

## TI Designs: TIDEP0084

## Sub-1GHzのセンサクラウド間、産業用IoT (Internet-of-Things) ゲートウェイのリファレンス・デザイン



## 概要

このリファレンス・デザインでは、長距離のSub-1GHzワイヤレス・ネットワーク経由でセンサをクラウドに接続する方法を紹介します。これは、ビルディング制御やアセット・トラッキングなどの産業用機器に最適です。このデザインは、TIのSitara™AM335xプロセッサと、SimpleLink™超低消費電力(ULP) Sub-1GHzデバイスであるCC13x0およびCC13x2を使用して動作します。このリファレンスデザインには、TIのSimpleLink MCUプラットフォームの一部であるTI SimpleLink CC13x0ソフトウェア開発キット(SDK)のTI 15.4-Stack部分が既に組み込まれているため、TIの低消費電力の有線および無線MCU全体にわたり、統一したソフトウェア環境が実現されます。また、このリファレンス・デザインには、Linux®プロセッサSDKが含まれており、このSDKはTexas Instruments™から提供されます。TI Designネットワーク・パートナーであるstackArmor社を通じて、クラウド・コネクティビティと、センサ・ノード・データの視覚化のためのクラウド・アプリケーション・サービスをサポートしています。

## リソース

<a href="#">TIDEP0084</a>	デザイン・フォルダ
<a href="#">CC1310</a>	プロダクト・フォルダ
<a href="#">CC1350</a>	プロダクト・フォルダ
<a href="#">CC1312R</a>	プロダクト・フォルダ
<a href="#">CC1352R</a>	プロダクト・フォルダ
<a href="#">AM335x</a>	製品概要

## 特長

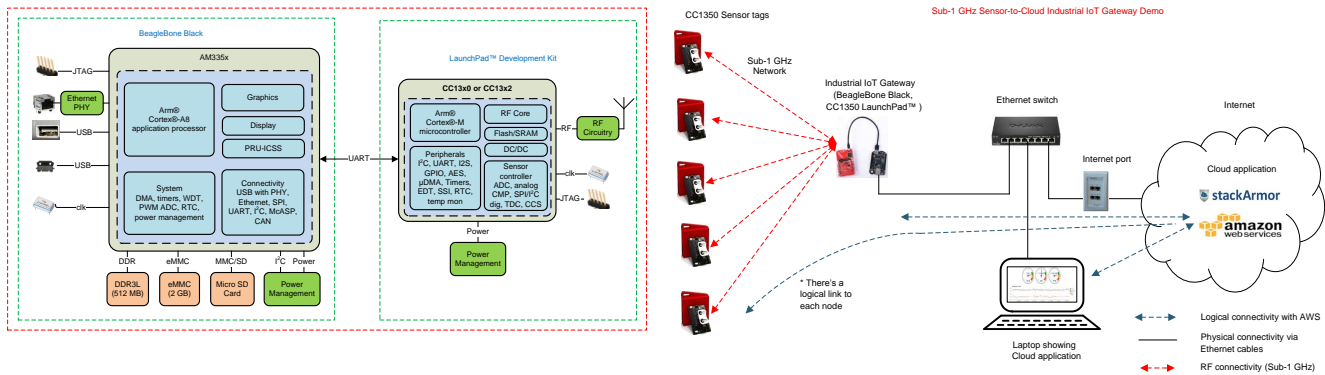
- 最大1kmの直線見通し距離を可能にする、大規模なネットワークからクラウドへの接続性
- IEEE 802.15.4e/g標準をベースとする、TI 15.4-Stack搭載のSub-1GHzソリューション
- 実績のあるハードウェア設計を基礎としており、変更不要ですぐに使用可能なデモンストレーション用ソフトウェアが付属しているため、製品開発期間を短縮可能
- TIのLinux用プロセッサSDKにより、AM437xやAM57xなど複数のSitaraプロセッサに対応したスケーラビリティを実現
- スター型ネットワークをサポート
- 超低消費電力のセンサ・ノード

## アプリケーション

- ビルのセキュリティ・ゲートウェイ
- ドアおよび窓のセンサ・ネットワーク
- HVACゲートウェイ
- アセット管理およびアセット・トラッキング



[E2Eエキスパートに質問](#)



使用許可、知的財産、その他免責事項は、最終ページにあるIMPORTANT NOTICE(重要な注意事項)をご参照くださいますようお願いいたします。英語版のTI製品についての情報を翻訳したこの資料は、製品の概要を確認する目的で便宜的に提供しているものです。該当する正式な英語版の最新情報は、[www.ti.com](http://www.ti.com)で閲覧でき、その内容が常に優先されます。TIでは翻訳の正確性および妥当性につきましては一切保証いたしません。実際の設計などの前には、必ず最新版の英語版をご参照くださいますようお願いいたします。

## 1 System Description

This reference design provides a reference for creating an industrial IoT gateway that is capable of connecting a network of wireless sensors to an enterprise cloud provider. In this reference design, a long-range, low-power wireless network, made up of Sub-1 GHz CC13x0 or CC13x2 devices (both families are supported) that run the TI 15.4-Stack-based application, is connected to the cloud. An online dashboard is provided that allows the user to visualize the real-time sensor data as well as send actuation commands from anywhere in the world using an Internet-connected device with a web browser.

This reference design provides a list of required hardware, schematics, and foundational software to quickly begin your Internet of things (IoT) product development. Amazon Web Services™ (AWS) IoT service, which is brokered by stackArmor™, was chosen as the default cloud service provider for the demonstration. The software design, however, is architected to be flexible to enable other cloud service providers. This document also outlines how to get this design up and running on the cloud platform from IBM®.

This reference design enables IoT in numerous applications such as building security gateways, door and window sensor networks, asset management and tracking, and other IoT-enabled home and industrial automation applications.

The connection between the wireless sensor network and the cloud is made possible by TI's Sitara AM335x device on the BeagleBone Black development platform. On one side, the AM335x is connected to a Sub-1 GHz device acting as the central node in the wireless network, and on the other side, the device is connected to the cloud using Ethernet or the element14 Wireless Cape. These two connections allow the AM335x device to act as a gateway to get the sensor messages from the wireless network to the cloud and also to get the actuation requests from the cloud dashboard sent back to the wireless network.

Due to the long-range and low-power capabilities of the Sub-1 GHz sensors, this reference design is useful for any type of application that would benefit from distributed sensing. This reference design provides a blueprint that gives the ability to visualize or actuate tens or hundreds of sensors while only needing one gateway device, TI's Sitara AM335x, to be connected to the Internet.

## 2 System Overview

### 2.1 Block Diagram

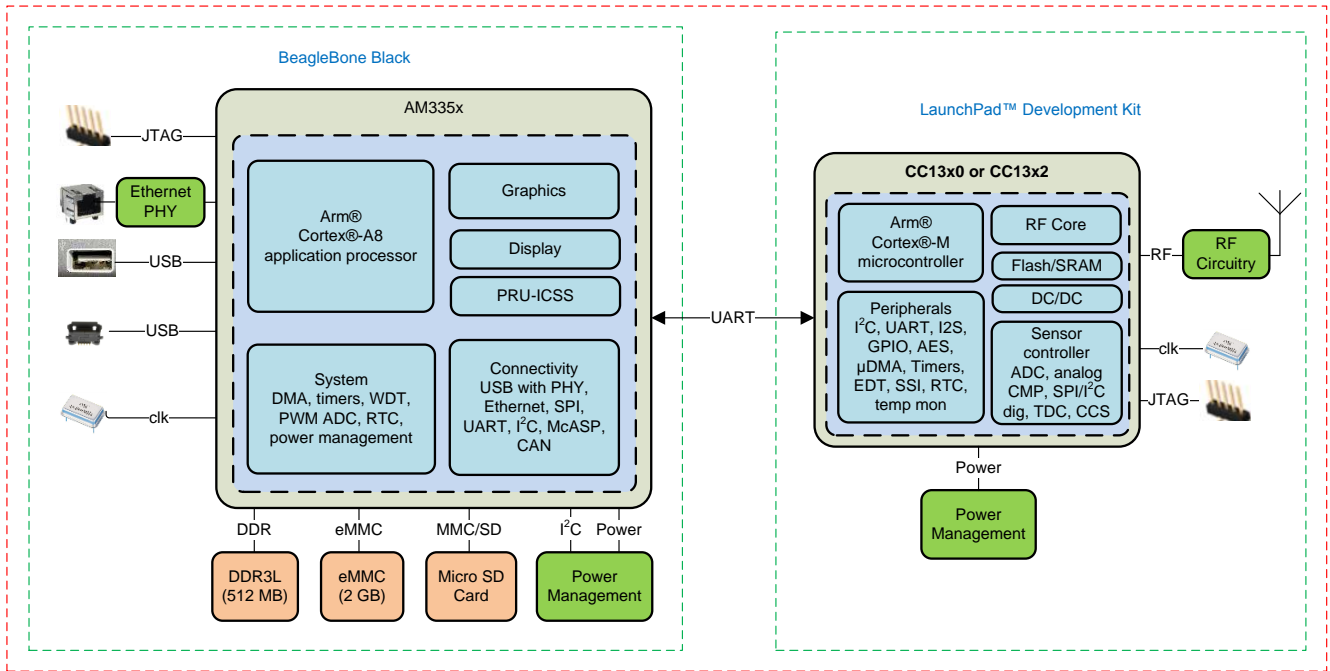
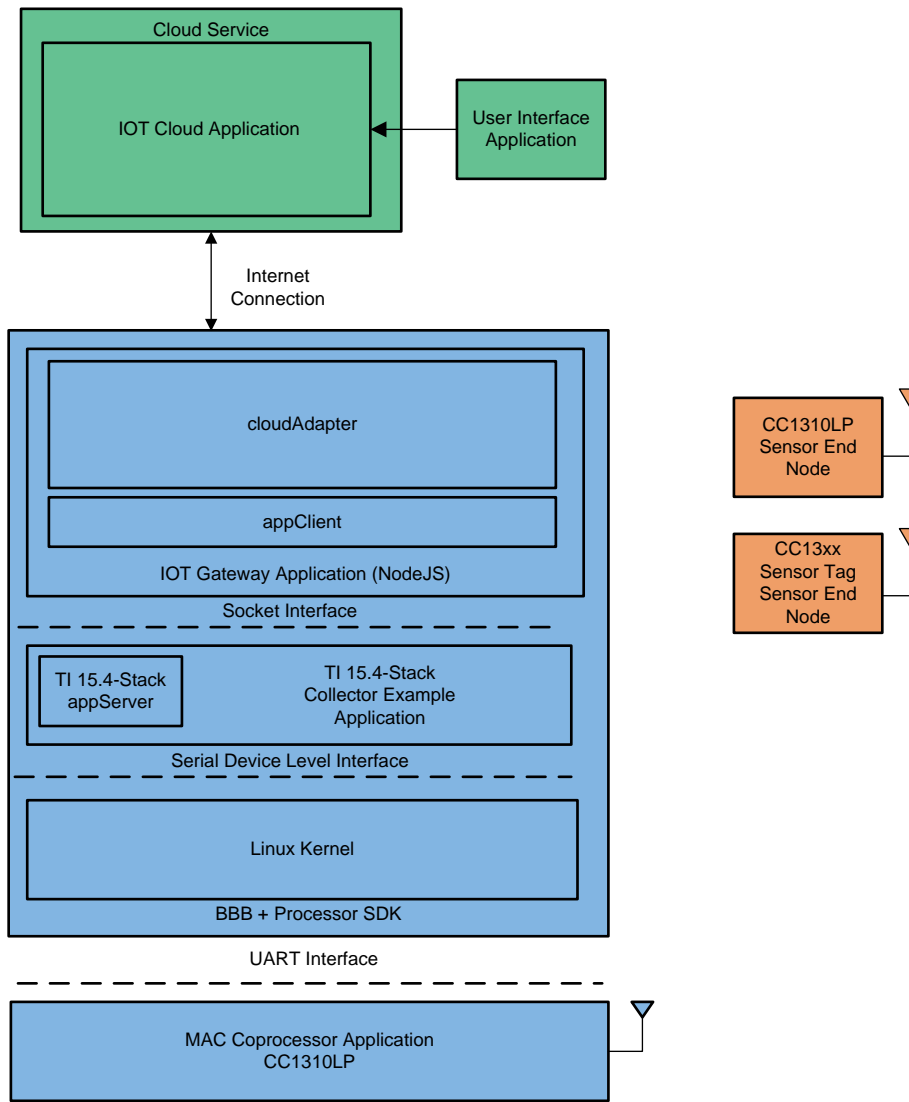


図 1. IoT Gateway Reference Design Block Diagram

### 2.1.1 Software Block Diagram



Copyright © 2016, Texas Instruments Incorporated

図 2. TI 15.4-Stack Sensor-to-Cloud Reference Design Software Block Diagram

The following is a high-level description of each module in the software block diagram:

- **User Interface Application:** This application presents the network information, device information, and provides ability to control network behavior to the end user.
- **IOT Cloud Application:** This application runs on the cloud, which communicates with the IoT gateway application. The interface of the IoT cloud application with the cloud server is described in [3.1.2.10](#) and [3.1.2.11](#).
- **IoT Gateway Application:** This application runs on the BeagleBone Black board. The application interfaces on one side with the cloud service to enable cloud connectivity and on the other side to the Linux collector application to interface with the TI 15.4-Stack based network. The interface between the IoT gateway and the cloud service is described in [3.1.2.10](#).
  - **cloudAdapter:** This application provides the cloud service provider specific functionality and is described in [3.1.2.11](#). Users can take the current interface, which is designed as an extensible framework, and quickly modify the interface to add their own functionality for their end product development.
  - **appClient:** This application interfaces with the Linux collector application over the socket interface to enable connection with the TI 15.4-Stack network. The interface is described in [3.1.2.9](#).
- **TI 15.4-Stack Linux Collector Example Application:** This application implements an example application that starts the network, allows new devices to join the network, configures the joining devices on how often to report the sensor data, configures how often to poll for buffered messages in case of non-beacon and frequency-hopping mode of network operation for sleepy network devices, and tracks connected devices to determine if they are active or inactive on the network. This determination is achieved by the collector periodically sending tracking request messages and awaiting corresponding tracking response messages.
  - **TI 15.4-Stack appServer:** The collector application also opens up a socket server to talk to the *iot-gateway* application. The interface between the collector application and the *iot-gateway* application is described in [3.1.2.9](#).
- **MAC CoP Application:** The MAC coprocessor application runs on the CC13x0 or CC13x1 LaunchPad™ Development Kit, which provides a UART-based interface from TI 15.4-Stack sensor to cloud IoT gateway SDK.
- **CC13xx LaunchPad Sensor End Node:** The sensor example application from TI 15.4-Stack and runs on the CC13x0 or CC13x2 LaunchPad Development Kit.
- **CC1350 SensorTag:** The CC1350 SensorTag runs the sensor example application ported from the TI 15.4-Stack out-of-box sensor example applications, which enable support of the CC1350 SensorTag platform and integrate support for various sensors on the SensorTag platform.

## 2.2 Highlighted Products

This section highlights key hardware devices and software components used in the reference design.

### 2.2.1 AM335x

The AM335x processors, based on the Arm® Cortex®-A8 core, are enhanced with image, graphics processing, peripherals, and industrial interface options, such as EtherCAT® and PROFIBUS®.

These devices support high-level operating systems (HLOS) such as Linux, which is available free of charge from TI. The AM335x processors contain the subsystems shown in [Figure 3](#). The microprocessor unit (MPU) subsystem is based on the Arm Cortex-A8 core and the PowerVR SGX™ graphics accelerator subsystem provides 3-D graphics acceleration to support display and gaming effects.

The PRU-ICSS is separate from the Arm core, which allows independent operation and clocking for greater efficiency and flexibility. The programmable real-time unit subsystem and industrial communication subsystem (PRU-ICSS) enables additional peripheral interfaces and real-time protocols such as EtherCAT, PROFINET®, EtherNet/IP®, PROFIBUS, Ethernet Powerlink®, Sercos®, and others.

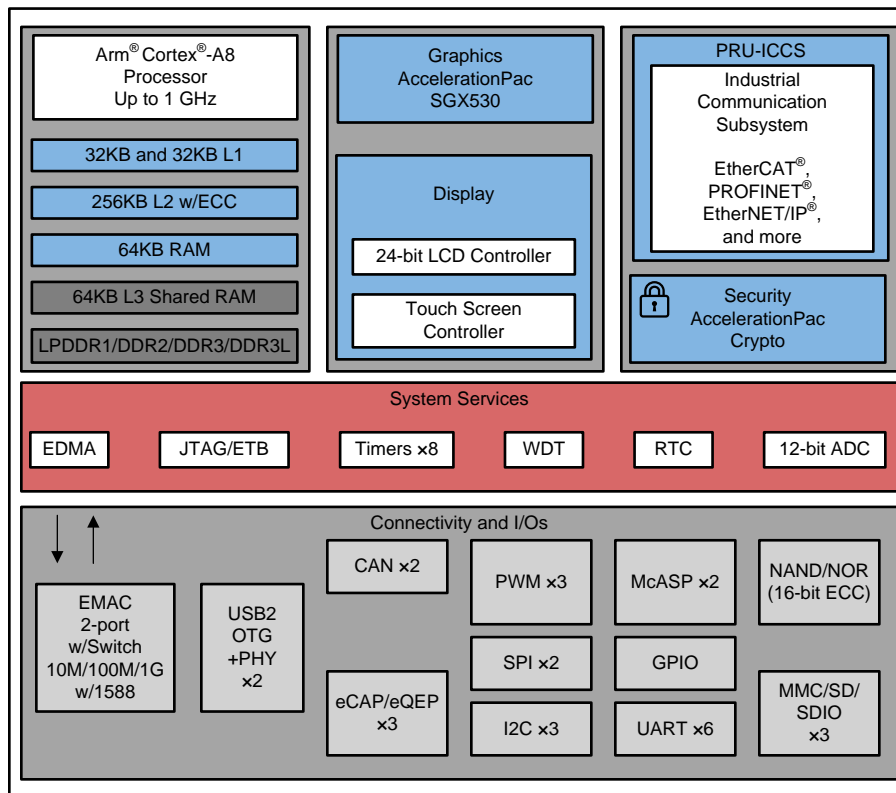


図 3. AM335x Block Diagram

Additionally, the programmable nature of the PRU-ICSS, along with its access to pins, events, and all system-on-chip (SoC) resources, provides flexibility in implementing fast, real-time responses, specialized data handling operations, custom peripheral interfaces, and in offloading tasks from the other processor cores of the SoC.

## 2.2.2 SimpleLink™ Ultra-Low-Power CC13x0 or CC13x2

The CC13x0 and CC13x2 are members of the CC26xx and CC13xx family of cost-effective, ultra-low-power, 2.4-GHz and Sub-1 GHz RF devices. Very-low active RF and microcontroller (MCU) current consumption, in addition to flexible low-power modes, provide excellent battery lifetime and allow long-range operation on small coin-cell batteries and in energy-harvesting applications.

The CC135x devices in the CC13xx and CC26xx family of cost-effective, ultra-low-power wireless MCUs are capable of handling both Sub-1 GHz and 2.4 GHz RF frequencies. The CC135x devices combines a flexible, very-low-power RF transceiver with a powerful 48-MHz Arm® Cortex®-M3 MCU (the CC13x2 has an even more powerful 48-MHz Arm Cortex-M4F MCU) in a platform supporting multiple physical layers and RF standards. A dedicated radio controller (Arm® Cortex®-M0) handles low-level RF protocol commands that are stored in ROM or RAM, thus, ensuring ultra-low power and flexibility to handle both Sub-1 GHz protocols and 2.4-GHz protocols [for example *Bluetooth*® low energy (BLE)]. This enables the combination of a Sub-1 GHz communication solution that offers the best possible RF range together with a BLE smartphone connection that enables great user experience through a phone application. The CC131x is the Sub-1 GHz-only device in this family.

The CC135x devices are highly-integrated, true single-chip solutions that incorporate a complete RF system and an on-chip DC/DC converter.

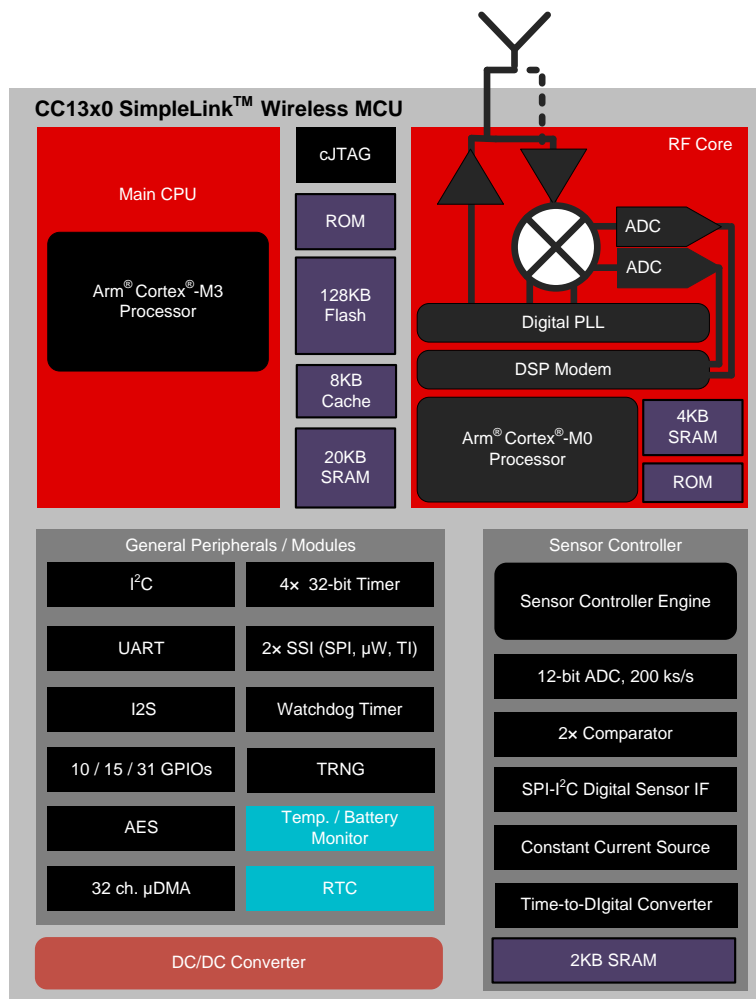


図 4. CC1350 Block Diagram

Sensors can be handled in a very low-power manner by a dedicated autonomous ultra-low-power MCU that can be configured to handle analog and digital sensors; thus, the main MCU (Arm Cortex-M3 or the Arm Cortex-M4F) can maximize sleep time.

### 2.2.3 TI 15.4-Stack

TI 15.4-Stack is an IEEE802.15.4e/g-based software stack part of the SimpleLink CC13x0 and CC13x2 SDK supporting a Star network topology for Sub-1 GHz applications. TI 15.4-Stack software runs on TI's SimpleLink Sub-1 GHz CC13x0 or CC13x2 wireless MCU. TI 15.4 Stack offers several key benefits such as longer range in FCC band and better protection against in-band interference by implementing frequency hopping. The SDK also provides customers an accelerated time to market with a complete end-to-end, node-to-gateway solution. TI 15.4-Stack is supported on the industry's lowest-power SimpleLink Sub-1 GHz wireless MCU platform.

This release is available royalty-free to customers using TI's CC13x0 or CC13x2 wireless MCU and also runs on TI's SimpleLink Sub-1 GHz CC13x0 or CC13x2 wireless MCU LaunchPad development kit.

Features:

- IEEE 802.15.4e/g standards-based solution
- Frequency hopping
- Medium access with CSMA/CA
- Built in acknowledgment and retries
- Network and device management (joining, commissioning, service discovery)
- Security feature through AES-128 encryption and integrity check
- Supported on SimpleLink Sub-1 GHz CC13x0 and CC13x2 wireless MCU
- Star topology: Point-to-point, one-to-many, and data concentrator
- Synchronous (beacon) and asynchronous (non-beacon) modes
- Designed for 915-MHz FCC, 863-MHz ETSI, and 433-MHz China bands
- SimpleLink long range mode for all supported frequency bands
- Support for SimpleLink CC1190
- Bluetooth low energy beacon advertisement support
- Sensor-to-web example application
- Easy application development guided through sample applications showcasing the stack configuration and APIs
- Coprocessor mode for adding connectivity to any MCU or MPU, with Linux host middleware and console application

For more details and to get the TI 15.4-Stack software, download the *SimpleLink CC13x0 SDK* [1], which includes the TI 15.4-Stack.



## 2.2.4 TI Processor Linux® SDK for AM335x

The TI processor SDK is a unified software platform for TI embedded processors, which provides easy setup and fast out-of-the-box access to benchmarks and demonstrations. All releases of the processor SDK are consistent across TI's broad portfolio, which allows developers to seamlessly reuse and migrate software across devices. Developing scalable platform solutions has never been easier with the processor SDK and TI's embedded processor solutions.

TI processor Linux SDK highlights:

- Long-term stable (LTS) mainline Linux kernel support
- U-Boot bootloader support
- Linaro GNU compiler collection (GCC) tool chains
- Yocto Project® OE Core compatible file systems

For more details and to get the processor SDK, see *AM335x Processor SDK* [2].

## 3 Hardware, Software, Testing Requirements and Test Results

### 3.1 Required Hardware and Software

This section provides details on required hardware and software to be able to run the out-of-box TI 15.4-Stack sensor-to-cloud reference design software application. Developers can then quickly use the out-of-box application as a framework to develop end products.

#### 3.1.1 Required Hardware

The following hardware is required to get the out-of-box application running and to develop applications:

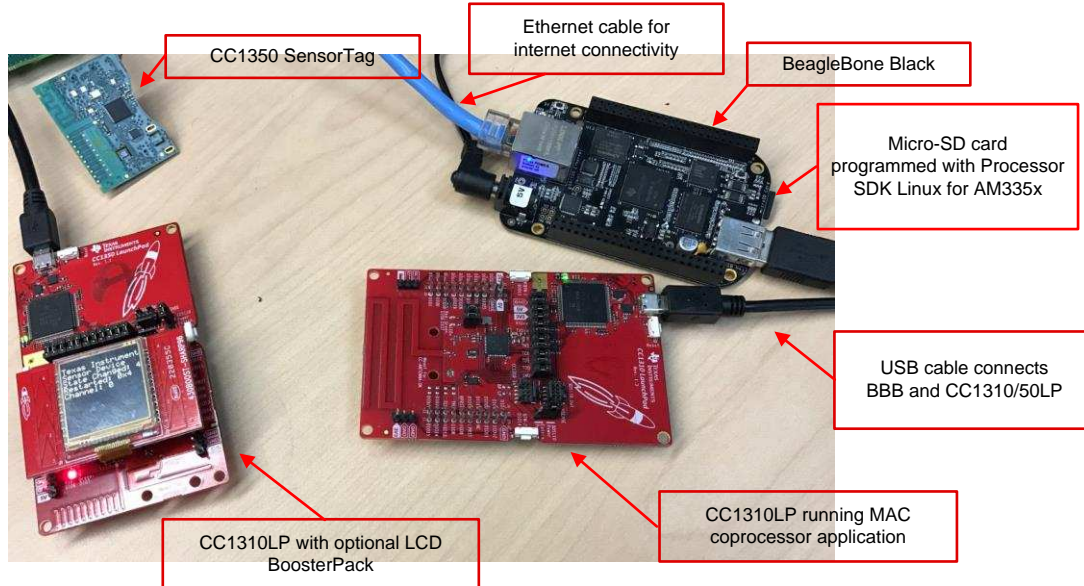
- A [CC13x0](#) or [CC13x2](#) LaunchPad Development Kit to run the MAC coprocessor application
- One or more [CC13x0](#) or [CC13x2](#) LaunchPad Development Kit or [CC1350 SensorTag](#) to run the TI 15.4-Stack sensor application to create one or more Sub-1 GHz network devices
- An AM335x-based [BeagleBone Black](#) board
- An 8-GB micro SD card (the TI processor SDK image requires at least 8 GB of space)
- A [5-V power supply for the BeagleBone Black](#)
- An Ethernet cable or [Wireless Cape](#) to connect the BeagleBone Black to the Internet
- A means to configure and set up the BeagleBone Black micro SD card (Windows® or Linux machine)
- A PC to host and run the web browser used to view the web application
- A standard Ethernet router required for internet connectivity to the BeagleBone Black and the host computer or tablet to view the web-application to monitor and control the sensor nodes in the network
- A USB cable to connect the BeagleBone Black with the [CC13x0](#) or [CC13x2](#) LaunchPad

---

注: The out-of-box application is demonstrated using a USB cable to connect the AM335x-based BeagleBone Black with the CC13x0 or CC13x2 LaunchPad. The reference design includes design files for a hardware adapter board that connects the BeagleBone Black with the CC131x0 or CC13x2 LaunchPad the way an end product should. The adapter board is not available for purchase but customers can either build their own using the design files provided, or they can jump straight to their own form factor design using the adapter board design files as a reference for how to connect the AM335x and CC13x0 or CC13x2 devices for an end product. When designing an end product, customers must also keep in mind that certificates must be stored in secure memory; therefore, a trusted platform module (TPM) or other means of having secure storage must be included in the end-product design.

---

☒ 5 shows the hardware setup to run the demonstration.



☒ 5. Demonstration Hardware Setup

### 3.1.2 Required Software

With the required hardware, perform the following steps to replicate the software portion of the demonstration:

1. Boot the Linux kernel and file system from the Linux Processor SDK on the BeagleBone Black.
2. Copy the provided Sub-1 GHz IoT gateway demonstration reference design software to the BeagleBone Black.
3. Program a CC13x0 or CC13x2 LaunchPad with the provided MAC coprocessor application.
4. Program the remaining CC13x0 or CC13x2 LaunchPad and CC1350 SensorTags with the provided sensor application.

The following sections in this chapter detail these instructions. For the purposes of this design guide, it is assumed that a Windows host machine is being used.

#### 3.1.2.1 BeagleBone Black SD Card

Program the SD card with the Linux processor SDK image using the following steps:

1. Download the prebuilt TI Linux processor SDK SD card image `am335x-evm-linux-xx.xx.xx.xx.img.zip` from [http://software-dl.ti.com/processor-sdk-linux/esd/AM335X/latest/index\\_FDS.html](http://software-dl.ti.com/processor-sdk-linux/esd/AM335X/latest/index_FDS.html) (where `xx.xx.xx.xx` is the version number of the latest Linux Processor SDK).
2. To program the micro SD memory card, see the instructions in *Processor SDK Linux Creating an SD Card with Windows* [4].

### 3.1.2.2 Booting BeagleBone Black

Boot the BeagleBone Black from the micro SD card using the following steps:

1. Disconnect power and unplug the USB cable from the BeagleBone Black board.
2. Insert the micro SD card into the BeagleBone Black (see [Figure 6](#)).
3. Press and hold the boot switch (S2).
  - Important: The boot switch is detected only at initial power on.
4. Provide power to the BeagleBone Black (1.5 A, 5 V).
5. Wait a few seconds then release the boot switch. In about 5 to 15 seconds, the LEDs begin to blink.

#### 3.1.2.2.1 Configuring BeagleBone Black With Wireless Connectivity Cape (Wi-Fi® Optional)

A few extra steps must be taken after booting the BeagleBone Black for the first time to enable use of the element14 Wireless Connectivity Cape.

1. Clone the Sensor To Cloud repository to the BeagleBone Black
2. On the BeagleBone run the `setup_beaglebone.sh` script. This script will prompt for various setting and configure the BeagleBone with the correct pins upon reboot. After reboot the BeagleBone broadcasts a Wi-Fi network (SSID and password are configured using the `setup_beaglebone` script). This step requires an active internet connection in order to download and install the required Node.js dependencies.
3. For more information on configuring the Wireless Cape can be found at [Using the WL18xx Cape with BeagleBone Black](#).

---

注: The first boot from a freshly-formatted SD card takes about one to two minutes longer. During this extended time, the BeagleBone Black Linux distribution performs some one-time-only steps.

---

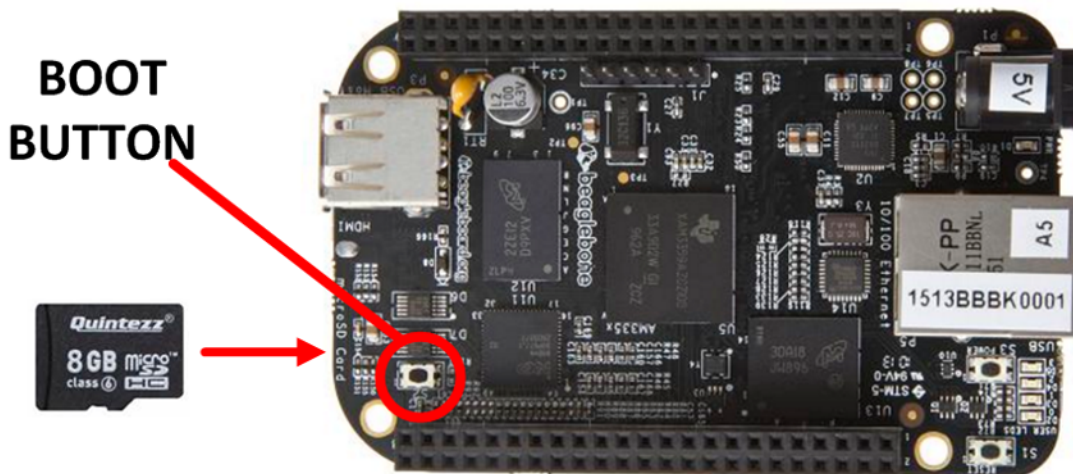


図 6. Boot BeagleBone Black From SD Card

### 3.1.2.3 Determining BeagleBone Black Network Address

In order to transfer files to the BeagleBone Black using its network interface, it is necessary to find its network address (IP address). There are two methods to determine the IP address of the BeagleBone Black:

- Method 1: Use the FTDI cable to connect through the serial header on the BeagleBone Black, and use the ifconfig command to determine the IP address allocated to the BeagleBone Black.

```
an335x-evm login: root
root@an335x-evm:~# ifconfig eth0
eth0      Link encap:Ethernet  HWaddr D8:39:72:18:44:4D
          inet addr:          Bcast:          Mask:255.255.255.0
          inet6 addr:          Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:842 errors:0 dropped:0 overruns:0 frame:0
          TX packets:12 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueue len:1000
          RX bytes:69103 (67.4 KiB) TX bytes:1552 (1.5 KiB)
          Interrupt:172
root@an335x-evm:~#
```

- Method 2: Most routers include a built-in web server to configure the device (see 表 1).
  - Connect the BeagleBone Black to the router.
  - Boot the BeagleBone Black.
  - Find the DHCP client page to determine the IP address of the BeagleBone Black. Some examples follow. The generic name for this feature is the DHCP client table.

注: Troubleshooting—the DHCP IP address is often determined by the order in which the devices boot. If the user's laptop booted first, it may receive address: xx.xx.xx.100. The BeagleBone Black boots second and receives the address: xx.xx.xx.101; however, on the next use or if another device is attached (for example, a cell phone or tablet), the resulting boot order may change, and therefore, the IP address might change.

表 1. Commercial Routers

BRAND	EXAMPLE LINK
LINKSYS™	<a href="http://www.linksys.com/us/support-article?articleNum=139502">http://www.linksys.com/us/support-article?articleNum=139502</a>
NETGEAR®	<a href="http://documentation.netgear.com/fvs336g/enu/202-10257-01/FVS336G_RM-11-07.html">http://documentation.netgear.com/fvs336g/enu/202-10257-01/FVS336G_RM-11-07.html</a>
BELKIN™	<a href="http://www.belkin.com/pyramid/AdvancedInfo/F5D8235-4/Advance/reserveIP.htm">http://www.belkin.com/pyramid/AdvancedInfo/F5D8235-4/Advance/reserveIP.htm</a>

### 3.1.2.4 Get Sub-1 GHz IoT Gateway Demonstration Software

The Sub-1 GHz sensor to cloud Industrial IoT gateway reference design demonstration software is located on a Git repository found at <https://git.ti.com/apps/tidep0084>. Clone the repository to the host machine and copy it over to the BeagleBone Black using secure copy (SCP). It is also possible to clone the repository directly on the BeagleBone Black.

- On the Windows® host machine:
  - cd C:\path\to\desired\clone\directory\
  - git clone git://git.ti.com/apps/tidep0084.git tidep0084
  - Use WinSCP, Tera Term, or FileZilla® to copy the tidep0084 directory to the BeagleBone Black using the network address found earlier.

### 3.1.2.5 Logging in to BeagleBone Black Using Secure Shell (SSH) Protocol

Putty or Tera Term can be used (along with the IP address found in [3.1.2.3](#)) to connect to the BeagleBone Black using SSH. The user name is *root*, and there is no password. Once connected, the root user will be logged into the board and the Linux console prompt will appear.

### 3.1.2.6 Programming CC13x0 or CC13x2 LaunchPad™ Development Kit

To run the example application users must first program one CC13x0 or CC13x2 LaunchPad Development Kit with the MAC CoP hex file and the other LaunchPad Development Kits with the sensor example application hex file. In this design guide, the UniFlash tool running on a Windows machine is used. Developers can also use the Serial Flash Programmer tool, described in the *CC13x0 SimpleLink TI 15.4-Stack 2.x.x Linux Developer's Guide* [5] to program the desired hex image onto the CC13x0 or CC13x2 LaunchPad Development Kit.

---

注: It is easy to confuse the sensor and CoP devices. Be sure to label the devices as they are programmed.

---

To program the LaunchPad Development Kit or SensorTag, follow these steps:

1. Download and install the [UniFlash Standalone Flash Tool for TI MCUs, Sitara™ Processors, and SimpleLink™ Devices](#).
2. Program CC13x0 or CC13x2 LaunchPad 1 – this device runs the CoP example application.
  - a. Label this device collector. The LCD BoosterPack Plug-in Module is not supported in the CoP application.
  - b. If using the CC13x0LP as MAC coprocessor: From a Windows PC, use UniFlash to program a CC13x0 LaunchPad MAC CoP with the coprocessor\_cc13x0\_lp.hex file located here:  
{demo software clone directory}/firmware/CC13x0\_LAUNCHXL/coprocessor\_cc13x0\_lp.hex
  - c. If using the CC13x2LP as MAC coprocessor: From a Windows PC, use UniFlash to program a CC13x2 LaunchPad MAC CoP with the coprocessor\_cc13x2\_lp.hex file located here:  
{demo software clone directory}/firmware/CC13x2\_LAUNCHXL/coprocessor\_cc13x2\_lp.hex
3. Program CC13x0 or CC13x2 LaunchPad 2 or SensorTag – this device runs the sensor example application.
  - a. Label this device sensor. Optional: connect the LCD BoosterPack Plug-in Module to this LaunchPad Development Kit.
  - b. To program the CC13x0 LaunchPad Development Kit: From a Windows PC, use UniFlash to program the hex file sensor\_cc13x0\_lp\_default\_915.hex file located here:  
{demo software clone directory}/firmware/CC13x0\_LAUNCHXL/sensor\_cc13x0\_lp\_default\_915.hex
  - c. To program the CC13x2 LaunchPad Development Kit: From a Windows PC, use UniFlash to program the hex file sensor\_cc13x2\_lp\_default\_915.hex file located here:  
{demo software clone directory}/firmware/CC13x2\_LAUNCHXL/sensor\_cc13x2\_lp\_default\_915.hex
  - d. To program CC1350 SensorTag: From a Windows PC, use UniFlash to program the hex file sensor\_cc1350stk\_915mhz.hex file located here:  
{demo software clone directory}/firmware/CC1350\_SensorTag/sensor\_cc1350stk\_915mhz.hex

---

注: Important—the default hex files are built for 915-MHz, 863-MHz, and 433-MHz bands of operation at 50 kbps. To rebuild the hex files for other bands (for example, SimpleLink Long Range mode), see the *CC13x0 SimpleLink TI 15.4-Stack 2.x.x Embedded Developer's Guide* [6] or *TI 15.4-Stack CC13x0 SimpleLink Embedded Applications Quick Start Guide* [7]. See the *CC13x0 SimpleLink TI 15.4-Stack 2.x.x Linux Developer's Guide* [5], specifically the Example Collector Application configuration section, to change the Linux example application.

To change the band of operation of the CoP, configure collector.cfg. For more information on configuring the CoP, refer to *CC13x0 SimpleLink TI 15.4-Stack 2.x.x Linux Developer's Guide* [5].

For porting the out-of-box TI 15.4-Stack sensor application, which is supported on the LaunchPad platform to the CC1350 SensorTag platform, see the *TI 15.4-Stack Wiki* [3].

---

### 3.1.2.7 Running the Demonstration

With the required hardware and software together, the demonstration can be completed. At this point, the following assumptions are made:

- The BeagleBone Black is booted from the SD card using the latest kernel and file system from the Linux processor SDK.
- The BeagleBone Black is powered up, and the user is logged in using SSH and can send commands on the Linux console.
- The Git repository containing the demonstration software was copied to the file system of the BeagleBone Black.
- The coprocessor LaunchPad Development Kit has been programmed with the coprocessor firmware.
- The remaining LaunchPad Development Kits and SensorTags have been programmed with the sensor example application.

If any of these assumptions are not true at this point, return to the previous corresponding sections in this chapter.

#### 3.1.2.7.1 Connecting CC13x0 or CC1350 LaunchPad™ Development Kit Coprocessor

Plug the CC13x0 or CC13x2 LaunchPad running tx2 coprocessor application into the BeagleBone Black using the USB cable. In [Figure 7](#), the USB connection on the right side of the image is connected to the CC13x0 or CC13x2 LaunchPad coprocessor.



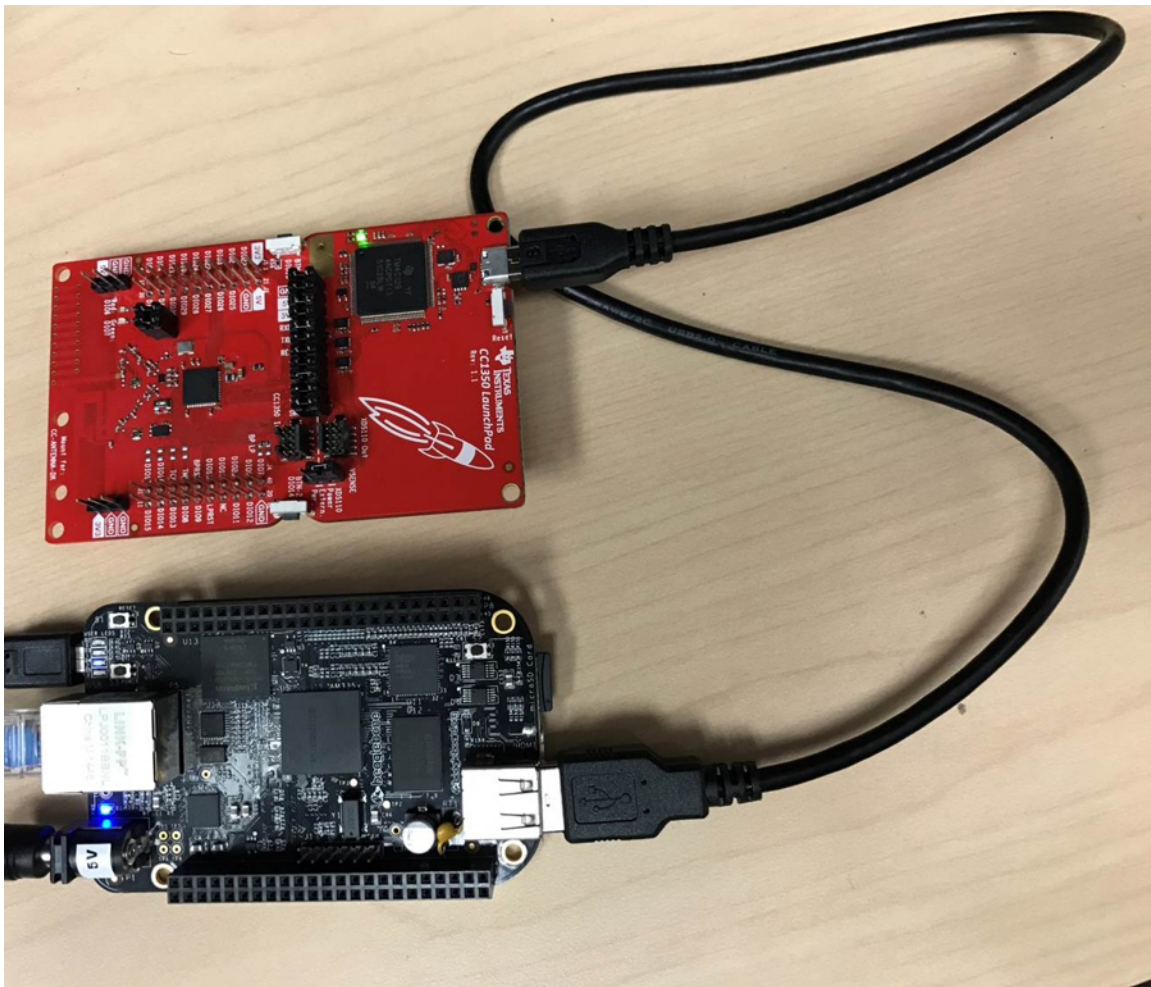


図 7. Coprocessor LaunchPad™ Development Kit Connected to BeagleBone Black

Once this connection is made, type

```
ls -l /dev/ttyACM*
```

at the BeagleBone Black console. There are two ttyACM devices that correspond to the serial ports from the CC13x0 or CC13x2 LaunchPad Development Kit (similar to [Figure 8](#)).

```
root@am437x-evm:~# ls -l /dev/ttyACM*
crw-rw----  1 root  dialout  166,  0 Oct 24 16:52 /dev/ttyACM0
crw-rw----  1 root  dialout  166,  1 Oct 24 16:52 /dev/ttyACM1
root@am437x-evm:~#
```

**Figure 8. /dev/ttyACM0 Device Check**

Make sure /dev/ttyACM0 shows up in the list. This is the UART connection between the BeagleBone Black and the CC13x0 or CC13x2 LaunchPad device over which all of the sensor and network information is transferred. Open the {demo software directory}/prebuilt/bin/collector.cfg file and double check that the [uart-cfg] section for the collector application is pointing to the correct device, as shown in [Figure 9](#).

```
[uart-cfg]
;; Launchpads use USB and show up as: /dev/ttyACM0 and ACM1
;; Solutions using an FTDI or Prolific cable use /dev/ttyUSB0 or USB1
;; Hard serial ports are: /dev/ttyS0 to ttyS9
;devname = /dev/ttyUSB1
devname = /dev/ttyACM0
baudrate = 115200
; we use the default flags
flag = default
```

**Figure 9. UART Configuration**

### 3.1.2.7.2 AWS Certificates and Configuration From stackArmor™

To connect the IoT Gateway to the AWS IoT service, the gateway needs authentication certificates provisioned by AWS. For these certificates, as well as a unique AWS URL, see the stackArmor web page[\[8\]](#). Return to this guide once obtaining the following:

- certificate.pem.crt
- private.pem.key
- public.pem.key
- root-CA.crt
- a URL to the AWS host that should be used

Use SCP to copy the four files into the {demo software directory}/example/iot-gateway/cloudAdapter/certs/ directory on the BeagleBone Black's file system.

Open the {demo software directory}/example/iot-gateway/cloudAdapter/awsConfig.json file and do the following:

- **certDir** - Make sure that the *certDir* parameter is set to the correct path to the certs directory where the four files were copied.
- **host** - Set the *host* parameter equal to the URL that was provided by stackArmor.
- **region** - Make sure that the *region* parameter matches the region portion of the URL. It should be something similar to *us-east-1*.
- **clientId** - The *clientId* parameter must be changed to a unique string. Only one connection to the AWS

cloud from a specific *clientId* is allowed. If the same *clientId* is used by more than one device connecting to the AWS cloud, connectivity issues can occur as the connection may timeout or be refused.

### 3.1.2.7.3 Starting the Application

The {demo software directory}/prebuilt/ directory has a simple shell script called *run\_demo.sh*. Type the following at the BeagleBone Black console to run the IoT Gateway application:

```
cd {demo software directory}/prebuilt/
```

```
chmod +x bin/bbb_collector
```

```
bash run_demo.sh
```

The shell script will start all of the necessary programs in order to get the full demonstration application up and running. The script will also print the URL to the IoT dashboard to the console. Navigate to the URL from the console output using the web browser on the host machine. If no arguments are provided to this script it will launch the default AWS IoT gateway; however, it is possible to use this script to launch AWS, IBM, IBM Quickstart, and Localhost gateways. To do this provide a single argument when executing the script specifying which gateway to launch. The argument should be one of the following: 'aws', 'ibm', 'quickstart', or 'localhost' (for example: 'bash run\_demo.sh localhost').

#### 3.1.2.7.3.1 Common Issues

The following is a list of common issues that might be seen while starting or running the application:

- **Error: Rcvd Error on the socket connection with AppServer (ECONNREFUSED 127.0.0.1:5000)**  
This error occurs when the AppClient (which is started by the IoT Gateway) is not able to make a local socket connection with the AppServer (which is started by the *bbb\_collector*). Make sure that the *bbb\_collector* application is up and running before starting the IoT Gateway. The *run\_demo.sh* script in the prebuilt directory gives an example on how to start the demonstration in the correct order. This script starts up the *bbb\_collector* application and then starts the IoT Gateway.
- **Error: getaddrinfo ENOTFOUND <your unique AWS URL> (AWS Cloud Adapter error)**  
This error can happen if the BeagleBone Black is behind a firewall and cannot connect to the servers at the AWS URL. This issue can be resolved by using a mobile hotspot to connect the BeagleBone Black to the Internet or possibly by configuring the local network settings to allow the BeagleBone Black to access outside servers.
- **Error: certificate is not yet valid (AWS Cloud Adapter error)**  
This issue can occur if the date and time on the BeagleBone Black are set incorrectly to a time before the AWS certificates were generated by stackArmor. Setting the date of the BeagleBone Black to the current date and time should resolve this issue.
- **Removing Sensor Nodes from the Sub-1 GHz Wireless Network**  
The current demonstration does not provide a method in the user interface to remove sensor nodes from the Sub-1 GHz wireless network. The *bbb\_collector* application uses a file named *nv-simulation.bin* (that can be found in the *prebuilt/bin/* directory) to save the information of the sensor nodes that have connected to the Sub-1 GHz wireless network. Delete the *nv-simulation.bin* file and restart the demonstration in order to remove sensor nodes. This process also means the remaining sensor nodes must reconnect to the Sub-1 GHz wireless network before they will show up in the user interface again.

- **Error: Cannot find module *moduleName* (or any other Node-JS error)**

Cloning the TIDEP0084 Git repository to a Windows machine and then copying it to the BeagleBone Black might produce Node-JS errors when starting the demonstration. These errors appear to be caused by the line endings in the repository getting changed by Windows before being copied to the BeagleBone Black. To correct this issue, the TIDEP0084 Git repository can be cloned directly to the BeagleBone Black. To accomplish this, make sure your BeagleBone Black has an internet connection and then run the following command from the terminal:

```
git clone git://git.ti.com/apps/tidep0084.git.
```

### 3.1.2.7.4 IoT Dashboard Web Page—Open Network for New Device Joins

Figure 10 shows the IoT dashboard provided by stackArmor. Navigate to the dashboard by following the URL provided by the console output in the previous step. Initially, the application starts with no devices present (not shown), the network is closed to new devices joining (not shown), and the network will not accept new devices.

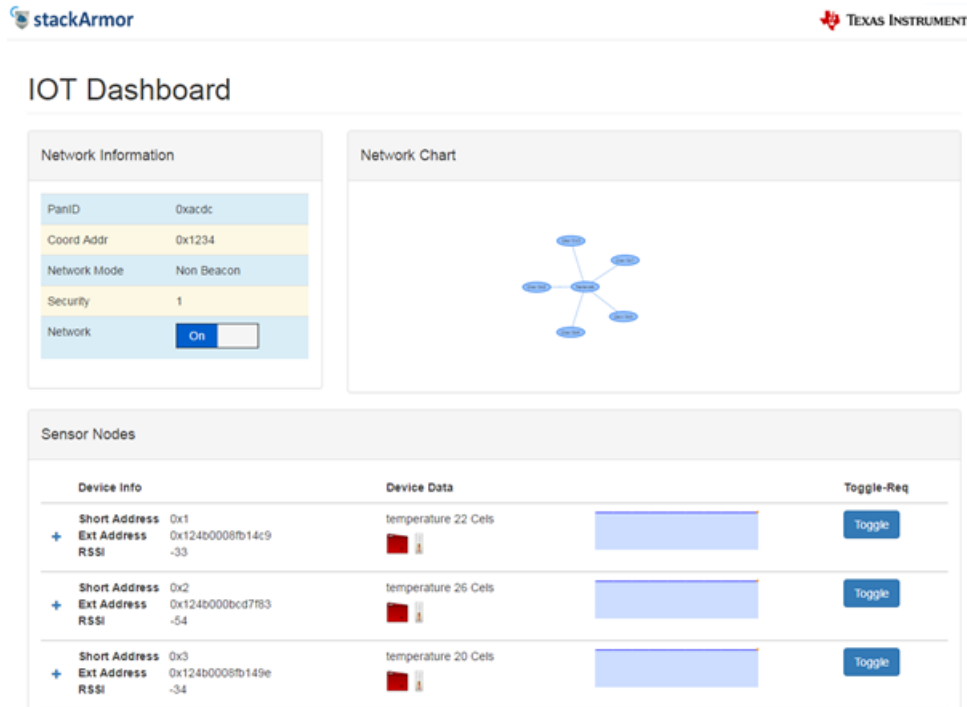


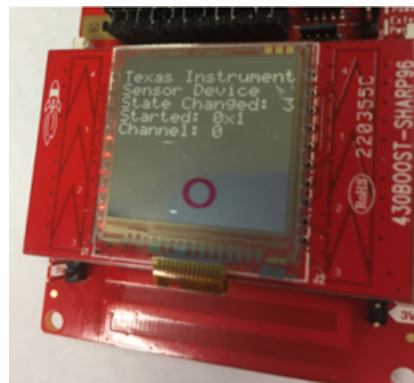
Figure 10. IoT Dashboard

### 3.1.2.7.5 Joining the Sensor Devices to the Network

At start up, the collector example application initially has the network closed; therefore, sensor devices cannot join. To open the network, switch the *On/Off* button on the web browser to the *On* state. Within a few seconds (time depends on the polling interval and other configuration settings), the sensor joins the network. When the device joins the network, the red LED turns on. If the sensor LaunchPad Development Kit has an LCD module, the device indicates the current state on the LCD. See [Figure 11](#).

- State 1 = Not joined
- State 3 = Joined
- State 4 = Restored
- State 5 = Orphan condition

More details can be found in the *CC13x0 SimpleLink TI 15.4-Stack 2.x.x Embedded Developer's Guide* [\[6\]](#).



**Figure 11. Sensor LaunchPad™ Development Kit State Change LCD**

### 3.1.2.7.6 Data Communication

After the new device appears, initially only the short and extended addresses appear. The data fields will not show any data as none have been reported yet.

Sensor Data Reports:

After about one minute data appears on the screen (the exact interval is configured in the collector application using a `#define` value), see the *CC13x0 SimpleLink TI 15.4-Stack 2.x.x Embedded Developer's Guide* [\[6\]](#) or the Linux example collector source code for more details. After this time, the sensor nodes periodically report the sensor data.

Actuation:

Clicking on the toggle LED button sends a message to the sensor module to toggle the LED. There may be a slight delay (a few seconds) in toggle operation on the desired sensor LaunchPad Development Kit. This delay is because the sensor nodes are in sleep mode and only wake up periodically to get the command buffered on the collector.

See [Figure 10](#) for an example of the IoT dashboard with multiple sensors and reported data.

### 3.1.2.8 Interactive GUI

TI's Sensor-to-Cloud design now includes a web interface that can be used to setup, connect to a network, and launch a cloud connected gateway. Wireless functionality is enabled with the use of element14 wireless cape, which allows the user to easily get a gateway up and running without knowing Linux, networking, or terminal commands. Refer to the *TI 15.4-Stack CC13x0 SimpleLink Embedded Applications Quick Start Guide [7]* for more information on getting started with the Sensor-to-Cloud web interface.

### 3.1.2.9 IoT-Gateway and Collector Application Interface API

The purpose of this section is to provide a description of the application programming interface between the TI 15.4-Stack Linux collector example application and the IoT gateway application. The collector example application implements an `appsrv` module, which opens up a server socket to which a client application can connect. The interface allows management and data interface to the client application, connecting to the socket server, to monitor and control the TI 15.4-Stack-based network. Management functionalities include the ability to open and close the network for new device joins, whereas the data interface allows sending and receiving data to and from the network devices. It is easy to add new APIs or modify the current implementation.

This API is defined at a specific interface level, which is a TCP socket pipe.

For transport using a TCP socket, the packets are preceded by a 4-byte header, containing the following fields (in this order):

1. **len** – 16-bit number that specifies the actual length (in bytes) of the protobuf-packed packet
2. **Subsystem** – 1 byte: specifies the subsystem to or from which the packet is sent or received. The value '10' is reserved for TI 15.4-Stack application server interface.
3. **cmd\_id** – 1 byte: The command ID of the actual command being sent. This value is also available inside the packed packet. The actual command ID numbers are provided in the protobuf definition files that are part of the TI 15.4-Stack Linux SDK (collector example application and the gateway example application). When using command IDs in code, always use the defined names (never hardcode the command ID numbers), as the numbers may change between releases.

#### 3.1.2.9.1 Management Interface

##### 3.1.2.9.1.1 APPSRV\_SET\_JOIN\_PERMIT\_REQ

##### 3.1.2.9.1.1.1 Description

Allows client application to enable or disable network for join for new devices.

##### 3.1.2.9.1.1.2 Parameter List

**表 2. APPSRV\_SET\_JOIN\_PERMIT\_REQ Parameter List**

PARAMETER	TYPE	DESCRIPTION
Duration	INT32	Duration for join permit to be turned on in milliseconds: <ul style="list-style-type: none"> <li>• 0 sets the join permit pff, and 0xFFFFFFFF sets the join permit on indefinitely.</li> <li>• Any other non-zero value sets the join permit on for that duration.</li> </ul>

### 3.1.2.9.1.2 APPSRV\_SET\_JOIN\_PERMIT\_CNF

#### 3.1.2.9.1.2.1 Description

The application server notifies the client of the result of processing of permit join request message.

#### 3.1.2.9.1.2.2 Parameter List

表 3. APPSRV\_SET\_JOIN\_PERMIT\_CNF Parameter List

PARAMETER	TYPE	DESCRIPTION
Status	INT32	0 if success

### 3.1.2.9.1.3 APPSRV\_NWK\_INFO\_IND

#### 3.1.2.9.1.3.1 Description

The application server notifies the client of the network information when a network is formed using this API.

#### 3.1.2.9.1.3.2 Parameter List

表 4. APPSRV\_NWK\_INFO\_IND Parameter List

PARAMETER	TYPE	DESCRIPTION	
Fh	UINT32	True if network is frequency hopping	
channel	UINT32	Channel number used, if non-frequency hopping network configuration	
panID	UINT32	The 16-bit PAN identifier of the network	
shortAddress	UINT32	The 16-bit short address of the PAN coordinator	
extAddress	INT64	The 64-bit IEEE extended address of the PAN coordinator device	
securityEnabled	INT32	<i>true</i> if security enabled, <i>false</i> otherwise	
nwkMode	ENUM	Network operation mode BEACON_ENABLED = 1 NON_BEACON = 2 FREQUENCY_HOPPING = 3	
state	ENUM	PAN coordinator state values	
		<b>STATE</b>	<b>VALUE</b>
		Initialized waiting for user to start	1
		Starting coordinator	2
		Restoring coordinator (from NV)	3
		Started	4
		Restored	5
		Joining allowed for new devices	6
Joining not allowed for new devices	7		

### 3.1.2.9.1.4 APPSRV\_GET\_NWK\_INFO\_REQ

#### 3.1.2.9.1.4.1 Description

The application server's client can use this API to get the current network information



### 3.1.2.9.1.4.2 Parameter List

There is no parameter in the command message.

### 3.1.2.9.1.5 APPSRV\_GET\_NWK\_INFO\_CNF

#### 3.1.2.9.1.5.1 Description

The application server sends the current network information as a response to the get network information request from the client using this API.

#### 3.1.2.9.1.5.2 Parameter List

表 5. APPSRV\_GET\_NWK\_INFO\_CNF Parameter List

PARAMETER	TYPE	DESCRIPTION	
Status	INT32	0 if success	
Fh	UINT32	True if network is frequency hopping (optional)	
channel	UINT32	Channel number used, if non-frequency hopping network configuration (optional)	
panID	UINT32	The 16-bit PAN identifier of the network (optional)	
shortAddress	UINT32	The 16-bit short address of the PAN coordinator (optional)	
extAddress	INT64	The 64-bit IEEE extended address of the PAN coordinator device (optional)	
securityEnabled	INT32	<i>true</i> if security enabled, <i>false</i> otherwise (optional)	
nwkMode	ENUM	Network operation mode (optional) BEACON_ENABLED = 1 NON_BEACON = 2 FREQUENCY_HOPPING = 3	
state	ENUM	PAN coordinator state values (optional)	
		<b>STATE</b>	<b>VALUE</b>
		Initialized waiting for user to start	1
		Starting coordinator	2
		Restoring coordinator (from NV)	3
		Started	4
		Restored	5
		Joining allowed for new devices	6
Joining not allowed for new devices	7		

### 3.1.2.9.1.6 APPSRV\_GET\_DEVICE\_ARRAY\_REQ

#### 3.1.2.9.1.6.1 Description

The application client requests the current list of connected device using this API.

#### 3.1.2.9.1.6.2 Parameter List

There is no parameter in the command message.

### 3.1.2.9.1.7 APPSRV\_GET\_DEVICE\_ARRAY\_CNF

#### 3.1.2.9.1.7.1 Description

The application server sends the current list of connected device as a response to the get device array request message using this API.

#### 3.1.2.9.1.7.2 Parameter List

表 6. APPSRV\_GET\_DEVICE\_ARRAY\_CNF Parameter List

PARAMETER	TYPE	DESCRIPTION
Status	INT32	0 if success
devInfo	Csf_deviceInformation	Multiple entries of this structure element. Number of entries is equal to the number of connected devices in the network.
panID	UINT32	The 16-bit PAN identifier of the network
shortAddress	UINT32	The 16-bit short address of the network device
extAddress	INT64	The 64-bit IEEE extended address of the network device
panCoord	UINT32	True if the device is PAN coordinator
ffd	UINT32	True if the device is a full function device
mainsPower	UINT32	True if the device is mains powered
rxOnWhenIdle	UINT32	True if the device's RX is on when the device is idle
security	UINT32	True if the device is capable of sending and receiving secured frames
allocAddr	UINT32	True if allocation of a short address in the associate procedure is needed.

### 3.1.2.9.1.8 APPSRV\_DEVICE\_JOINED\_IND

#### 3.1.2.9.1.8.1 Description

The application server informs the client of a new device join in the network using this API.

#### 3.1.2.9.1.8.2 Parameter List

表 7. APPSRV\_DEVICE\_JOINED\_IND Parameter List

PARAMETER	TYPE	DESCRIPTION
panID	UINT32	The 16-bit PAN identifier of the network
shortAddress	UINT32	The 16-bit short address of the network device
extAddress	INT64	The 64-bit IEEE extended address of the network device
panCoord	UINT32	True if the device is PAN coordinator
ffd	UINT32	True if the device is a full function device
mainsPower	UINT32	True if the device is mains powered
rxOnWhenIdle	UINT32	True if the device's RX is on when the device is idle
security	UINT32	True if the device is capable of sending and receiving secured frames
allocAddr	UINT32	True if allocation of a short address in the associate procedure is needed.

### 3.1.2.9.1.9 APPSRV\_DEVICE\_NOTACTIVE\_UPDATE\_IND

#### 3.1.2.9.1.9.1 Description

The application server informs the client of an inactive device using this API.

#### 3.1.2.9.1.9.2 Parameter List

**表 8. APPSRV\_DEVICE\_NOTACTIVE\_UPDATE\_IND Parameter List**

PARAMETER	TYPE	DESCRIPTION
panID	UINT32	The 16-bit PAN identifier of the network
shortAddress	UINT32	The 16-bit short address of the network device
extAddress	INT64	The 64-bit IEEE extended address of the network device
timeout	UINT32	True if not active because of tracking timeout, meaning that the device didn't respond to the tracking request within the timeout period.

### 3.1.2.9.1.10 APPSRV\_COLLECTOR\_STATE\_CNG\_IND

#### 3.1.2.9.1.10.1 Description

The application server informs the client of change in the state of the collector application using this API.

#### 3.1.2.9.1.10.2 Parameter List

**表 9. APPSRV\_COLLECTOR\_STATE\_CNG\_IND Parameter List**

PARAMETER	TYPE	DESCRIPTION	
		STATE	VALUE
state	ENUM	Initialized waiting for user to start	1
		Starting coordinator	2
		Restoring coordinator (from NV)	3
		Started	4
		Restored	5
		Joining allowed for new devices	6
		Joining not allowed for new devices	7

### 3.1.2.9.2 Data Interface

#### 3.1.2.9.2.1 APPSRV\_DEVICE\_DATA\_RX\_IND

##### 3.1.2.9.2.1.1 Description

The application server informs the client of receipt of sensor data from a network device using this API.

##### 3.1.2.9.2.1.2 Parameter List

表 10. APPSRV\_DEVICE\_DATA\_RX\_IND Parameter List

PARAMETER	TYPE	DESCRIPTION
srcAddr	UINT32	The 16-bit PAN identifier of the network
Rssi	SINT32	RSSI of the message received
sDataMsg	Smsgs_sensorMsg	Received sensor message (optional)
sConfigMsg	Smsgs_configRspMsg	Received config response message (optional)

表 11. Smsgs\_sensorMsg

PARAMETER	TYPE	DESCRIPTION		
cmdld	ENUM	Sensor message command ID		
		COMMAND ID	DESCRIPTION	VALUE
		Smsgs_cmdlds_configReq	Configuration message, sent from the collector to the sensor	1
		Smsgs_cmdlds_configRsp	Configuration response message, sent from the sensor to the collector	2
		Smsgs_cmdlds_trackingReq	Tracking request message, sent from the collector to the sensor	3
		Smsgs_cmdlds_trackingRsp	Tracking response message, sent from the sensor to the collector	4
		Smsgs_cmdlds_sensorData	Sensor data message, sent from the sensor to the collector	5
		Smsgs_cmdlds_toggleLedReq	Toggle LED message, sent from the collector to the sensor	6
		Smsgs_cmdlds_toggleLedRsp	Smsgs_cmdlds_toggleLedRsp	7
Framecontrol	UINT32	Frame control field states what data fields are included in reported sensor data, each value is a bit mask value so that they can be combined (OR'd together) in a control field. When sent over-the-air in a message this field is 2 bytes.		
		PARAMETER	DESCRIPTION	VALUE
		Smsgs_dataFields_tempSensor	Bit mask for temperature sensor	0x0001
		Smsgs_dataFields_lightSensor	Bit mask for light sensor	0x0002
		Smsgs_dataFields_humiditySensor or	Bit mask for humidity sensor	0x0004
		Smsgs_dataFields_msgStats	Bit mask for stats message	0x0008
		Smsgs_dataFields_configSettings	Bit mask for configuration settings	0x0010
		Smsgs_dataFields_pressureSensor or	Bit mask for pressure sensor	0x0020
Smsgs_dataFields_toggleSettings	Bit mask for toggle settings	0x0030		

**表 11. Smsgs\_sensorMsg (continued)**

PARAMETER	TYPE	DESCRIPTION		
tempSensor	Smsgs_tempSensorField	Lists the reported temperature sensor data (optional) Smsgs_tempSensorField:		
		PARAMETER	TYPE	DESCRIPTION
		ambienceTemp	UINT32	Ambience chip temperature - each value represents a 0.01° C, so a value of 2475 represents 24.75° C.
		objectTemp	UINT32	Object temperature - each value represents a 0.01° C, so a value of 2475 represents 24.75° C.
lightSensor	Smsgs_lightSensorField	Lists the reported light sensor data (optional) Smsgs_lightSensorField:		
		PARAMETER	TYPE	DESCRIPTION
		rawData	UINT32	Raw sensor data read out of the OPT2001 light sensor
humiditySensor	Smsgs_humiditySensorField	Lists the reported humidity sensor data (optional) Smsgs_humiditySensorField:		
		PARAMETER	TYPE	DESCRIPTION
		temp	UINT32	Raw temperature sensor data
		humidity	UINT32	Raw humidity sensor data
configSettings	Smsgs_configSettingsField	Lists the reported configuration settings (optional) Smsgs_configSettingsField:		
		PARAMETER	TYPE	DESCRIPTION
		reportingInterval	UINT32	Reporting interval - in milliseconds, how often to report sensor data to the pan-coordinator, 0 means reporting is off
		pollingInterval	UINT32	Polling interval - in milliseconds (32 bits) - If the sensor device is a sleep device, this states how often the device polls its parent for data. This field is 0 if the device does not sleep.
pressureSensor	Smsgs_pressureSensorField	Lists the reported pressure sensor data (optional) Smsgs_pressureSensorField:		
		PARAMETER	TYPE	DESCRIPTION
		tempValue	UINT32	Temperature value
		pressureValue	UINT32	Pressure value

表 12. Smsgs\_configRspMsg

PARAMETER	TYPE	DESCRIPTION
cmdId	Smsgs_cmdIds	Sensor message command ID
Status	Smsgs_statusValues	Status of the processing of the request message
Framecontrol	Smsgs_dataFields	Bit mask of Smsgs_dataFields
treportingInterval	UINT32	Sensor data reporting interval
pollingInterval	UINT32	Polling interval if the device is a sleepy device

### 3.1.2.9.2.2 APPSRV\_TX\_DATA\_REQ

#### 3.1.2.9.2.2.1 Description

The application client uses this to send data to a network device.

#### 3.1.2.9.2.2.2 Parameter List

表 13. APPSRV\_TX\_DATA\_REQ Parameter List

PARAMETER	TYPE	DESCRIPTION		
msgId	Smsgs_cmdIds	Sensor message command ID		
panID	UINT32	The 16-bit PAN identifier of the network		
shortAddress	UINT32	The 16-bit short address of the network device		
extAddress	INT64	The 64-bit IEEE extended address of the network device		
configReqMsg	Smsgs_configReqMsg	Configuration request message parameters (optional)		
		PARAMETER	TYPE	DESCRIPTION
		cmdId	Smsgs_cmdIds	The value will be <i>Smsgs_cmdIds_configReq</i> (= 1).
		frameControl	UINT32	Frame control field states what data fields are included in reported sensor data, each value is a bit mask value so that they can be combined (OR'd together) in a control field. When sent over the air in a message this field is 2 bytes.
		reportingInterval	UINT32	Sensor data reporting interval
		pollingInterval	UINT32	Polling interval if the device is a sleepy device
toggleLedReq	Smsgs_toggleLedReqMsg	Toggle led request message parameters (optional)		

### 3.1.2.9.2.3 APPSRV\_TX\_DATA\_CNF

#### 3.1.2.9.2.3.1 Description

The application server informs the client of result of the transmit data request

#### 3.1.2.9.2.3.2 Parameter List

表 14. APPSRV\_TX\_DATA\_CNF Parameter List

PARAMETER	TYPE	DESCRIPTION
Status	INT32	0 if success

### 3.1.2.10 TI IoT Gateway-to-Cloud Interface

The purpose of this section is to provide a description of the message types and expected data flows that will be shared between the TI IoT gateway and an IoT cloud server. The interface is designed to be flexible to support multiple cloud vendors. For this purpose, the Sub-1 GHz wireless network and node information will be exchanged between the gateway and the cloud using the long-established JavaScript object notation (JSON) format. Additionally, IPSO alliance smart object definitions will be used to define sensors (and their data) that are connected to each node in the wireless networks.

#### 3.1.2.10.1 Message Types

To fully specify the Sub-1 GHz wireless network information, as well as the Sub-1 GHz sensors and their data, two distinct message types have been defined for the IoT gateway to update the cloud. In order to allow the cloud to send messages back to the TI IoT gateway, two additional message types are defined that allow the cloud to update the wireless network state and also send actuation messages to specific devices in the network.

##### 3.1.2.10.1.1 Network Information Message Type (From TI IoT Gateway to Cloud)

This message type presents information about the wireless network, its current state, and a list of devices that are connected to the network. As shown later in this document, this will be the first message type sent after the network is initialized, and it contains all the information necessary to prepare for receiving sensor data from devices. This message type contains the following fields:

- **name:** begins as the short address of the network but allows for the cloud to provide a more specific name
- **channels:** list of channels that the wireless network is operating on
- **pan\_id:** the 16-bit PAN identifier of the network
- **short\_addr:** the 16-bit short address of the pan-coordinator
- **ext\_addr:** the 64-bit IEEE extended address of the pan-coordinator device
- **security\_enabled:** *yes* if security enabled, *no* otherwise
- **mode:** network operation mode (beacon, non-beacon, frequency hopping)
- **state:** PAN coordinator state values (waiting, starting, restoring, started, open, closed)
- **devices:** list of wireless nodes in the network
  - **name:** begins as the short address of the device but allows cloud to update
  - **active:** whether or not the wireless node is active
  - **rsi:** received signal strength indicator of the last message received
  - **last\_reported:** timestamp of the last message received
  - **short\_addr:** the 16-bit short address of the pan-coordinator
  - **ext\_addr:** the 64-bit IEEE extended address of the PAN coordinator device
  - **topic:** the topic that the device will send its sensor data updates to
  - **smart\_objects:** list of IPSO alliance smart objects (sensors) attached to this device
    - **object ID description:** type of sensor (as defined in the IPSO standard); can be multiple types of sensors connected to each device ('temperature' for example)
    - **instance ID:** the instance ID for the parent object type; can be multiple sensors of the same



type (is usually '0' and counts up with each instance added

- **resource ID description list:** sensor data name value pairs (for example, *sensorValue*: 32.5, *units:Celsius*, *dInState: true*, and so forth); these resources match what is specified for the given object ID in the IPSO standard

### 3.1.2.10.1.2 Device Information Message Type (From TI IoT Gateway to Cloud)

This message type provides information about the wireless device as well as the latest data for all of the sensors connected to the device. This message type will be sent when a device reports sensor data or switches between an active or inactive state. The following fields are contained in this message type:

- **active:** whether or not the wireless node is active
- **short\_addr:** the 16-bit short address of the device
- **ext\_addr:** the 64-bit IEEE extended address of the PAN coordinator device
- **rssi:** received signal strength indicator of the last message received
- **last\_reported:** timestamp of the last message received
- **smart\_objects:** list of the IPSO alliance smart objects connected to this wireless device
  - **object ID description:** type of sensor (as defined in the IPSO standard); can be multiple types of sensors connected to each device
    - **instance ID:** the instance ID for the parent object type; can be multiple sensors of the same type
    - **resource ID description list:** sensor data name value pairs (for example, *sensorValue: 32.5, units:Celsius*, and so forth); these resources match what is specified for the given object ID in the IPSO standard

### 3.1.2.10.1.3 Update Network State Message Type (From Cloud to TI IoT Gateway)

In the current implementation of the TI IoT gateway, this message type is intended to be able to open or close the wireless network to new devices joining. The cloud's front end user interface can allow a user to click a button to open or close the network and then generate this message type and send it to the TI IoT gateway. The gateway will then notify the network on whether it needs to open or close to new device joins. This message type only includes the desired state of the network and should be sent to the same topic that the cloud is receiving the network information messages from. The following field is all that is required:

- **state:** should be set to either *open* or *closed*

### 3.1.2.10.1.4 Device Actuation Message Type (From Cloud to TI IoT Gateway)

This message type is added to allow the cloud to send actuation messages to specific devices in the wireless network. The current implementation only supports toggling an LED on the wireless device's board. The device actuation message should be sent to the topic of the device as given in the devices list of the network information message. The following field is the only requirement for this message:

- **toggleLED:** should be set to *true*

### 3.1.2.10.2 Data Flows

This section of the document specifies the expected data flow when different events occur within the wireless network and also when the cloud must send configuration or commands to the TI IoT gateway.

### 3.1.2.10.2.1 Network Information Sent to the Cloud

The following items are the list of events that can occur on the TI IoT gateway that will cause a network information message type to be sent to the cloud. A description is given with each event, and the end of this section describes the expected behavior from the cloud upon receipt of this type of message.

- **Network Startup**

This is the initial event in the TI IoT gateway. The TI IoT gateway will aggregate the information about the wireless network as well as the list of connected devices and their sensor types. The TI IoT gateway will then make a connection to the cloud and will send the aggregated data encapsulated in the network information message type.

- **Network Information Update**

This event can occur if any of the information about the wireless network changes. For example, if the network operation mode of the wireless network was changed, the TI IoT gateway would once again aggregate all the information needed (network information and device list) and send the network information message type to the cloud.

- **Network State Change**

This event occurs if the state of the wireless network changes. For example, if the network state changes from open to closed, the TI IoT gateway will send a network information message type to the cloud.

- **Device Joins the Wireless Network**

When a new device joins the network, after the network is up and running, this event will occur. In this case, the TI IoT gateway will add the new device and its information to the devices list within the network information message type and then send the updated information to the cloud

#### **Expected Cloud Behavior**

It is expected that the cloud will be prepared for the network startup event and will be able to receive the network information message type (using a wildcard and then filtering or by having prior knowledge about the destination or topic of the message). Once the cloud receives the network information message, the wireless network information (PANID, security, mode, and so forth) can be displayed to users and the device list information (topic, object list, and so forth) can be used to prepare itself to receive and display device and sensor data.

### 3.1.2.10.2.2 Device Information Sent to the Cloud

The following is the list of events that will cause the TI IoT gateway to send a device information message type to the cloud. A description is given with each event and the end of this section describes the expected behavior from the cloud upon receipt of this type of message.

- **Device Becomes Inactive**

This event occurs when the TI IoT gateway detects that one of the devices in the connected devices list has stopped sending sensor data updates. The TI IoT gateway will update the *active* field and send a device information message type to the cloud for the inactive device.

- **Device Reports Sensor Data**

Each time a sensor on a connected device reports sensor data this event occurs. The TI IoT gateway updates the IPSO alliance smart object list in the device for each sensor and then sends a device information message type to the cloud.

### Expected Cloud Behavior

It is expected that the Cloud will be alert on each topic given in the connected devices list from the network information message. When one of the two events occur in this section, the TI IoT gateway will send the device information message to the topic (corresponding to the device being update) that the cloud should be listening on or subscribed to. When the device information message arrives at the cloud, the cloud should display the latest device information and sensor data to users.

#### 3.1.2.10.2.3 Update Network State Message Sent to the TI IoT Gateway

This message is used to open or close the wireless network to new devices joining. This should be an option provided to users in the front end user interface that the cloud presents. When the user decides to update the network state, the cloud should send an update network state message type to the TI IoT gateway on the same topic that the network information messages are arriving on.

#### Expected TI IoT Gateway Behavior

The TI IoT Gateway will receive the update network state message and will generate the correct command (either open or close) to the wireless network. This command should, in turn, cause a network state change event (from 3.1.2.10.2.1) that will send a network information message back to the cloud, which can confirm the successful completion of the update network state command.

#### 3.1.2.10.2.4 Device Actuation Message Sent to the TI IoT Gateway

This method is used to toggle the LED on the board of the connected devices. This is meant to be a proof-of-concept on the current device setup and will change for customer use-case specific actuations. A toggle LED button for each device will be provided to users of the cloud's front end interface. When the toggle LED button is clicked, the cloud should send a device actuation message to the TI IoT gateway on the same topic that the device information messages are arriving on.

#### Expected TI IoT Gateway Behavior

The TI IoT Gateway will generate a toggle LED command and send it to the device corresponding to the topic that the device actuation message was received on. This will cause the LED to toggle. Because the state of the LED is not captured in the device information message type, there will be no feedback to the cloud that the LED actually toggled.

### 3.1.2.11 AWS IoT

3.1.2.10 of this document was generic to any cloud host or vendor. This section will give specific implementation details when using AWS IoT as the Cloud vendor. The numbering and header names of this section will be the same as 3.1.2.10, but additional information specific to the AWS IoT implementation is added here.

#### 3.1.2.11.1 Message Types

The message types from 3.1.2.10.1 will remain the same for messages traveling in both directions. However, the message payload sent to and from the AWS cloud will be wrapped with some additional information specific to the use of the Amazon® thing shadow interface.

### 3.1.2.11.1.1 Network Information Message Type (From TI IoT Gateway to the Cloud)

The network information message type will be sent to the AWS cloud using a thing name that includes the extended address of the wireless collector node that is attached to the TI IoT gateway. For example, the thing name could be *ti\_iot\_0x124b000a27dda1\_network* and would use the base thing shadow topic of *\$aws/things/ti\_iot\_0x124b000a27dda1\_network/shadow* where *0x124b000a27dda1* is the extended address of the collector node. Because all of the initial information needed to describe a network will be sent to this thing shadow, the thing name will either require to be known beforehand or the cloud front end must subscribe to an MQTT wildcard topic and then filter on the *\_network* keyword in order to receive the initial message containing the network Information.

The message payload shown in 3.1.2.10.1.1 will remain the same, but the message will be in JSON format and will be encapsulated in a *state* JSON object to comply with the Amazon thing shadow interface. Further, all messages sent from the TI IoT gateway toward the AWS cloud will be sent to the *state.reported* property of the thing shadow document. Sending data to the *state.reported* property is how the AWS cloud receives and stores the latest state of the thing.

The only other note that should be made on this message type is that the *topic* property given in each connected device will be the base topic for the thing device shadow in the following format:

```
"topic": "$aws/things/ti_iot_0x124b000a27dda1_0x124b000a27d849/shadow"
```

where the thing name is *ti\_iot\_0x124b000a27dda1\_0x124b000a27d849*. This name is comprised of first the wireless network's extended address (*0x124b000a27dda1*) and second the extended address of the device connected to the wireless network (*0x124b000a27d849*). This naming convention guarantees a distinct thing name and also makes it easy to determine the wireless network that the device is connected to.

### 3.1.2.11.1.2 Device Information Message Type (From TI IoT Gateway to the Cloud)

The device information message type messages will be sent to the thing shadows or MQTT topics that are provided in the devices list from the network information message type. It is recommended that things are registered (or MQTT topics are subscribed to) for each device once the network Information message is received. This registration will allow the cloud front end to receive all sensor and information updates from all devices.

Similar to the network information message type above, the device information message type will be sent in JSON format and will be wrapped in a *state* JSON object to comply with the Amazon thing shadow interface. Once again, when this message type is sent from the TI IoT Gateway to the AWS Cloud, the message will be sent to the *state.reported* property of the thing shadow document.

### 3.1.2.11.1.3 Update Network State Message Type (From Cloud to TI IoT Gateway)

The update network state message type messages will be sent to the same thing shadow or MQTT topic that the cloud receives network information messages on. This message type will also be sent in JSON format and will also be wrapped in a *state* JSON object to comply with the Amazon Thing Shadow API.

The major difference is that this message (*from* the Cloud *to* the TI IoT Gateway) will send its data to the *state.desired* property of the thing shadow. This is the method that the Amazon thing shadow provides to request a thing to make a state or property change. In this case, the only currently supported wireless network change that can be requested is to either open or close the network for new device joins. The following is an example of the message in JSON format that should be sent to the thing shadow:

```
{ "state" : { "desired" : { "state" : "open" } } }
```

#### 3.1.2.11.1.4 Device Actuation Message Type (From Cloud to TI IoT Gateway)

The device actuation message type messages will be sent to the same thing shadow or MQTT topic that the Cloud receives device information messages on. This message type will also be sent in JSON format and will also be wrapped in a *state* JSON object to comply with the Amazon thing shadow API.

Similar to the update network state messages, this message type will also be sent to the *state.desired* property of the thing shadow. The only currently supported actuation message that can be sent is to request that the wireless device toggle an onboard LED. The following JSON object is the only currently supported device actuation message type that should be sent from the AWS cloud to the TI IoT gateway:

```
{ "state" : { "desired" : { "toggleLED" : "true" } } }
```

#### 3.1.2.11.2 Data Flows

The data flows for the AWS cloud remain the same as in [3.1.2.10.2](#). The only AWS specific information is that the data is being sent to thing shadows and that the messages are wrapped in either *state.reported* or *state.desired* JSON objects as described in [3.1.2.11.1](#).

#### 3.1.2.12 IBM® Cloud

[3.1.2.10](#) of this document was generic to any cloud host or vendor. This section will give specific implementation details when using IBM® Watson IoT™ as the cloud vendor. The numbering and header names will be the same as [3.1.2.10](#).

##### 3.1.2.12.1 Message Types

The message types from [3.1.2.10.1](#) will remain the same for messages traveling in both directions. However, the message payload sent to and from the AWS cloud will be wrapped with some additional information specific to the use of the Amazon thing shadow interface.

##### 3.1.2.12.1.1 Network Information Message Type (From TI IoT Gateway to Cloud)

The network information message type will be sent to the IBM cloud by publishing the *nwkUpdate* gateway event. This publishes an MQTT topic with the gateway's device type and device ID as identifiers. This means the application running on IBM cloud must subscribe to this particular gateway's *nwkUpdate* event to receive this publication. The message payload shown in [3.1.2.10.1.1](#) will remain the same, but will be in JSON format.

##### 3.1.2.12.1.2 Device Information Message Type (From TI IoT Gateway to Cloud)

The device information message type will be sent to the IBM cloud by publishing the *deviceUpdate* gateway event. This publishes an MQTT topic with the gateway's device type and id. This means the application running on IBM cloud must subscribe to this particular gateway's *deviceUpdate* event to receive this publication. The message payload shown in [3.1.2.10.1.1](#) will remain the same, but will be in JSON format.

### 3.1.2.12.1.3 Update Network State Message Type (From Cloud to TI IoT Gateway)

The update network state message type messages will be sent to the same MQTT topic that the cloud receives network information messages on. This message will also be sent in JSON format. The gateway will receive the message as part of the “command” event. This event will include a command name and payload. The command name for this message will be *nwkUpdate* and the payload will be a JSON object. The payload JSON object specifies the new network state in an action field like so {action: “open”}.

### 3.1.2.12.1.4 Device Actuation Message Type (From Cloud to TI IoT Gateway)

The device actuation message type message will be sent to the same MQTT topic that the cloud receives device information messages on. This gateway will receive this message through a “command” event. This event includes command name and payload data parameters. The command name for this message type is *deviceUpdate* and the payload is a JSON object. The JSON object specifies the target device in a *dstAddr* field like so {dstAddr: ‘0x0001’}.

### 3.1.2.12.2 Data Flows

The data flows for IBM cloud remain the same as in [3.1.2.11.1](#).

### 3.1.2.12.3 IBM Cloud Application

In order to use IBM as the cloud provider, an application must be created and configured on the cloud. There is an example application *ibm-frontend* that can be used located in the examples directory of the sensor to cloud repository. This example application can be uploaded using the *cf* command-line utility provided by IBM. For a step by step walkthrough of setting up this application please refer to the Sensor To Cloud Quickstart guide.

### 3.1.2.13 IBM® Quickstart

TI's Sensor To Cloud supports the IBM Quickstart cloud platform as a way to quickly see sensor data and network metadata on the cloud without any cloud-side overhead. This gives a good idea as to the types of messages being sent to the cloud application. The gateway reports two types of messages on the IBM Quickstart dashboard *nwkUpdates* and *deviceUpdates*. A *nwkUpdate* is emitted when something in the network changes, such as a device joining or leaving. A *deviceUpdate* is reported whenever a sensor node reports data to the collector. Using the IBM Quickstart platform is a great way to get started and get a feel for how data is sent to the cloud. More information on IBM Quickstart can be found [here](#).

### 3.2 Testing and Results

During the development process of this reference design, the full hardware and software portions described in earlier sections were used for testing. Multiple CC1310 and CC1350 sensor nodes and a BeagleBone Black (connected to a CC1310 coprocessor) were used to verify the IoT gateway functionality with the AWS cloud enabled by stackArmor. The culmination of this reference design can be visualized by the IoT dashboard described in 3.2.1.

#### 3.2.1 Internet of Things Dashboard

Figure 12 shows an example of the IOT Dashboard being displayed on the web interface. Observe that the current network information is shown, the network chart displays the number of connected devices, and that the sensor nodes section shows the device and current sensor information for all the devices in the network.

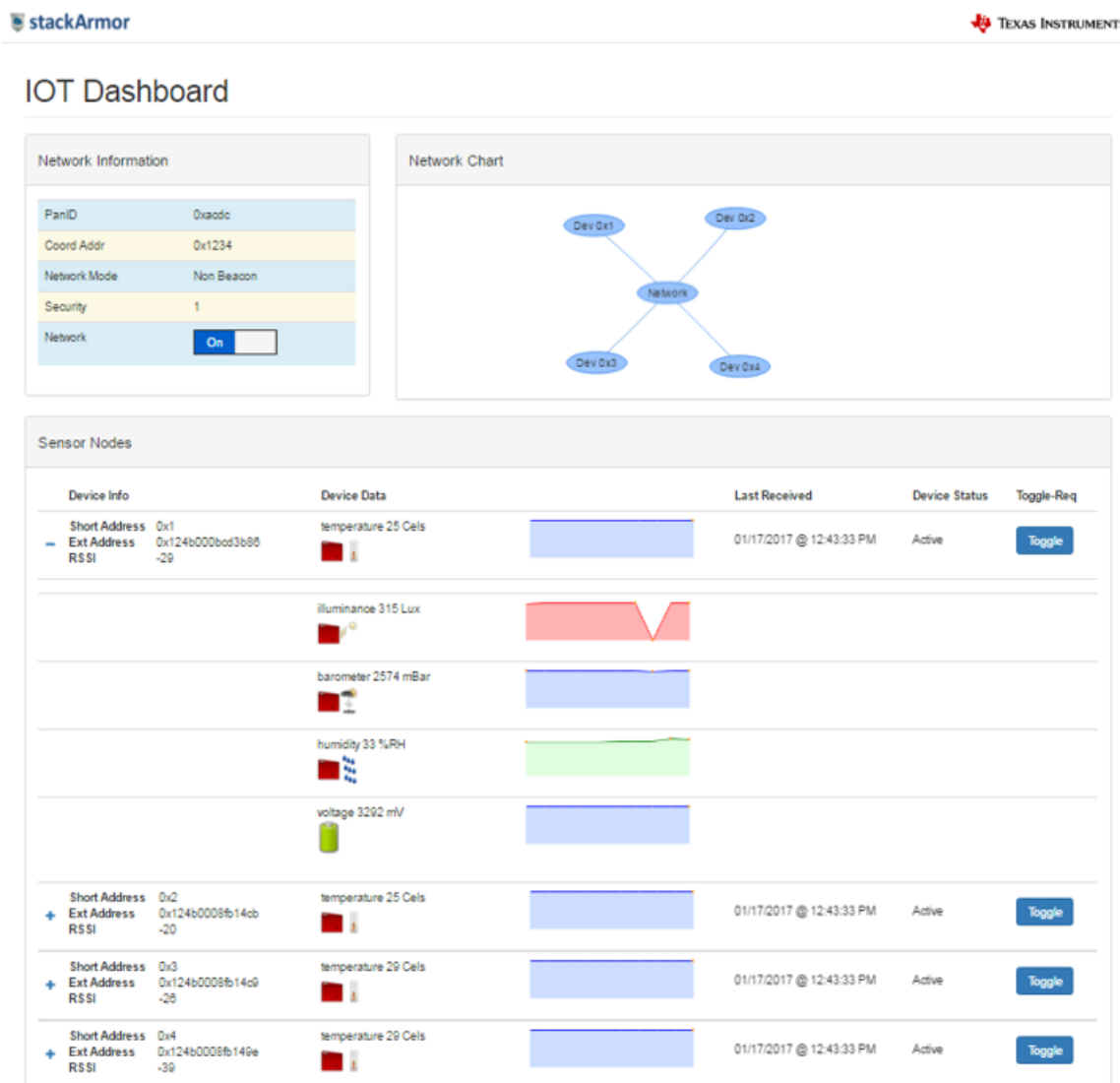


Figure 12. IOT Dashboard



## 4 Design Files

This reference design showcases the connectivity between AM335x and CC13x0 devices. The AM335x acts as a gateway processor and CC13x0 as communication node.

The AM335x-based BeagleBone Black is used as a platform for gateway processor, and the CC13x0-based LaunchPad Development Kit acts as communication node. The schematic for this reference design shows how to map one UART port and backdoor signals from BeagleBone Black to the LaunchPad Development Kit.

For software flexibility, the schematic also maps various SPI, I<sup>2</sup>C, and GPIOs from BeagleBone Black to the LaunchPad Development Kit; however, for this IoT gateway reference design only one UART port and backdoor signals are valid.

### 4.1 Schematics

To download the schematics for each board, see the design files at [TIDEP0084](#).

### 4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDEP0084](#).

### 4.3 PCB Layout Recommendations

#### 4.3.1 Layout Prints

To download the layout prints, see the design files at [TIDEP0084](#).

### 4.4 Altium Project

To download the Altium Designer® project files, see the design files at [TIDEP0084](#).

### 4.5 Gerber Files

To download the Gerber files, see the design files at [TIDEP0084](#).

### 4.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDEP0084](#).

## 5 Software Files

To download the software files for this reference design, please see the link at <https://git.ti.com/apps/tidep0084>.

## 6 Related Documentation

1. Texas Instruments, [TI 15.4-Stack: IEEE802.15.4e/g Standard Based Star Networking Software Development Kit \(SDK\)](#)
2. Texas Instruments, [Processor SDK for AM335x Sitara™ Processors - Linux® and TI-RTOS support](#)
3. Texas Instruments, [TI 15.4-Stack Wiki](#)
4. Texas Instruments, [Processor SDK Linux Creating an SD Card with Windows](#)
5. Texas Instruments, [CC13x0 SimpleLink™ TI 15.4-Stack 2.x.x Linux® Developer's Guide](#)
6. Texas Instruments, [CC13x0 SimpleLink™ TI 15.4-Stack 2.x.x Embedded Developer's Guide](#)
7. Texas Instruments, [TI 15.4-Stack CC13x0 SimpleLink™ Embedded Applications Quick Start Guide](#)

## 8. stackArmor, [Industrial IoT Gateway Demonstration Request Form](#)

### 6.1 商標

Sitara, SimpleLink, Texas Instruments, LaunchPad are trademarks of Texas Instruments.  
Altium Designer is a registered trademark of Altium LLC or its affiliated companies.  
Amazon Web Services is a trademark of Amazon Web Services, Inc.  
Amazon is a registered trademark of Amazon Web Services, Inc.  
Arm, Cortex are registered trademarks of Arm Limited.  
LINKSYS, BELKIN are trademarks of Belkin International, Incorporated.  
Ethernet Powerlink is a registered trademark of Bernecker + Rainer Industrie-ElektronikGes.m.b.H.  
*Bluetooth* is a registered trademark of Bluetooth SIG, Incorporated.  
EtherCAT is a registered trademark of EtherCAT Technology Group.  
Watson IoT is a trademark of IBM Corporation.  
IBM is a registered trademark of IBM Corporation.  
PowerVR SGX is a trademark of Imagination Technologies Limited.  
IBM is a registered trademark of International Business Machines Corporation.  
Linux, Yocto Project are registered trademarks of Linux Foundation.  
Windows is a registered trademark of Microsoft Corporation.  
NETGEAR is a registered trademark of NETGEAR, Incorporated.  
EtherNet/IP is a registered trademark of ODVA, INC.  
PROFIBUS, PROFINET are registered trademarks of PROFIBUS and PROFINET International (PI).  
Sercos is a registered trademark of Sercos International e.V.  
FileZilla is a registered trademark of Tim Kosse.  
stackArmor is a trademark of stackArmor.  
すべての商標および登録商標はそれぞれの所有者に帰属します。

## 7 About the Authors

**SUYASH JAIN** is an Applications Engineer at Texas Instruments, where he is responsible for supporting customers designing low power wireless systems. Suyash earned his Master of Science in Electrical Engineering (MSEE) from Texas Tech University in Lubbock, TX.

**JASON REEDER** is a Software Applications Engineer at Texas Instruments, where he is responsible for supporting customers using Linux on TI's Sitara family of devices. Jason earned his Bachelor of Science in Computer Software Engineering and his Master of Science in Electrical Engineering at the University of Florida in Gainesville, FL.

**AMRIT MUNDRA** is a part of the Systems Team in Catalog Processors business unit. He has been with TI for 13 years and has worked on multiple IPs and SoCs. He is the security architect for Keystone3 and security lead for the Catalog business unit. Amrit also is system lead for IoT EE initiative in the business unit.

**BROCK ALLEN** is a Wireless Applications Engineer at Texas Instruments. He is responsible for supporting customers designing low power and long range wireless systems using a Sub-1 GHz radio. Brock earned his Bachelor of Science in Computer Engineering from Virginia Polytechnic Institute and State University (Virginia Tech).

## 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Revision B (October 2017) から Revision C に変更	Page
• CC13x2デバイスをサポートするようドキュメントを更新 .....	1
• Updated the <i>IoT Gateway Reference Design Block Diagram</i> .....	3
• the <i>AM335x Block Diagram</i> 変更 .....	6
• <i>This step requires an active internet connection in order to download and install the required Node.js dependencies</i> 追加 .....	12
• <i>It is also possible to clone the repository directly on the BeagleBone Black</i> 追加 .....	13
• from "Flash Programmer 2" to "UniFlash" throughout the document 変更 .....	15
• the troubleshooting note 削除 .....	15
• <i>If no arguments are provided to this script it will launch the default AWS IoT gateway; however, it is possible to use this script to launch AWS, IBM, IBM Quickstart, and Localhost gateways. To do this provide a single argument when executing the script specifying which gateway to launch. The argument should be one of the following: 'aws', 'ibm', 'quickstart', or 'localhost'. example: 'bash run_demo.sh localhost'</i> 追加 .....	19
• <i>IoT-Gateway and Collector Application Interface API</i> 変更 .....	23

Revision A (April 2017) から Revision B に変更	Page
• 現行のデザイン・ガイド・テンプレートに準拠するためセクションの順序を 変更 .....	1
• <i>and 433-MHz China bands</i> to tenth bulleted list item. 追加 .....	9
• the following list items: <i>SimpleLink long range mode for all supported frequency bands, Support for SimpleLink CC1190, and Bluetooth low energy beacon advertisement support</i> 追加 .....	9
• <b>3.1.2.2.1</b> 追加 .....	12
• location of Note and 図 6 from <b>3.1.2.2</b> to <b>3.1.2.2.1</b> 変更 .....	12
• <i>, 863-MHz, and 433-MHz bands of operation at 50 kbps.</i> 追加 .....	15
• <i>To rebuild the hex files for other bands (for example, 868 MHz ETSI band) to To rebuild the hex files for other bands (for example, SimpleLink Long Range mode),</i> 変更 .....	15
• <b>3.1.2.8</b> 追加 .....	23
• the following bullet items: <b>active</b> : whether or not the wireless node is active, <b>rsssi</b> : received signal strength indicator of the last message received, <b>last_reported</b> : timestamp of the last message received, <b>smart_objects</b> : list of IPSO alliance smart objects (sensors) attached to this device, <b>object ID description</b> : type of sensor (as defined in the IPSO standard); can be multiple types of sensors connected to each device ('temperature' for example), <b>instance ID</b> : the instance ID for the parent object type; can be multiple sensors of the same type (is usually '0' and counts up with each instance added, and resource ID description list: sensor data name value pairs (for example, sensorValue: 32.5, units:Celsius, dlnState: true , and so forth); these resources match what is specified for the given object ID in the IPSO standard 追加 .....	32
• the following bullet items: <b>short_addr</b> : the 16-bit short address of the device and <b>last_reported</b> : timestamp of the last message received 追加 .....	34
• <b>3.1.2.12</b> and all child subsections 追加 .....	38
• <b>3.1.2.13</b> 追加 .....	39
• About the Author for Brock Allen 追加 .....	42

2016年11月発行のものから更新	Page
• <i>Cannot find module error to Section 2.3.3.1 Common Issues.</i> 追加 .....	19

## TIの設計情報およびリソースに関する重要な注意事項

Texas Instruments Incorporated ("TI")の技術、アプリケーションその他設計に関する助言、サービスまたは情報は、TI製品を組み込んだアプリケーションを開発する設計者に役立つことを目的として提供するものです。これにはリファレンス設計や、評価モジュールに関係する資料が含まれますが、これらに限られません。以下、これらを総称して「TIリソース」と呼びます。いかなる方法であっても、TIリソースのいずれかをダウンロード、アクセス、または使用した場合、お客様(個人、または会社を代表している場合にはお客様の会社)は、これらのリソースをここに記載された目的にのみ使用し、この注意事項の条項に従うことに合意したものとします。

TIによるTIリソースの提供は、TI製品に対する該当の発行済み保証事項または免責事項を拡張またはいかなる形でも変更するものではなく、これらのTIリソースを提供することによって、TIにはいかなる追加義務も責任も発生しないものとします。TIは、自社のTIリソースに訂正、拡張、改良、およびその他の変更を加える権利を留保します。

お客様は、自らのアプリケーションの設計において、ご自身が独自に分析、評価、判断を行う責任がお客様にあり、お客様のアプリケーション(および、お客様のアプリケーションに使用されるすべてのTI製品)の安全性、および該当するすべての規制、法、その他適用される要件への遵守を保証するすべての責任をお客様のみが負うことを理解し、合意するものとします。お客様は、自身のアプリケーションに関して、(1) 故障による危険な結果を予測し、(2) 障害とその結果を監視し、および、(3) 損害を引き起こす障害の可能性を減らし、適切な対策を行う目的での、安全策を開発し実装するために必要な、すべての技術を保持していることを表明するものとします。お客様は、TI製品を含むアプリケーションを使用または配布する前に、それらのアプリケーション、およびアプリケーションに使用されているTI製品の機能性を完全にテストすることに合意するものとします。TIは、特定のTIリソース用に発行されたドキュメントで明示的に記載されているもの以外のテストを実行していません。

お客様は、個別のTIリソースにつき、当該TIリソースに記載されているTI製品を含むアプリケーションの開発に関連する目的でのみ、使用、コピー、変更することが許可されています。明示的または黙示的を問わず、禁反言の法理その他どのような理由でも、他のTIの知的所有権に対するその他のライセンスは付与されません。また、TIまたは他のいかなる第三者のテクノロジーまたは知的所有権についても、いかなるライセンスも付与されるものではありません。付与されないものには、TI製品またはサービスが使用される組み合わせ、機械、プロセスに関連する特許権、著作権、回路配置利用権、その他の知的所有権が含まれますが、これらに限られません。第三者の製品やサービスに関する、またはそれらを参照する情報は、そのような製品またはサービスを利用するライセンスを構成するものではなく、それらに対する保証または推奨を意味するものでもありません。TIリソースを使用するため、第三者の特許または他の知的所有権に基づく第三者からのライセンス、もしくは、TIの特許または他の知的所有権に基づくTIからのライセンスが必要な場合があります。

TIのリソースは、それに含まれるあらゆる欠陥も含めて、「現状のまま」提供されます。TIは、TIリソースまたはその仕様に関して、明示的か暗黙的にかかわらず、他のいかなる保証または表明も行いません。これには、正確性または完全性、権原、続発性の障害に関する保証、および商品性、特定目的への適合性、第三者の知的所有権の非侵害に対する黙示的保証が含まれますが、これらに限られません。

TIは、いかなる苦情に対しても、お客様への弁済または補償を行う義務はなく、行わないものとします。これには、任意の製品の組み合わせに関連する、またはそれらに基づく侵害の請求も含まれますが、これらに限られず、またその事実についてTIリソースまたは他の場所に記載されているか否かを問わないものとします。いかなる場合も、TIリソースまたはその使用に関連して、またはそれらにより発生した、実際の、直接的、特別、付随的、間接的、懲罰的、偶発的、または、結果的な損害について、そのような損害の可能性についてTIが知らされていたかどうかにかかわらず、TIは責任を負わないものとします。

お客様は、この注意事項の条件および条項に従わなかったために発生した、いかなる損害、コスト、損失、責任からも、TIおよびその代表者を完全に免責するものとします。

この注意事項はTIリソースに適用されます。特定の種類の資料、TI製品、およびサービスの使用および購入については、追加条項が適用されます。これには、半導体製品(<http://www.ti.com/sc/docs/stdterms.htm>)、評価モジュール、およびサンプル(<http://www.ti.com/sc/docs/sampterms.htm>)についてのTIの標準条項が含まれますが、これらに限られません。