_PILLAR_ARDUINO_MODULE.1.5.3.pack	1/21/2019 12:45 PM	PACK File	26 KB

Figure 23. Load BSP Pack for AE-CLOUD1 Kit

Note: If e^2 studio or SSC is installed in any other location, the same path information needs to be provided to copy the pack.

4.3 Powering up the Board

To connect power to the board, connect the SEGGER J-Link® debugger to the PC, connect the board to the PC USB port, and run the debug application, using the following instructions:

1. For PK-S5D9 and AE-CLOUD2, connect the micro USB end of the supplied USB cable to the PK-S5D9 board's J19 connector (DEBUG_USB) or AE-CLOUD2 board's J6 connector (DEBUG_USB).
   Connect the other end of the USB cable to the USB port on your workstation.

Note: The kit contains a SEGGER J-Link® On-board (OB). J-Link provides full debug and programming for the PK-S5D9/AE-CLOUD2 board.

2. For AE-CLOUD1 board, connect the J-Link Lite supplied with the kit to the J2 connector on the AE-CLOUD1 and to the 10-pin header on the J-Link lite using supplied 10 pin flat ribbon cable.
   Connect the other end of the USB cable to the USB port on your workstation.
3. Attach the PMOD-based GT-202 Wi-Fi module in PMOD connector (**in case of PK-S5D9, connect to PMOD-A**).
4. For the AE-CLOUD2 kit, connect the BG96 Cellular shield on the AE-CLOUD2 Arduino Connector. Next, attach the Cellular antenna to the LTE antenna connector, and then the GPS antenna to the GNSS antenna connector on the BG96 shield.
5. Connect the second micro USB cable as follows, depending on your kit:
   — AE-CLOUD2/AE-CLOUD1 board's J9 connector
   — PK-S5D9 board's J5 connector
   Connect the other end of the USB cable to the USB port on your workstation. This connection is necessary for the serial console.

4.4 Connect to Azure IoT Cloud

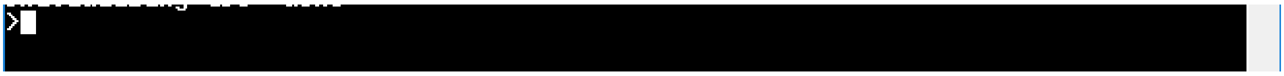
The following instructions show how to run the Synergy Cloud connectivity application project and connect to the Azure IoT Cloud.

Note: At this stage, it is assumed that you have completed the instructions in section 3.3 to create an Azure IoT account and have set up your device on the Azure IoT Hub.

- The instructions below show how the command line interface can be used to configure the boards, depending upon the desired interface for Cloud connectivity.
- While running the application on these boards, connectivity is done using one interface at a time (Ethernet or Wi-Fi or Cellular). Users must configure the desired interface to run the application. If you use Ethernet, be aware that Wi-Fi or Cellular is not available, and vice-versa.
- Users need to note that the CLI snapshots shown — in some cases — may not apply to some boards. For example, cellular is not applicable to PK-S5D9 and AE-CLOUD1 boards:

Board	Ethernet	Wi-Fi	Cellular
PK-S5D9	Supported	Supported	Not Supported
AE-CLOUD1	Supported	Supported	Not Supported
AE-CLOUD2	Supported	Supported	Supported

1. If you have not already done so, complete section 3 and then go to section 4.3 to power up and load the project on to the PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit.
   Connect the USB Device port of the kit to the test PC. It will be automatically detected as an USB Serial device in case of Windows 10 PC. In case of Windows 7/8 PC, refer to the following installation guide to load the Synergy USB CDC driver: www.renesas.com/en-us/products/synergy/software/add-ons/usb-cdc-drivers.html.
2. Open the serial console application, such as Tera Term, to connect it to the PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit.
   The default Tera Term settings are **8-N-1**, and the baud rate is **9600**.
3. Press **Enter** key in your keyboard; the similar to the following prompt appears on the serial console.

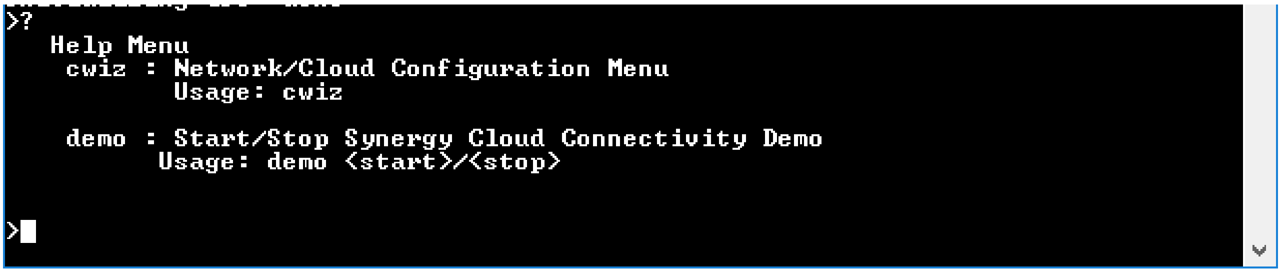


```
>
```

Figure 24. Command Line Prompt

Note: In case of AE-CLOUD2 kit, wait for the Cellular Modem and GPS initialization to complete. It may take around 7-10 seconds.

4. Press the **?** key on your keyboard to display the available CLI command options as shown in the following figure.

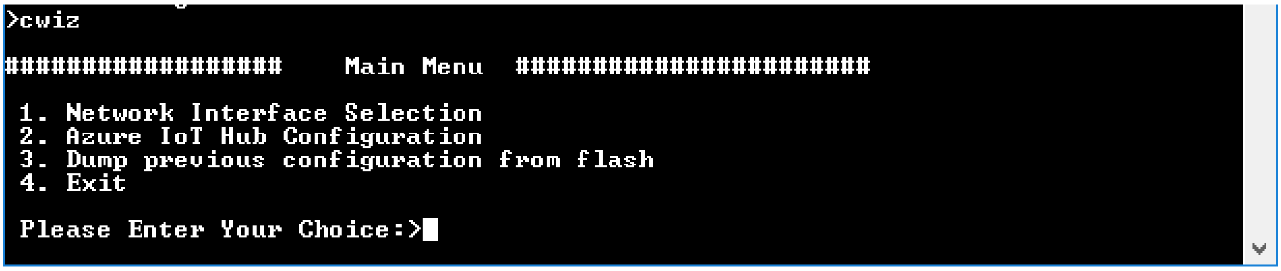


```
>?
   Help Menu
    cwiz : Network/Cloud Configuration Menu
           Usage: cwiz

    demo : Start/Stop Synergy Cloud Connectivity Demo
          Usage: demo <start>/<stop>


>
```

Figure 25. Help Menu

4.4.1 Configuration Wizard Menu

Enter command `cwiz` and press enter key in the serial console to enter the configuration menu. This command is used to configure the **1) Network interfaces**, **2) Azure IoT Hub Service**, **3) Dump previous configuration stored in the internal flash**.



```
>cwiz

##################    Main Menu  #######################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>
```

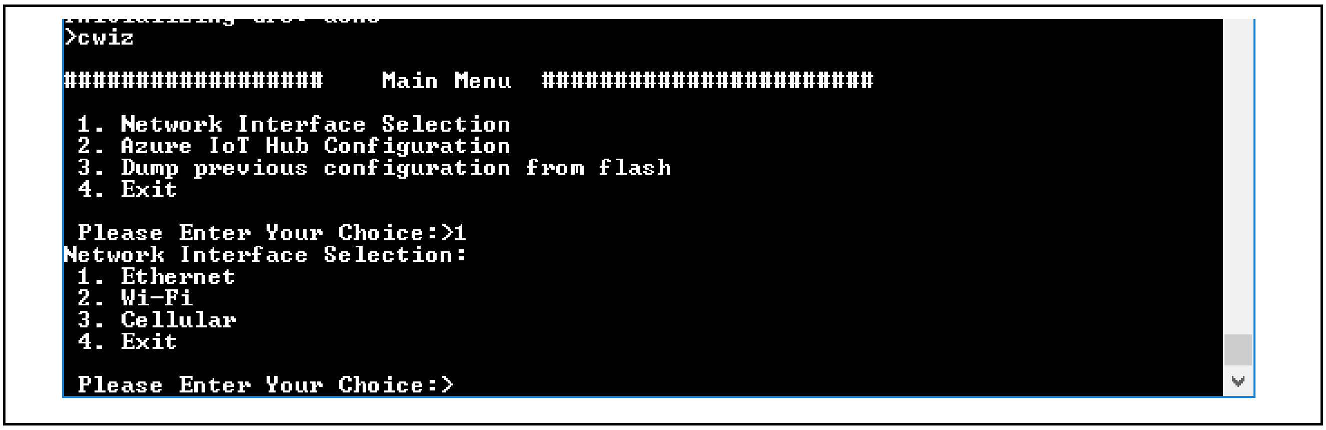
Figure 26. Configuration Menu

4.4.1.1 Network Interface Selection

From the configuration menu, press **'1'** key to configure the Network Interface. It lists the available network interface options, in this application project. Currently this application supports Ethernet, Wi-Fi, Cellular (in case of AE-CLOUD2 kit) network communication interfaces.

Note: The user can select only one network interface at a time. For instance, when Ethernet is selected, Wi-Fi and Cellular are not available, and vice-versa.

For example, if the user selects the **Ethernet Network Interface Configuration** as interface for cloud connectivity, and then the user can move directly to 4.4.1.2 (Azure IoT Hub Configuration). Similarly, this applies to Wi-Fi and Cellular as well.



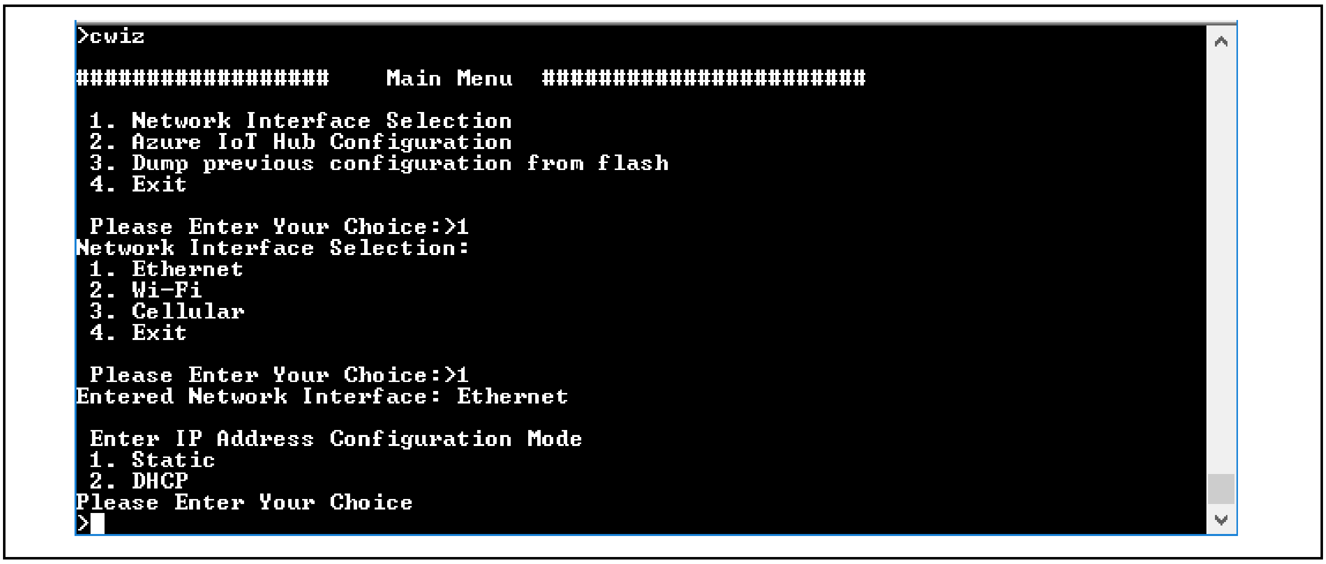
```
>cwiz

####################    Main Menu   #########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>1
Network Interface Selection:
 1. Ethernet
 2. Wi-Fi
 3. Cellular
 4. Exit

 Please Enter Your Choice:>
```

Figure 27. Network Interface Selection Menu

(1) Ethernet Network Interface Configuration

From the **Network Interface Selection menu**, press ‘**1’** key to select the Ethernet Network Configuration.

You see the submenu where you choose the IP Address Configuration mode from the available options (DHCP/Static). Choose the **IP Address Configuration** mode. The selected Ethernet configuration setting is stored in internal flash; it is used at later stage, when communication is initialized.

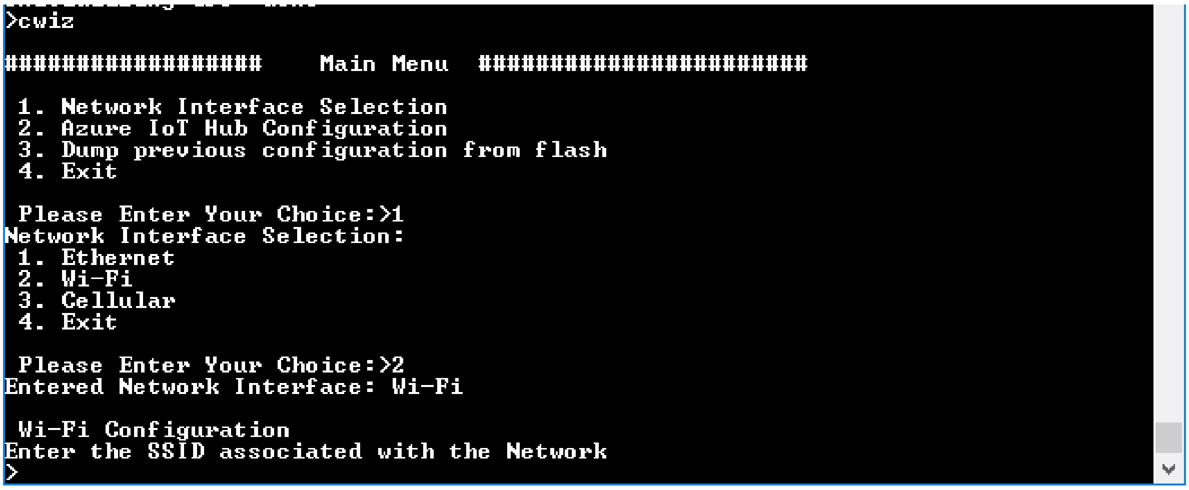


```
>cwiz

####################    Main Menu   #########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>1
Network Interface Selection:
 1. Ethernet
 2. Wi-Fi
 3. Cellular
 4. Exit

 Please Enter Your Choice:>1
Entered Network Interface: Ethernet

 Enter IP Address Configuration Mode
 1. Static
 2. DHCP
Please Enter Your Choice
>
```

Figure 28. Ethernet Network Interface Configuration Menu

(2) Wi-Fi Network Interface Configuration

When the user wants to choose Wi-Fi as interface, from the **Network Interface Selection menu**, press **‘2’** key to select the Wi-Fi Network Configuration.

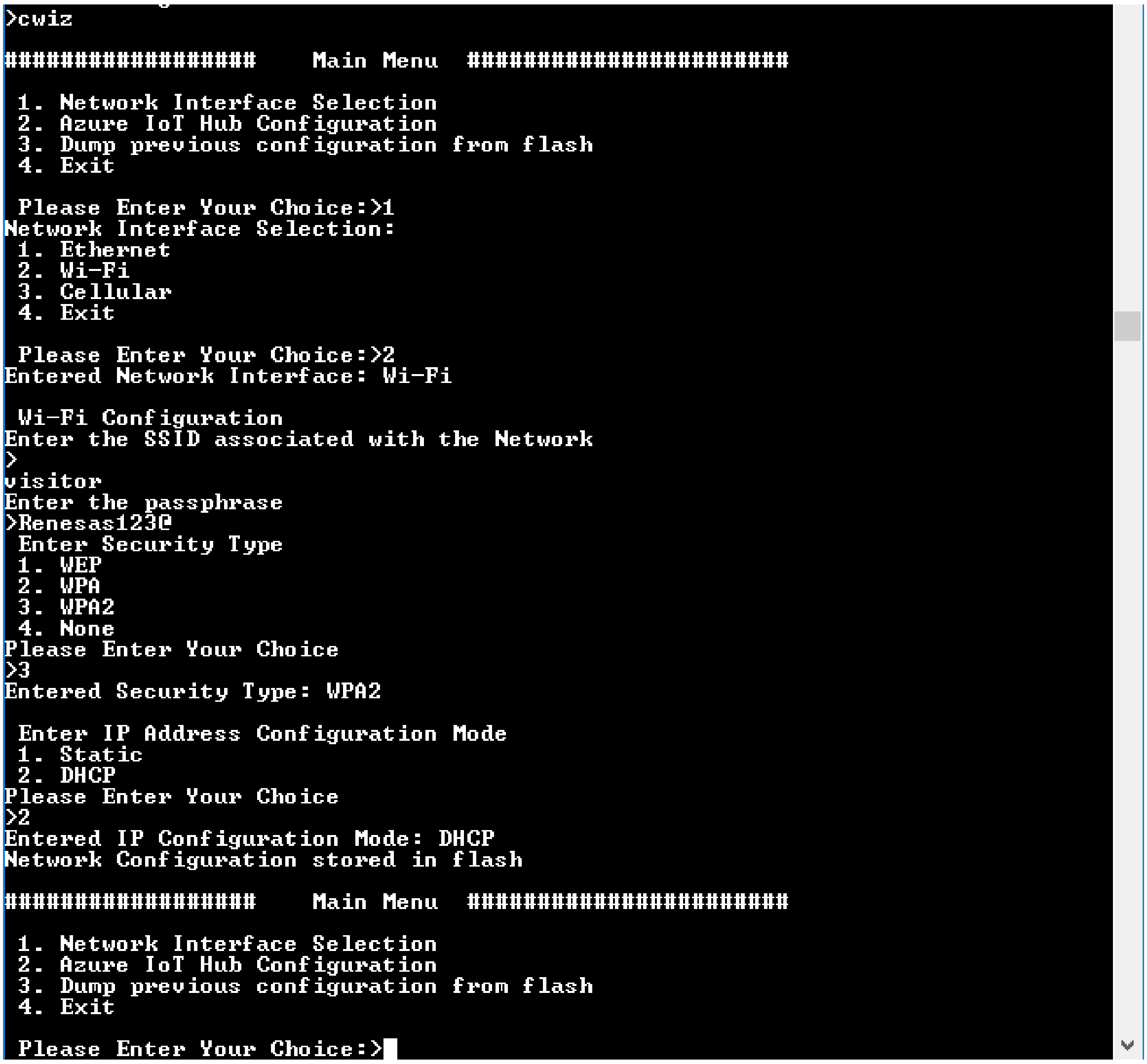


```
>cwiz

###################    Main Menu  ########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>1
Network Interface Selection:
 1. Ethernet
 2. Wi-Fi
 3. Cellular
 4. Exit

 Please Enter Your Choice:>2
Entered Network Interface: Wi-Fi

 Wi-Fi Configuration
Enter the SSID associated with the Network
>
```

Figure 29. Wi-Fi Network Interface Configuration Menu

You are given the option to enter Wi-Fi Configuration settings, such as **SSID**, **Pass key**, **Security type** and **IP Address Configuration mode**.

The selected Wi-Fi configuration settings are stored in the internal flash to be used at a later stage, when the communication is initialized.



```
>cwiz

###################    Main Menu  ########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>1
Network Interface Selection:
 1. Ethernet
 2. Wi-Fi
 3. Cellular
 4. Exit

 Please Enter Your Choice:>2
Entered Network Interface: Wi-Fi

 Wi-Fi Configuration
Enter the SSID associated with the Network
>
visitor
Enter the passphrase
>Renesas123@
 Enter Security Type
 1. WEP
 2. WPA
 3. WPA2
 4. None
Please Enter Your Choice
>3
Entered Security Type: WPA2

 Enter IP Address Configuration Mode
 1. Static
 2. DHCP
Please Enter Your Choice
>2
Entered IP Configuration Mode: DHCP
Network Configuration stored in flash

###################    Main Menu  ########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>
```

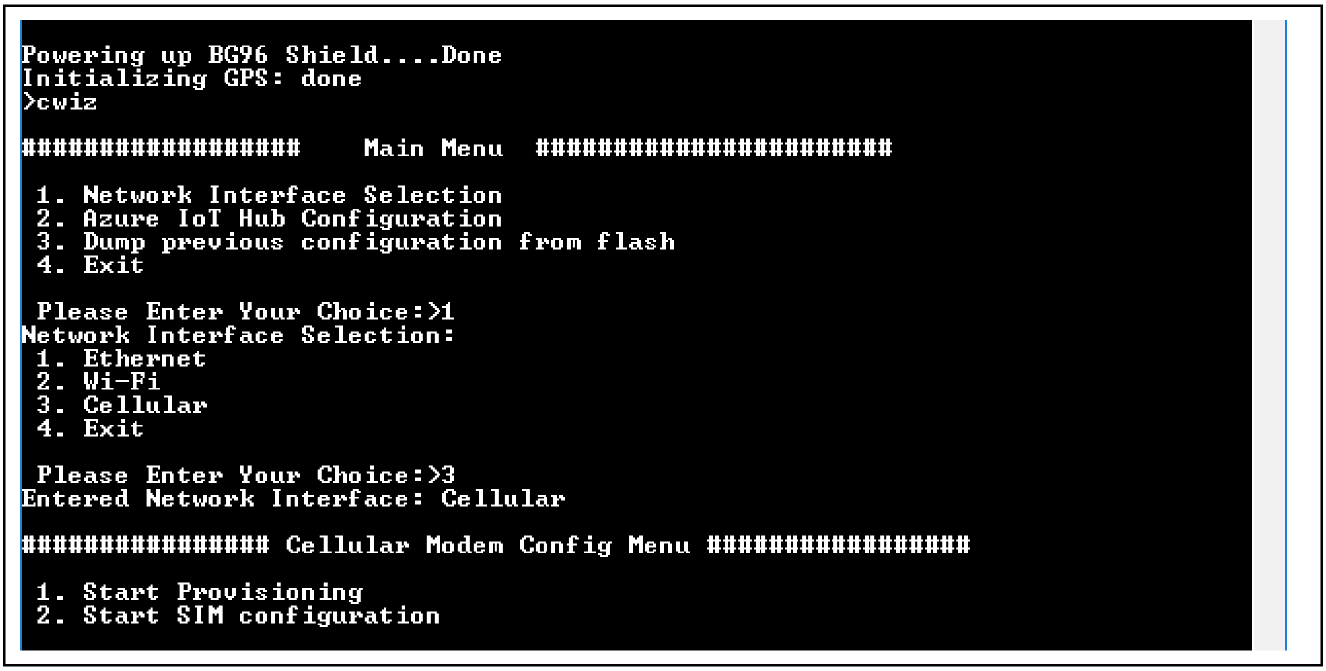
Figure 30. Wi-Fi Configuration

(3) Cellular Network Interface Configuration

When the user wants to choose Cellular as interface, from the **Network Interface Selection menu**, press **'3'** to select the Cellular Network Configuration.

You will be given two choices as shown in the following figure:

- **Option 1**: Enter **1** in case of SIM provisioning. In this case, it is assumed that you already pre-configured the SIM card.
- **Option 2**: Enter **2** in case of SIM configuration. This option is ideal if you wish to configure your brand-new SIM card using the AT shell interface.

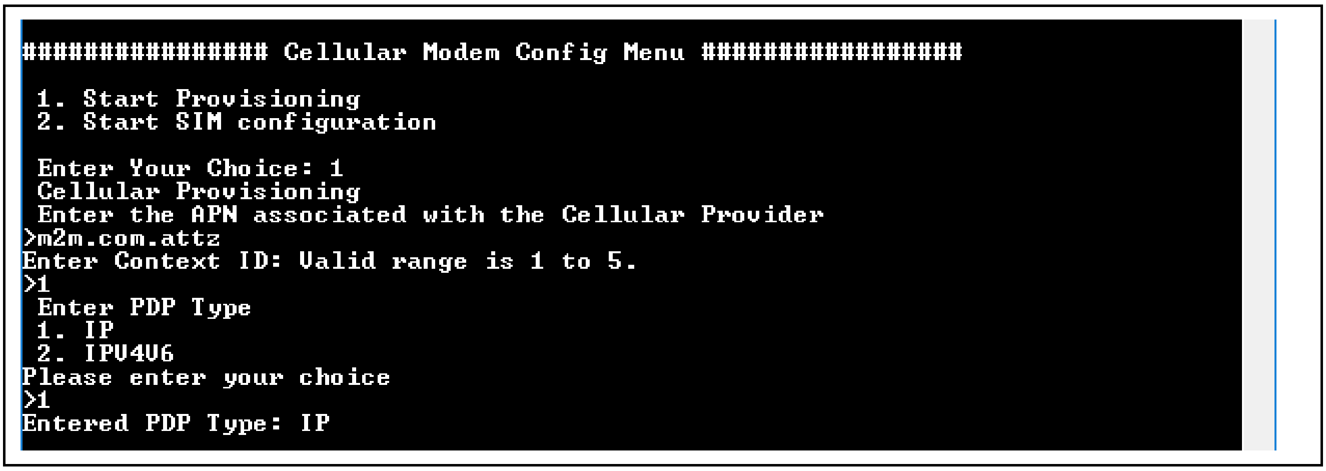


```
Powering up BG96 Shield....Done
Initializing GPS: done
>cwiz

##################    Main Menu  #######################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>1
Network Interface Selection:
 1. Ethernet
 2. Wi-Fi
 3. Cellular
 4. Exit

 Please Enter Your Choice:>3
Entered Network Interface: Cellular

################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration
```

Figure 31. Cellular Configuration

(a) Start Provisioning Option

In the **cellular modem configuration menu**, choose **option 1** to enter the Start provisioning sub-menu shown in the following figure.



```
################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration

 Enter Your Choice: 1
 Cellular Provisioning
 Enter the APN associated with the Cellular Provider
>m2m.com.attz
Enter Context ID: Valid range is 1 to 5.
>1
 Enter PDP Type
 1. IP
 2. IPV4V6
Please enter your choice
>1
Entered PDP Type: IP
```

Figure 32. Cellular Modem Provisioning Menu

The screen shot shows the Cellular configuration settings used for AT&T (USA Carrier) SIM card.

You are given the option to enter Cellular Configuration settings, such as **APN**, **Context ID**, **PDP type**.

Note: The APN name, Context ID, and PDP Type are provided by the Cellular Service provider. If you already know this information, start entering them using CLI.

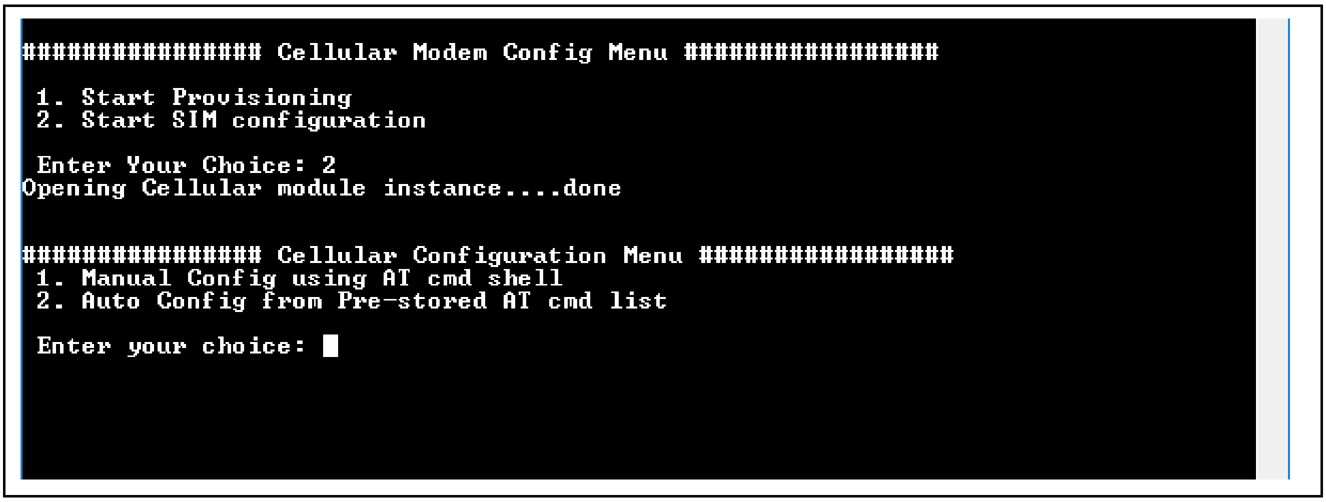
The selected Cellular configuration setting is stored in the internal flash to be used at a later stage, when the communication interface is initialized.

Note: If you have configured your SIM and provisioned the Cellular Modem you can skip the section 4.4.1.1(3)(b),

(b) Start SIM Configuration Option

In the **cellular modem configuration menu**, choose **option 2** to enter the Start SIM Configuration submenu shown in the following figure.

Note: It will take a few seconds to enter the Cellular Configuration menu since the firmware is opening the cellular framework instance in the background.



```
################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration

 Enter Your Choice: 2
Opening Cellular module instance....done


################ Cellular Configuration Menu #################
 1. Manual Config using AT cmd shell
 2. Auto Config from Pre-stored AT cmd list

 Enter your choice:
```

Figure 33. Cellular Configuration Menu

In this Mode, **Option 1** opens the AT command Shell mode where you can enter individual AT commands and verify them. You can also store the required AT commands in flash, based on the sequence needed for the Cellular service provider. **Option 2** retrieves the pre-stored AT command list.

Note: It will take a few seconds to enter the Cellular Configuration menu since the firmware is opening the cellular framework instance in the background.

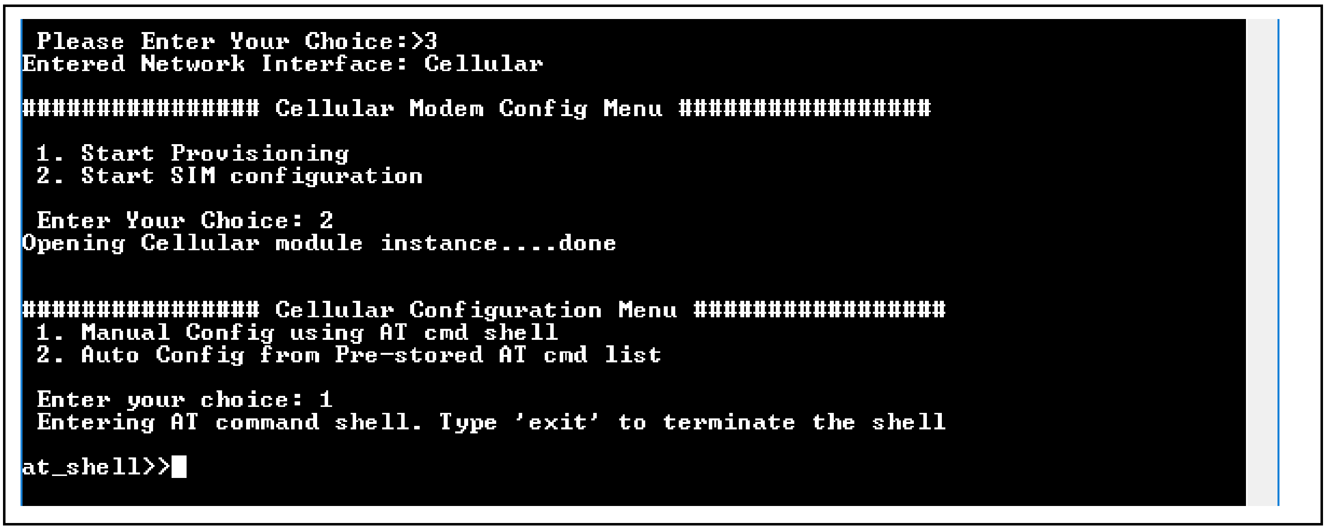
You can either choose **option 1** to enter the Manual Configuration mode using AT command shell or choose **option 2** to enter Auto Configuration from pre-stored AT command list. You generate this list at the end of previous Manual configuration.

Manual Configuration using AT Command Shell

In case of **Option 1**, enter the AT command shell shown as follows. You can experiment various AT commands to configure the SIM cards.

Refer the following knowledge base article provided by Renesas as a baseline to provisioning the SIM card using the BG96 Cellular modem:

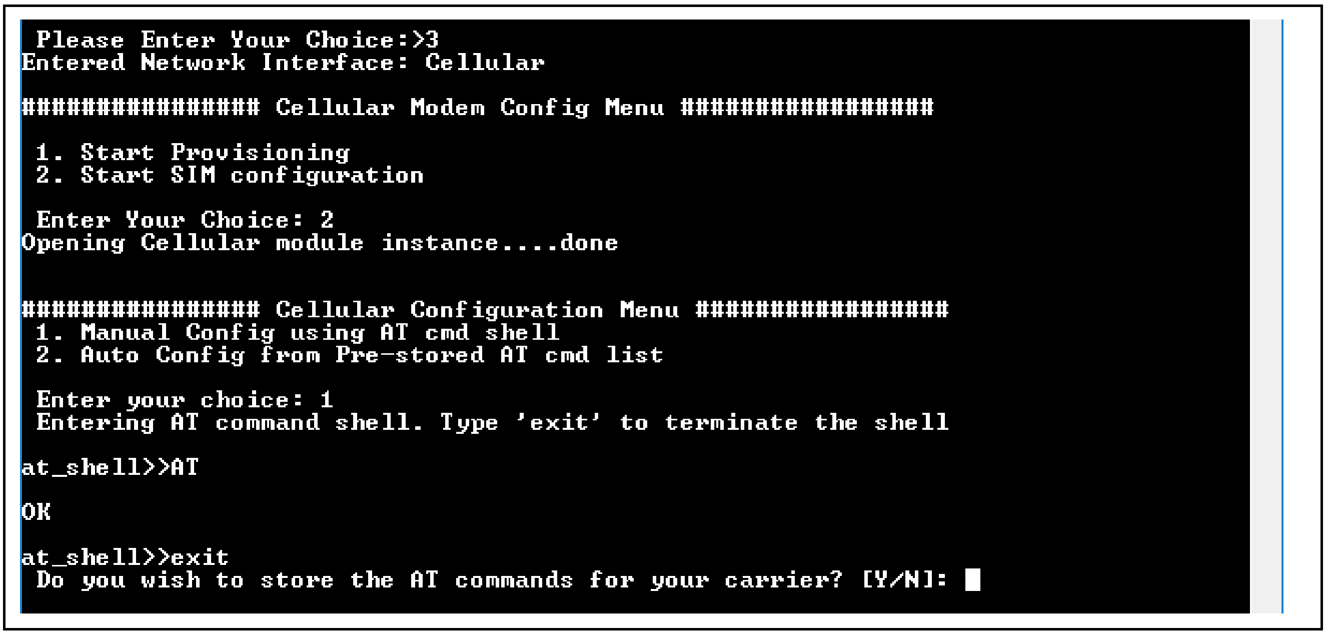
https://en.na4.teamsupport.com/knowledgeBase/18027787



```
 Please Enter Your Choice:>3
Entered Network Interface: Cellular

################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration

 Enter Your Choice: 2
Opening Cellular module instance....done


################ Cellular Configuration Menu #################
 1. Manual Config using AT cmd shell
 2. Auto Config from Pre-stored AT cmd list

 Enter your choice: 1
 Entering AT command shell. Type 'exit' to terminate the shell

at_shell>>
```

Figure 34. AT Command Shell

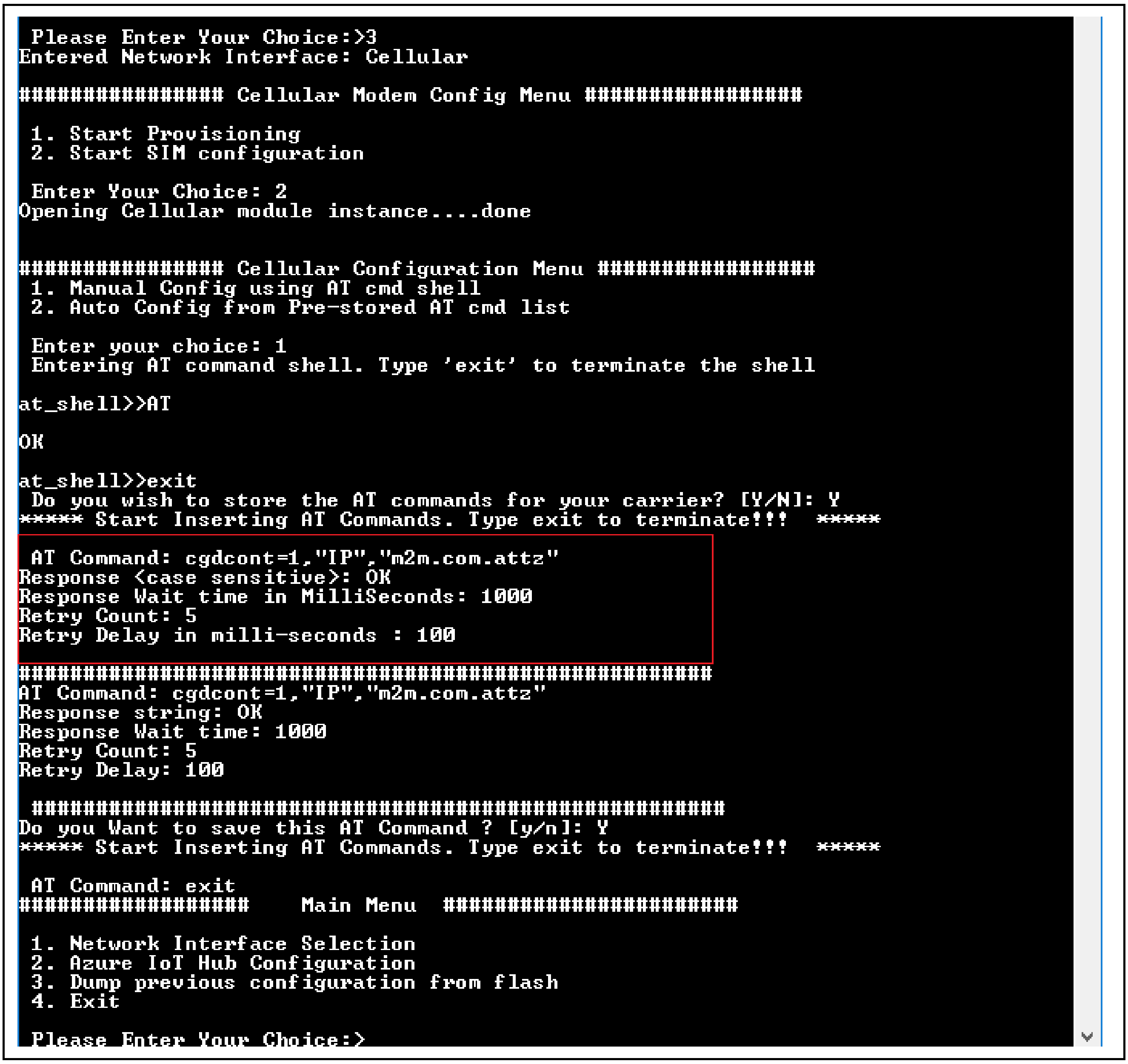
To exit the AT command shell, enter the command **"exit or EXIT"**. You will be asked whether you want to save the AT command as showing in the following figure.



```
 Please Enter Your Choice:>3
Entered Network Interface: Cellular

################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration

 Enter Your Choice: 2
Opening Cellular module instance....done


################ Cellular Configuration Menu #################
 1. Manual Config using AT cmd shell
 2. Auto Config from Pre-stored AT cmd list

 Enter your choice: 1
 Entering AT command shell. Type 'exit' to terminate the shell

at_shell>>AT

OK

at_shell>>exit
 Do you wish to store the AT commands for your carrier? [Y/N]:
```

Figure 35. AT Command Shell Usage

If you choose the to save the AT commands which can be later used to auto configure the new SIM cards, enter '**Y**'. In that case, you will be asked to enter the AT command details shown in the following figure.

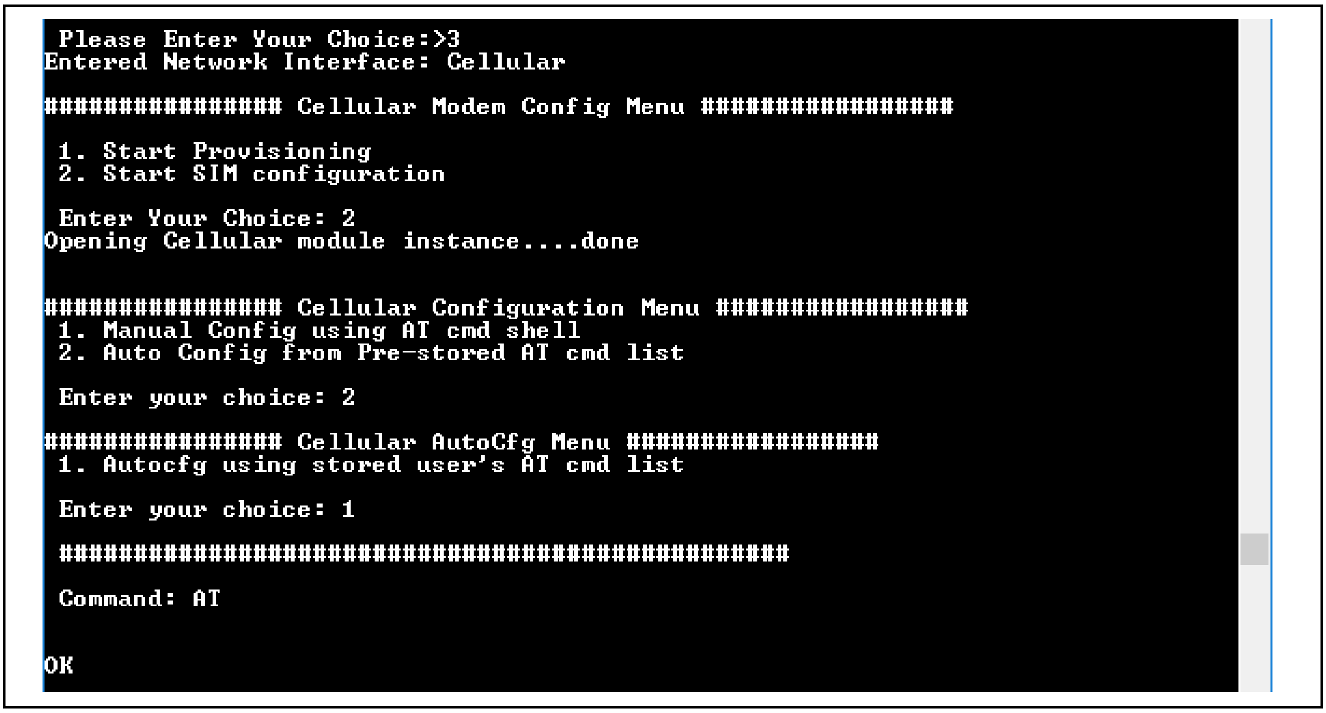


```
 Please Enter Your Choice:>3
Entered Network Interface: Cellular

################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration

 Enter Your Choice: 2
Opening Cellular module instance....done


################ Cellular Configuration Menu #################
 1. Manual Config using AT cmd shell
 2. Auto Config from Pre-stored AT cmd list

 Enter your choice: 1
 Entering AT command shell. Type 'exit' to terminate the shell

at_shell>>AT

OK

at_shell>>exit
 Do you wish to store the AT commands for your carrier? [Y/N]: Y
***** Start Inserting AT Commands. Type exit to terminate!!!  *****

 AT Command: cgdcont=1,"IP","m2m.com.attz"
Response <case sensitive>: OK
Response Wait time in MilliSeconds: 1000
Retry Count: 5
Retry Delay in milli-seconds : 100
######################################################
AT Command: cgdcont=1,"IP","m2m.com.attz"
Response string: OK
Response Wait time: 1000
Retry Count: 5
Retry Delay: 100

 ######################################################
Do you Want to save this AT Command ? [y/n]: Y
***** Start Inserting AT Commands. Type exit to terminate!!!  *****

 AT Command: exit
##################    Main Menu  #######################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>
```

Figure 36. Manual Mode Configuration using AT Command Shell

Auto Configuration from pre-stored AT command list

From the Cellular Configuration menu, choose **option 2** to enter **Auto configuration from pre-stored AT command list** menu shown in the following figure.



```
 Please Enter Your Choice:>3
Entered Network Interface: Cellular

################ Cellular Modem Config Menu #################

 1. Start Provisioning
 2. Start SIM configuration

 Enter Your Choice: 2
Opening Cellular module instance....done


################ Cellular Configuration Menu #################
 1. Manual Config using AT cmd shell
 2. Auto Config from Pre-stored AT cmd list

 Enter your choice: 2

################ Cellular AutoCfg Menu #################
 1. Autocfg using stored user's AT cmd list

 Enter your choice: 1

 #################################################

 Command: AT


OK
```

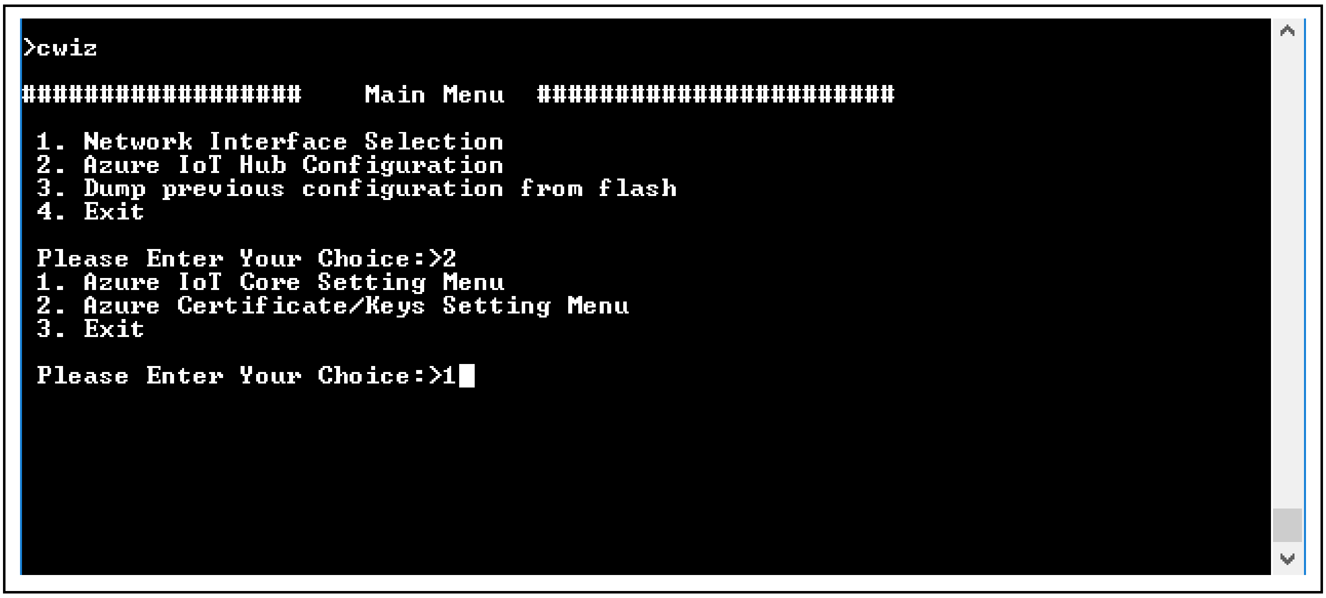
Figure 37. Auto configuration from Pre-stored AT Command List

The pre-stored AT commands will be sent to the cellular modem and their responses will be displayed in the console window.

4.4.1.2 Azure IoT Hub Configuration

At this stage, it is assumed that you followed the instructions in section 3.3 to create device in Azure Cloud Platform and selected the desired communication interface in the section 4.4.1.1. If not, please complete the steps mentioned in the section 3.3 and 4.4.1.1 before proceeding.

From the **Main Menu**, press **'2'** and **enter key** to configure the Azure Cloud IoT Core service as shown in the following figure.

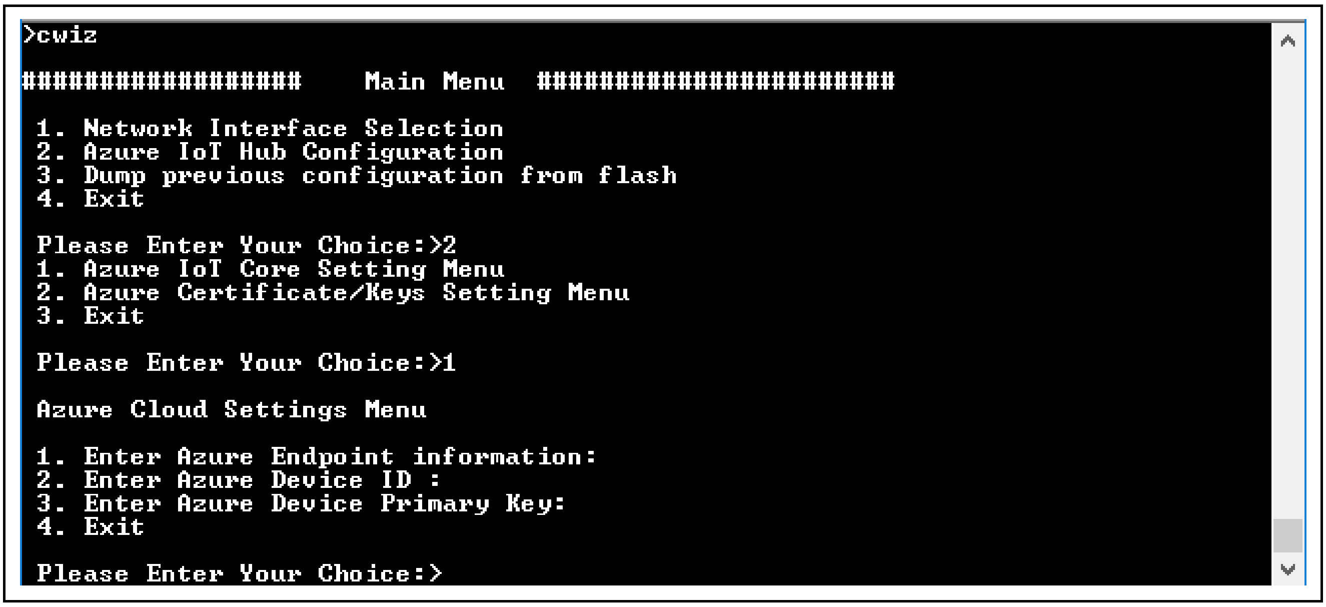


```
>cwiz

##################    Main Menu  #######################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>2
 1. Azure IoT Core Setting Menu
 2. Azure Certificate/Keys Setting Menu
 3. Exit

 Please Enter Your Choice:>1
```

Figure 38. Azure IoT Hub Configuration Menu

(1) Azure IoT Core Setting Menu

From the **Azure IoT Core configuration menu**, press **'1'** and **Enter** key to configure the Azure IoT Cloud settings. In the Azure IoT settings menu, you have the option to enter the information as shown in the following figure.



```
>cwiz

###################    Main Menu  ########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>2
 1. Azure IoT Core Setting Menu
 2. Azure Certificate/Keys Setting Menu
 3. Exit

 Please Enter Your Choice:>1

 Azure Cloud Settings Menu

 1. Enter Azure Endpoint information:
 2. Enter Azure Device ID :
 3. Enter Azure Device Primary Key:
 4. Exit

 Please Enter Your Choice:>
```

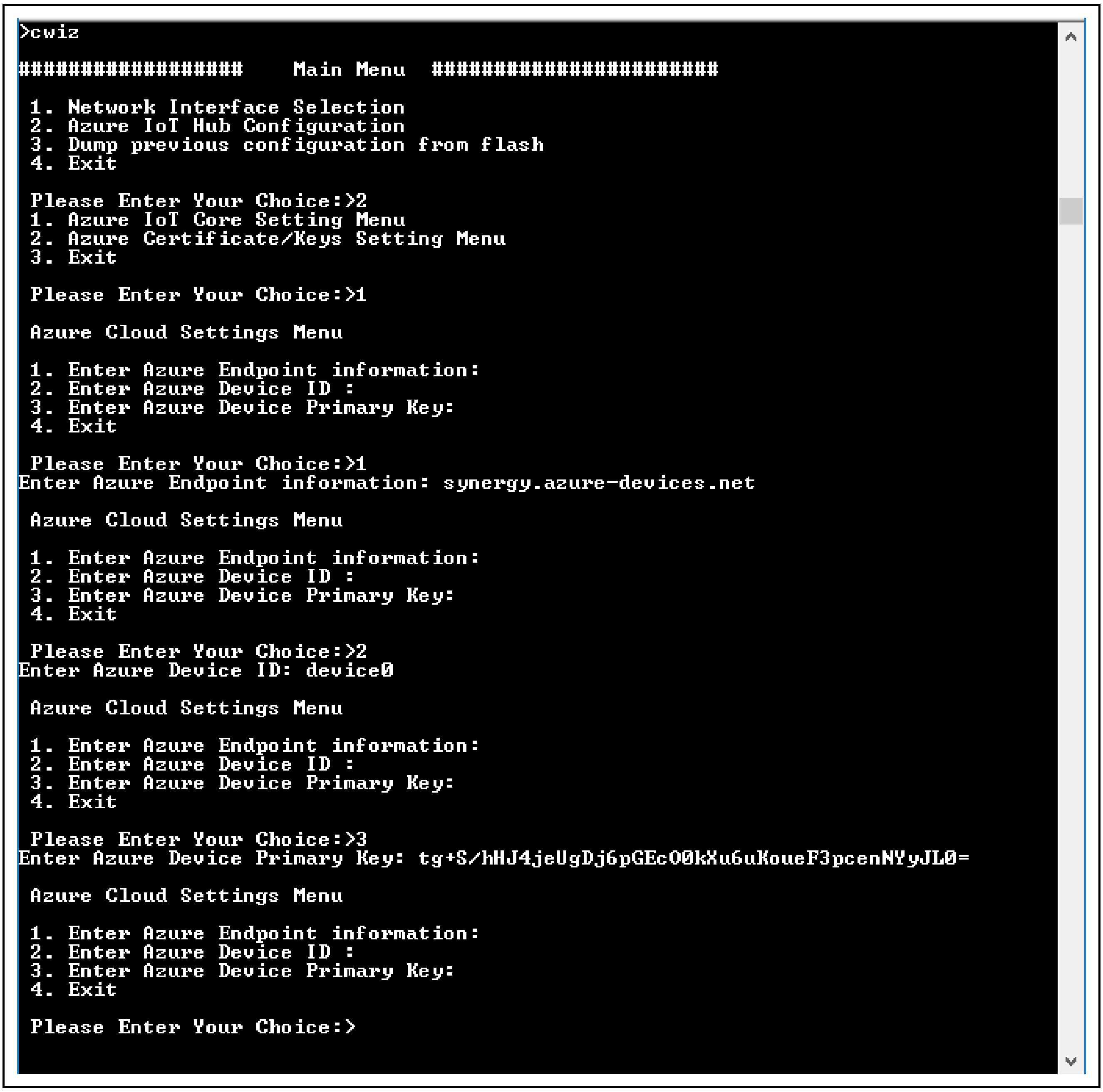
Figure 39. Azure IoT Hub Device Configuration Menu

Notes:

1. In case of **option 1** (Enter Endpoint Information), enter **'IoTHubName'.azure-devices.net**. The information can be taken from the connection string got created as part of the device creation on the IoT Hub, as shown in the snapshot of the Device details (see Figure 19)**.**

   Note: IoTHubName is the name of the IoT Hub. Choose your IoT Hub name

2. In case of **option 2** (**Enter Device ID Information**), enter **DeviceId.** The information can also be taken from the connection string as shown in the sample snapshot of the **Device details** in Figure 19.
3. In case of **option 3** (**Primary Key Information**), enter **Primary Key**. The information can also be taken from the **Device Details** as shown in the snapshot in the Figure 19.
4. The Azure credentials shown in the snapshots as part of this document are sample credentials and demonstration purpose only. These credentials need to be used with the credentials you created as part of the section 3.3.3
5. The snapshot of the Azure IoT configuration is shown in the following figure**.**



```
>cwiz

##################    Main Menu   ########################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>2
 1. Azure IoT Core Setting Menu
 2. Azure Certificate/Keys Setting Menu
 3. Exit

 Please Enter Your Choice:>1

 Azure Cloud Settings Menu

 1. Enter Azure Endpoint information:
 2. Enter Azure Device ID :
 3. Enter Azure Device Primary Key:
 4. Exit

 Please Enter Your Choice:>1
Enter Azure Endpoint information: synergy.azure-devices.net

 Azure Cloud Settings Menu

 1. Enter Azure Endpoint information:
 2. Enter Azure Device ID :
 3. Enter Azure Device Primary Key:
 4. Exit

 Please Enter Your Choice:>2
Enter Azure Device ID: device0

 Azure Cloud Settings Menu

 1. Enter Azure Endpoint information:
 2. Enter Azure Device ID :
 3. Enter Azure Device Primary Key:
 4. Exit

 Please Enter Your Choice:>3
Enter Azure Device Primary Key: tg+S/hHJ4jeUgDj6pGEcO0kXu6uKoueF3pcenNYyJL0=

 Azure Cloud Settings Menu

 1. Enter Azure Endpoint information:
 2. Enter Azure Device ID :
 3. Enter Azure Device Primary Key:
 4. Exit

 Please Enter Your Choice:>
```

Figure 40. Snapshot of Azure IoT Hub Device Configuration

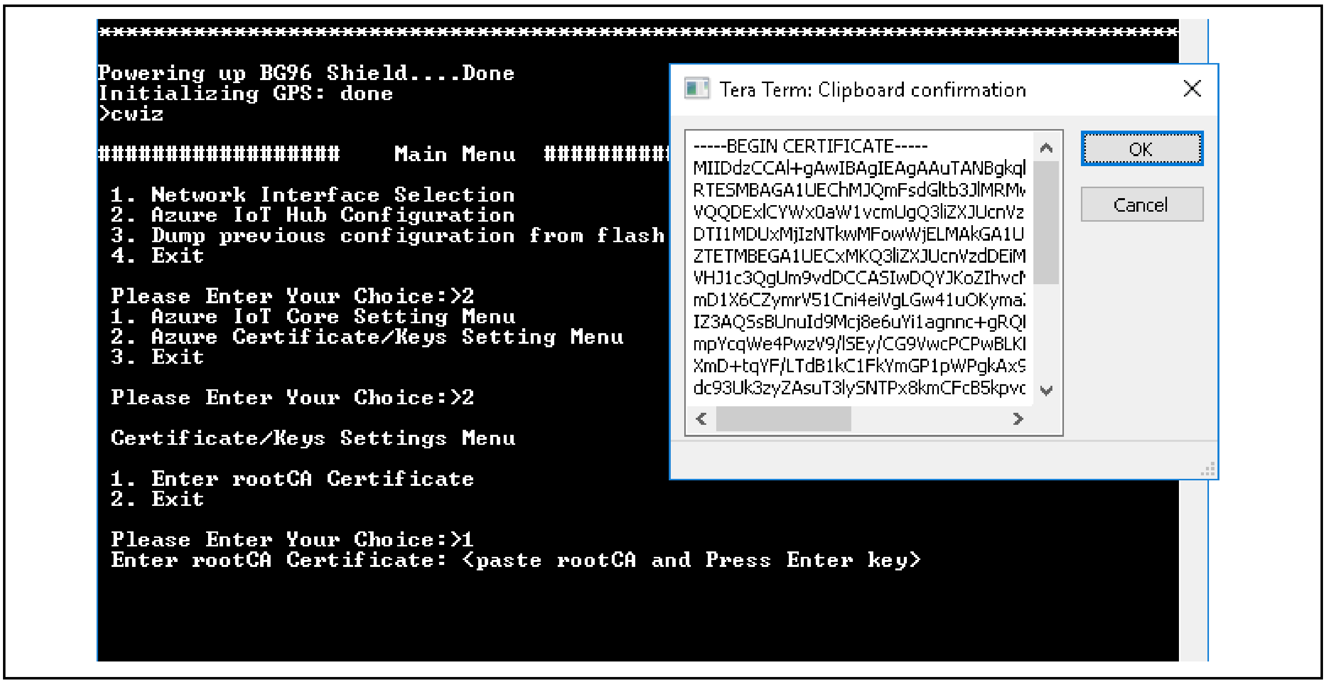
4.4.1.3 Azure Certificate/Key Settings Menu

From the **Azure IoT Hub configuration menu**, press **‘2’** and **Enter** key to configure the Azure Certificate/Keys settings.

In the **Azure Certificate/Keys settings menu**, you have the option of entering the root CA, in .pem format.

Open the attached generic certificate as part of this application Project in a text editor, copy and paste them in the serial console, and press **Enter** key.

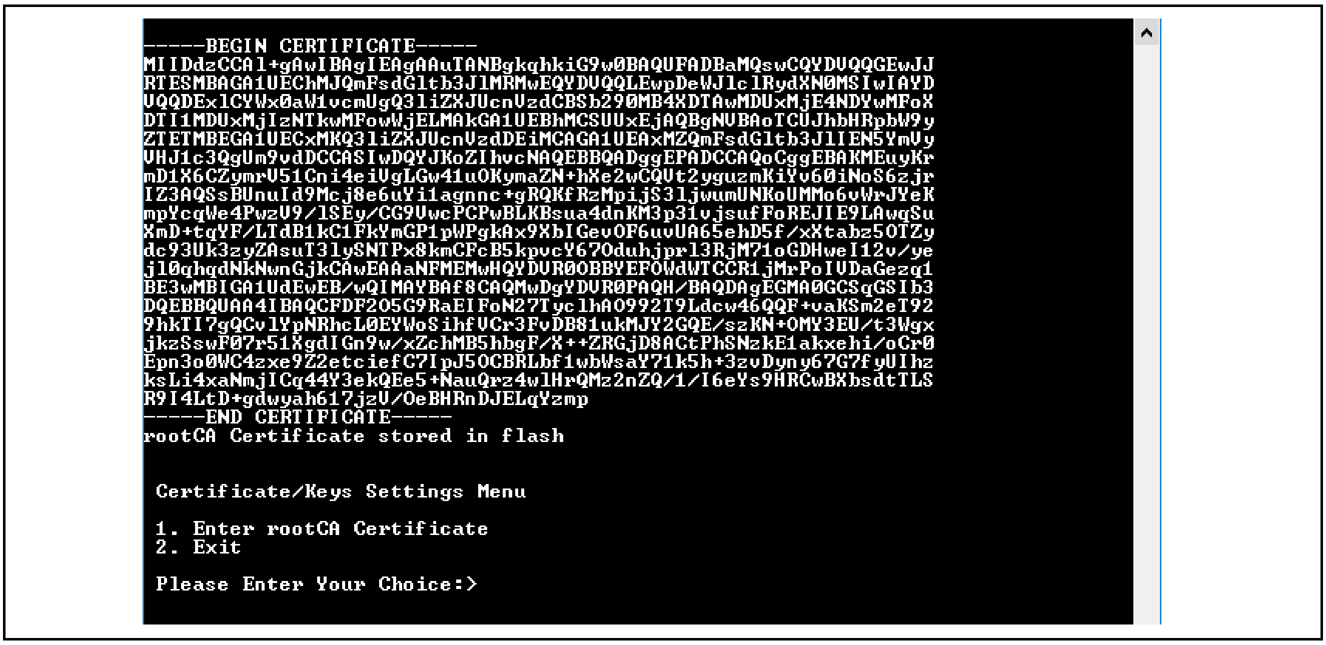
The root CA certificate (**azure_rootCA.pem**) for Azure Cloud is enclosed as part of the package.



```
*******************************************************************************

Powering up BG96 Shield....Done
Initializing GPS: done
>cwiz

####################    Main Menu   ##########

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>2
 1. Azure IoT Core Setting Menu
 2. Azure Certificate/Keys Setting Menu
 3. Exit

 Please Enter Your Choice:>2

 Certificate/Keys Settings Menu

 1. Enter rootCA Certificate
 2. Exit

 Please Enter Your Choice:>1
 Enter rootCA Certificate: <paste rootCA and Press Enter key>
```

```
-----BEGIN CERTIFICATE-----
MIIDdzCCAl+gAwIBAgIEAgAAuTANBgkql
RTESMBAGA1UEChMJQmFsdGltb3JlMRMw
VQQDExlCYWx0aW1vcmUgQ3liZXJUcnVz
DTI1MDUxMjIzNTkwMFowWjELMAkGA1U
ZTETMBEGA1UECxMKQ3liZXJUcnVzdDEiM
VHJ1c3QgUm9vdDCCASIwDQYJKoZIhvcN
mD1X6CZymrV51Cni4eiVgLGw41uOKyma
IZ3AQSsBUnuId9Mcj8e6uYi1agnnc+gRQl
mpYcqWe4PwzV9/lSEy/CG9VwcPCPwBLKl
XmD+tqYF/LTdB1kC1FkYmGP1pWPgkAx9
dc93Uk3zyZAsuT3lySNTPx8kmCFcB5kpvc
```

Figure 41. Certificates/Keys Setting Menu



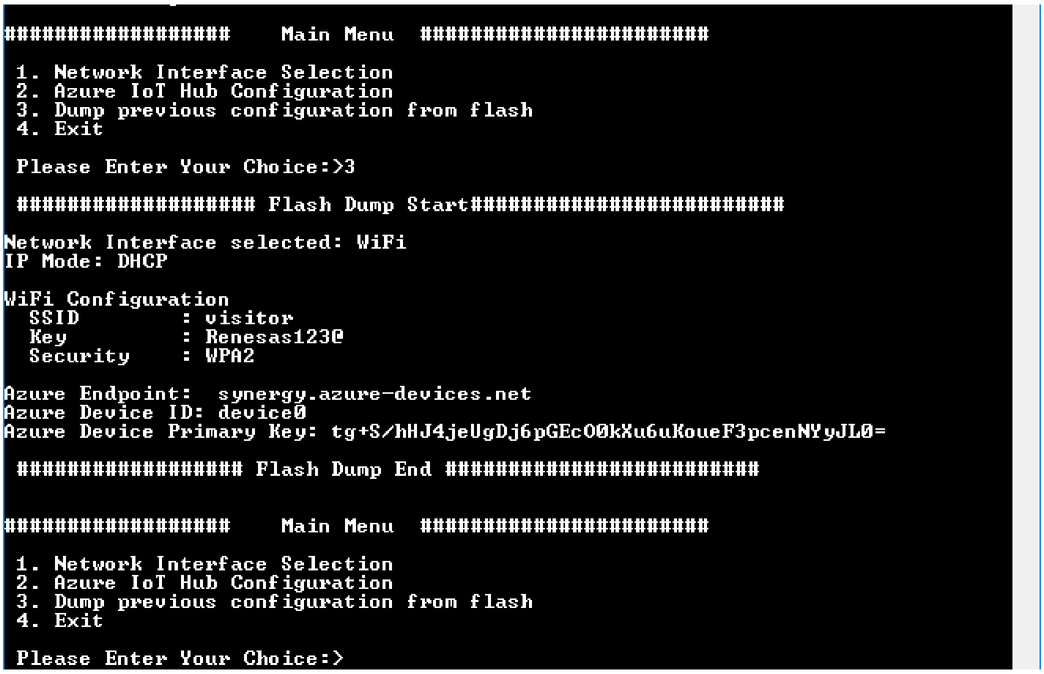
```
-----BEGIN CERTIFICATE-----
MIIDdzCCAl+gAwIBAgIEAgAAuTANBgkqhkiG9w0BAQUFADBaMQswCQYDVQQGEwJJ
RTESMBAGA1UEChMJQmFsdGltb3JlMRMwEQYDVQQLEwpDeWJlclRydXN0MSIwIAYD
VQQDExlCYWx0aW1vcmUgQ3liZXJUcnVzdCBSb290MB4XDTAwMDUxMjE4NDYwMFoX
DTI1MDUxMjIzNTkwMFowWjELMAkGA1UEBhMCSUUxEjAQBgNVBAoTCUJhbHRpbW9y
ZTETMBEGA1UECxMKQ3liZXJUcnVzdDEiMCAGA1UEAxMZQmFsdGltb3JlIEN5YmVy
VHJ1c3QgUm9vdDCCASIwDQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBAKMEuyKr
mD1X6CZymrV51Cni4eiVgLGw41uOKymaZN+hXe2wCQVt2yguzmKiYv60iNoS6zjr
IZ3AQSsBUnuId9Mcj8e6uYi1agnnc+gRQKfRzMpijS3ljwumUNKoUMMo6vWrJYeK
mpYcqWe4PwzV9/lSEy/CG9VwcPCPwBLKBsua4dnKM3p31vjsufFoREJIE9LAwqSu
XmD+tqYF/LTdB1kC1FkYmGP1pWPgkAx9XbIGevOF6uvUA65ehD5f/xXtabz5OTZy
dc93Uk3zyZAsuT3lySNTPx8kmCFcB5kpvcY67Oduhjprl3RjM71oGDHweI12v/ye
jl0qhqdNkNwnGjkCAwEAAaNFMEMwHQYDVR0OBBYEFOWdWTCCR1jMrPoIVDaGezq1
BE3wMBIGA1UdEwEB/wQIMAYBAf8CAQMwDgYDVR0PAQH/BAQDAgEGMA0GCSqGSIb3
DQEBBQUAA4IBAQCFDF2O5G9RaEIFoN27TyclhAO992T9Ldcw46QQF+vaKSm2eT92
9hkTI7gQCvlYpNRhcL0EYWoSihfVCr3FvDB81ukMJY2GQE/szKN+OMY3EU/t3Wgx
jkzSswF07r51XgdIGn9w/xZchMB5hbgF/X++ZRGjD8ACtPhSNzkE1akxehi/oCr0
Epn3o0WC4zxe9Z2etciefC7IpJ5OCBRLbf1wbWsaY71k5h+3zvDyny67G7fyUIhz
ksLi4xaNmjICq44Y3ekQEe5+NauQrz4wlHrQMz2nZQ/1/I6eYs9HRCwBXbsdtTLS
R9I4LtD+gdwyah617jzV/OeBHRnDJELqYzmp
-----END CERTIFICATE-----
rootCA Certificate stored in flash


 Certificate/Keys Settings Menu

 1. Enter rootCA Certificate
 2. Exit

 Please Enter Your Choice:>
```

Figure 42. Snapshot of Azure IoT Hub Root CA Certificate

The selected configuration setting is stored in the internal flash. It is used at a later stage during the device connecting to Azure IoT Hub connection.

4.4.1.4 Dump Previous Configuration

From the **Main Menu**, choose option **3** to dump the pre-selected network, the Azure IoT Hub Service Configuration options you made from the internal flash, as shown in the following figure.

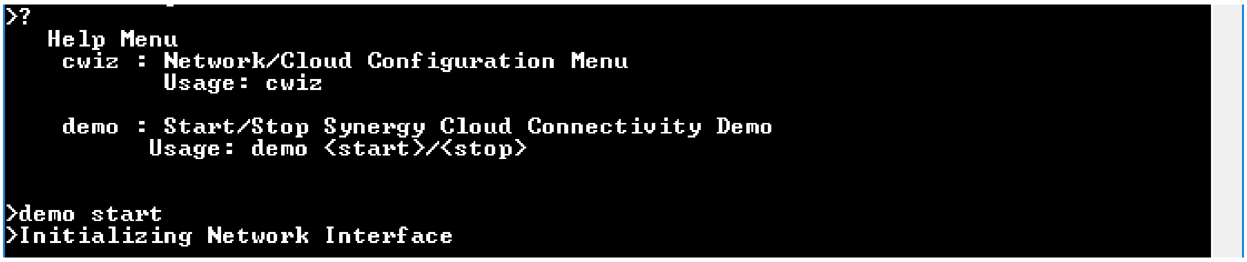


```
##################    Main Menu   #######################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>3

 ################### Flash Dump Start#########################

Network Interface selected: WiFi
IP Mode: DHCP

WiFi Configuration
  SSID         : visitor
  Key          : Renesas123@
  Security     : WPA2

Azure Endpoint:  synergy.azure-devices.net
Azure Device ID: device0
Azure Device Primary Key: tg+S/hHJ4jeUgDj6pGEcO0kXu6uKoueF3pcenNYyJL0=

 ################## Flash Dump End #########################


##################    Main Menu   #######################

 1. Network Interface Selection
 2. Azure IoT Hub Configuration
 3. Dump previous configuration from flash
 4. Exit

 Please Enter Your Choice:>
```

Figure 43. Dump Configuration Menu

4.4.2 Demo Start/Stop Command

From the CLI console, enter `demo start` command to start the Synergy Cloud Connectivity Application Demonstration.



```
>?
   Help Menu
    cwiz : Network/Cloud Configuration Menu
           Usage: cwiz

    demo : Start/Stop Synergy Cloud Connectivity Demo
          Usage: demo <start>/<stop>


>demo start
>Initializing Network Interface
```

Figure 44. Azure Running Demo

The application framework reads your pre-configured selection options for the network interface, the IoT service from the internal flash, and checks for its validity. If the content is valid, it then initializes the network interface and establishes a MQTT connection with the Azure IoT Hub.

This application wakes up periodically (every 5 seconds) and checks for your input event flag state. The flag state is set once you have entered the `demo start/stop` command on the CLI. This application does the following functions periodically until you enter the `demo stop` command.

1. Initialize communication interface (Ethernet or Wi-Fi, or Cellular), based on the selection.
2. Initialize Azure IoT Cloud interface.
3. Read sensor data and publish them periodically on MQTT topics.
4. Updates your LED state based on the type of MQTT message received.

If the `demo stop` command is issued, it de-initializes the IoT Cloud interface, which in turn stops MQTT messages from publishing and clears any pending MQTT messages from its internal queue.

4.5 Verifying the Demo

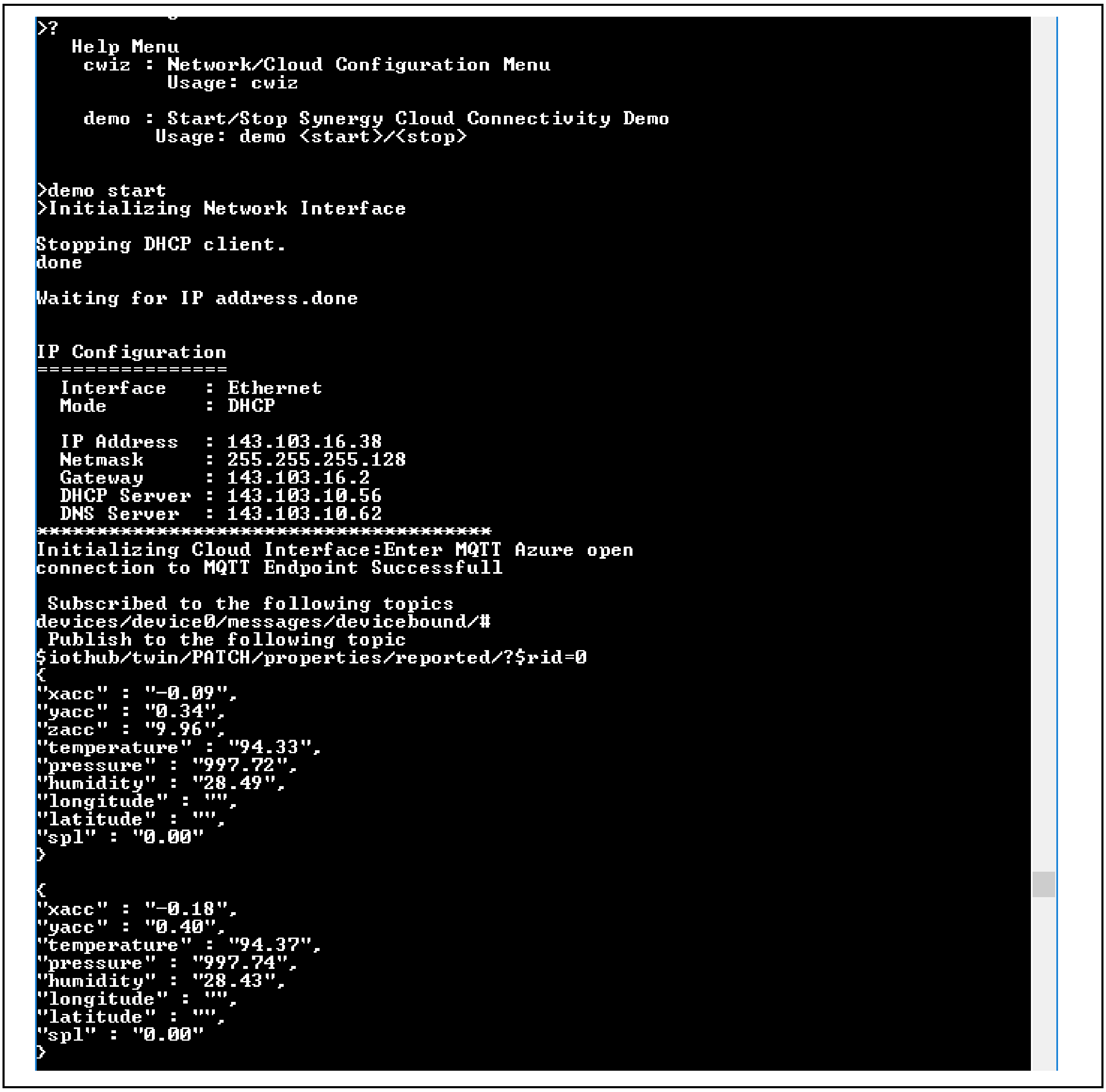
Use the following instructions to verify the functionality of this Synergy Cloud Connectivity Application Project.

Note: It is assumed that you completed the instructions in section 3.3 to create an Azure Cloud IoT account, set up your device on the Azure IoT Hub, configured network credentials, and Azure IoT credentials using CLI, as well as compiled and downloaded the application project to the PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit.

4.5.1 Running the Synergy Cloud Connectivity Demonstration

Run this application demonstration using the **`demo start`** command from the serial console.

Once you run `demo start`, it begins to configure the network interface, establish a connection with Azure IoT Hub, and start publishing sensor data periodically (every 5 seconds).



```
>?
   Help Menu
    cwiz : Network/Cloud Configuration Menu
           Usage: cwiz

    demo : Start/Stop Synergy Cloud Connectivity Demo
          Usage: demo <start>/<stop>


>demo start
>Initializing Network Interface

Stopping DHCP client.
done

Waiting for IP address.done


IP Configuration
================
  Interface    : Ethernet
  Mode         : DHCP

  IP Address   : 143.103.16.38
  Netmask      : 255.255.255.128
  Gateway      : 143.103.16.2
  DHCP Server  : 143.103.10.56
  DNS Server   : 143.103.10.62
**************************************
Initializing Cloud Interface:Enter MQTT Azure open
connection to MQTT Endpoint Successfull

 Subscribed to the following topics
devices/device0/messages/devicebound/#
 Publish to the following topic
$iothub/twin/PATCH/properties/reported/?$rid=0
{
"xacc" : "-0.09",
"yacc" : "0.34",
"zacc" : "9.96",
"temperature" : "94.33",
"pressure" : "997.72",
"humidity" : "28.49",
"longitude" : "",
"latitude" : "",
"spl" : "0.00"
}

{
"xacc" : "-0.18",
"yacc" : "0.40",
"temperature" : "94.37",
"pressure" : "997.74",
"humidity" : "28.43",
"longitude" : "",
"latitude" : "",
"spl" : "0.00"
}
```

Figure 45. Application Demo Snapshot from CLI

4.5.2 Monitoring MQTT messages on Device and Azure MQTT Broker

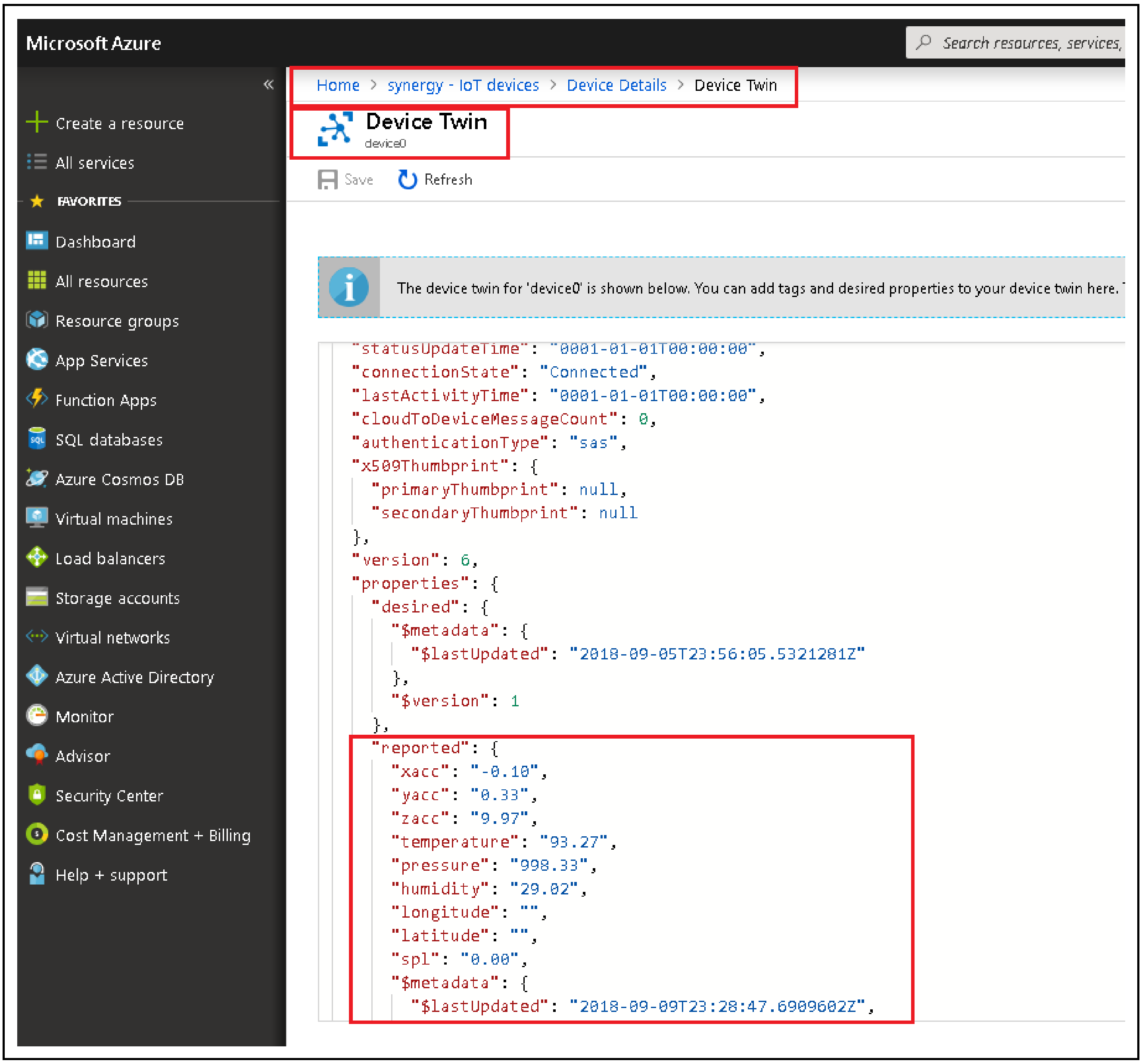
Once the demo is running, sensor data is periodically published to the Azure IoT Hub. To view the data published, user has 2 options to view the data**. 1) On the Device Side using CLI log. 2) Using the Device Twin for the Device on the IoT Hub**.

4.5.2.1 Monitoring on the Device Side

The console logs when the **demo start** is issued on the device side using the command line interface (**CLI**), initiating the gathering of sensor data pushed on to the cloud. When the device is controlled from the IoT Hub (to turn LEDs ON/OFF), the user can view messages on the console.

4.5.2.2 Monitoring on the Azure IoT Hub

The sensor data can be viewed on the IoT Hub using the device twin. The data is in the JSON format under the reported tag. Details are available on the device twin, in addition to the sensor data. Go to **IoT Hub**. Click the Device to open the Device details blade. Click "**Device Twin"** on the Device details blade to open the Device Twin blade shown in the following figure**.**



The device twin for 'device0' is shown below. You can add tags and desired properties to your device twin here.

```
"statusUpdateTime": "0001-01-01T00:00:00",
"connectionState": "Connected",
"lastActivityTime": "0001-01-01T00:00:00",
"cloudToDeviceMessageCount": 0,
"authenticationType": "sas",
"x509Thumbprint": {
  "primaryThumbprint": null,
  "secondaryThumbprint": null
},
"version": 6,
"properties": {
  "desired": {
    "$metadata": {
      "$lastUpdated": "2018-09-05T23:56:05.5321281Z"
    },
    "$version": 1
  },
  "reported": {
    "xacc": "-0.10",
    "yacc": "0.33",
    "zacc": "9.97",
    "temperature": "93.27",
    "pressure": "998.33",
    "humidity": "29.02",
    "longitude": "",
    "latitude": "",
    "spl": "0.00",
    "$metadata": {
      "$lastUpdated": "2018-09-09T23:28:47.6909602Z",
```

Figure 46. Sensor Data Snapshot on Device Twin

4.5.3 Publishing the MQTT message from Azure IoT Hub

You can publish the MQTT message to turn ON/OFF your LEDs on the PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit by using the following table indicating messages for various LED states.

Note: The Messages listed under Message Column are **case sensitive**. Users need to be aware while using your kit to turn ON/OFF the LEDs.

Table 1. Turning the User LED ON/OFF on your PK-S5D9/AE-CLOUD2/AE-CLOUD1 kit

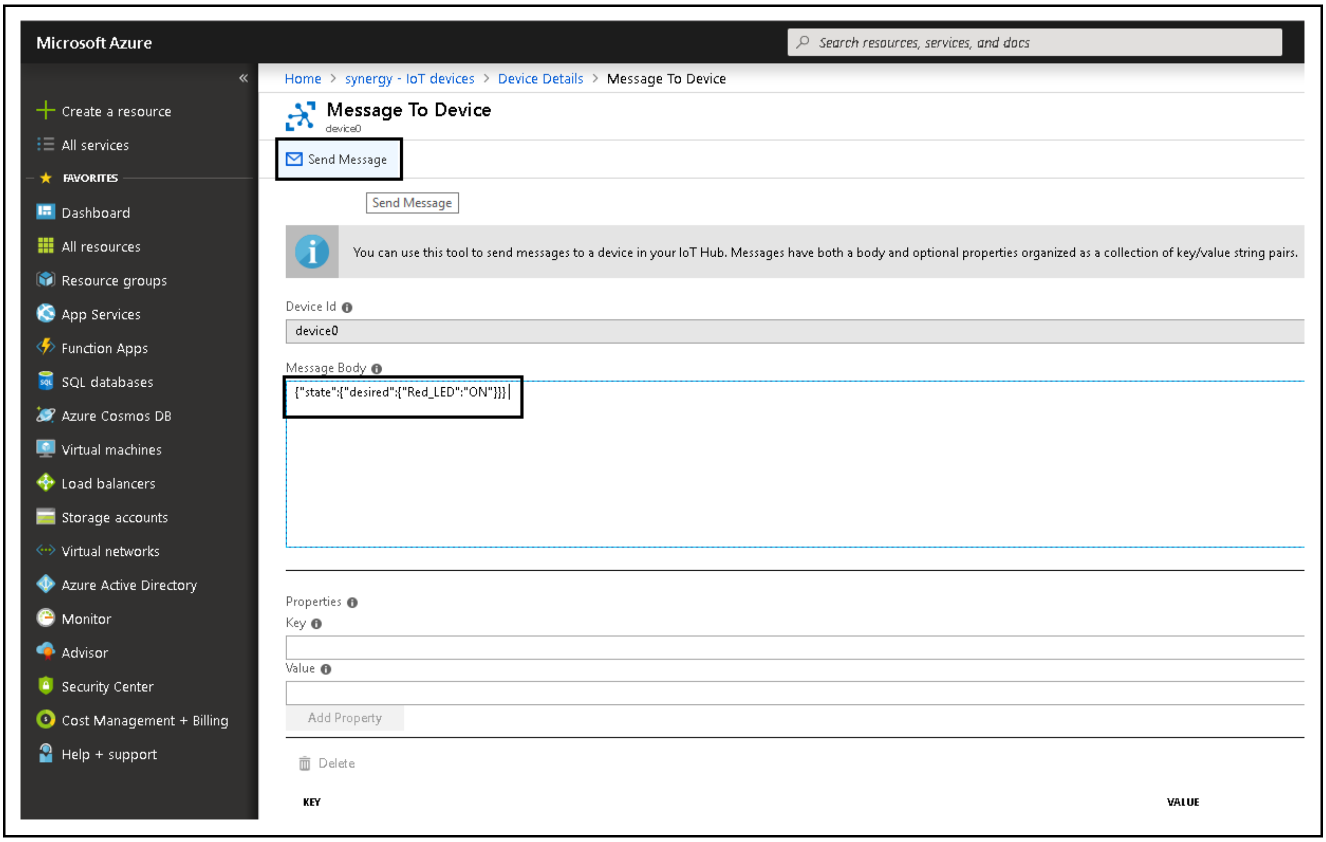
LED State	Message
RED LED ON	{"state":{"desired":{"Red_LED":"ON"}}}
RED LED OFF	{"state":{"desired":{"Red_LED":"OFF"}}}
YELLOW LED ON	{"state":{"desired":{"Yellow_LED":"ON"}}}
YELLOW LED OFF	{"state":{"desired":{"Yellow_LED":"OFF"}}}
GREEN LED ON	{"state":{"desired":{"Green_LED":"ON"}}}
GREEN LED OFF	{"state":{"desired":{"Green_LED":"OFF"}}}

To publish the message, use the following steps:

1. Go to the IoT Hub. Click on the Device, opens the **Device details** blade. Click the "**Message to Device"** on the **Device details** blade, it will open up Message to Device blade as shown in the following figure.
2. Under the Message Body, paste the corresponding message to turn ON/OFF the LED e.g. **{"state":{"desired":{"Red_LED":"ON"}}}** and click the **"Send Message"**

Note: Leave the Key and Value Field Blank.

3. You can see the corresponding LEDs that turn ON, on the actual device, as well as the print message on the console **"Red LED ON".**



You can use this tool to send messages to a device in your IoT Hub. Messages have both a body and optional properties organized as a collection of key/value string pairs.

Device Id: device0

Message Body: {"state":{"desired":{"Red_LED":"ON"}}}

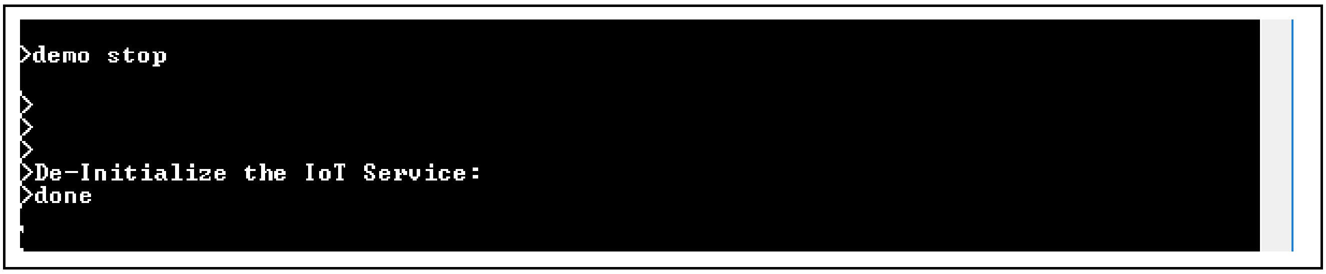
Key:

Value:

Figure 47. Snapshot of Send Message to Device from Azure IoT Hub

4.5.4 Stopping the Synergy Cloud Connectivity Demonstration

To stop the demonstration, enter the **`demo stop`** command. Issuing this command de-initializes the IoT Cloud interface, stops it from publishing MQTT messages, and clears any pending MQTT messages from its internal queue.



```
>demo stop

>
>
>
>De-Initialize the IoT Service:
>done
```

Figure 48. Application Demo Stop Sequence

5. Next Steps

Visit www.renesas.com/synergy/tools to learn more about development tools & utilities.

Visit www.renesas.com/synergy/gallery to download development tools & utilities.

Renesas Synergy Module Guides collateral link: www.renesas.com/synergy/applicationprojects

6. MQTT/TLS Reference

- SSP 1.5.0 User Manual can be downloaded from the Renesas Synergy™ Gallery (www.renesas.com/synergy/ssp)
- Azure IoT documentation https://docs.microsoft.com/en-us/azure/iot-hub/

7. Known Issues and Limitations

If a user running this demo using Wi-Fi and Cellular connection, tries to stop the demo using **`demo stop`** command and then restart the demo using **`demo start`** command, the demo fails to reconnect to the Azure IoT MQTT broker.

Currently, there is no support for direct device-to-device communications with Azure IoT hub.

Website and Support

Visit the following vanity URLs to learn about key elements of the Synergy Platform, download components and related documentation, and get support.

Synergy Software	www.renesas.com/synergy/software
Synergy Software Package	www.renesas.com/synergy/ssp
Software add-ons	www.renesas.com/synergy/addons
Software glossary	www.renesas.com/synergy/softwareglossary
Development tools	www.renesas.com/synergy/tools
Synergy Hardware	www.renesas.com/synergy/hardware
Microcontrollers	www.renesas.com/synergy/mcus
MCU glossary	www.renesas.com/synergy/mcuglossary
Parametric search	www.renesas.com/synergy/parametric
Kits	www.renesas.com/synergy/kits
Synergy Solutions Gallery	www.renesas.com/synergy/solutionsgallery
Partner projects	www.renesas.com/synergy/partnerprojects
Application projects	www.renesas.com/synergy/applicationprojects
Self-service support resources:	
Documentation	www.renesas.com/synergy/docs
Knowledgebase	www.renesas.com/synergy/knowledgebase
Forums	www.renesas.com/synergy/forum
Training	www.renesas.com/synergy/training
Videos	www.renesas.com/synergy/videos
Chat and web ticket	www.renesas.com/synergy/resourcelibrary

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Sep.24.18	—	Initial version
1.01	Feb.07.19	—	Added IAR Support and Bug fixes. Added Support for AE-CLOUD1.
1.02	Apr.03.19	—	Fixed Cellular at command shell bug.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.
   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit: www.renesas.com/contact/.