



Module 19

Introduction: Bluetooth Low Energy



Introduction: Bluetooth Low Energy

Educational Objectives:

UNDERSTAND Basic concepts of Bluetooth Low Energy

INTERFACE The CC2650 to the MSP432 using UART communication

CREATE A BLE service with multiple characteristics

DESIGN A robot system that can be controlled by a smart device using BLE

Prerequisites (Module 18)

- Interrupting UART interface (Module 18)

Recommended reading materials for students:

- Volume 3 Sections 9.3, 9.4, 9.5, and 9.6

Embedded Systems: Real-Time Operating Systems for ARM Cortex-M Microcontrollers, ISBN: 978-1466468863, Jonathan Valvano, copyright (c) 2017

Bluetooth is wireless medium and a data protocol that connects devices together over a short distance. Examples of Bluetooth connectivity include headset to phone, speaker to computer, and fitness device to phone/computer. Bluetooth is an important component of billions of products on the market today. Bluetooth operates from 1 to 100 meters, depending on the strength of the radio. Most Bluetooth devices operate up to a maximum of 10 meters. However, in order to improve battery life, many devices reduce the strength of the radio, and therefore save power by operating across distances shorter than 10 meters. If the computer or phone provides a bridge to the internet, a Bluetooth-connected device becomes part of the Internet of Things (IoT).

Bluetooth is classified as a **personal area network** (PAN) because it implements communication within the range of an individual person. Alternatively, devices within a Bluetooth network are usually owned or controlled by one person. When two devices on the network are connected, we often say the devices are **paired**.

At the highest level, we see Bluetooth devices implement profiles. A **profile** is a suite of functionalities that support a certain type of communication. For example, the Advanced Audio Distribution Profile (A2DP) can be used to stream data. The Health Device Profile (HDP) is a standard profile for medical devices. There are profiles for remote controls, images, printers, cordless telephones, health devices, hands free devices, and intercoms. The profile we will use in this chapter is the **generic attribute protocol** (GATT). Within the GATT there can be once or more services.

Within a **service** there may be one or more characteristics. A **characteristic** is user or application data that is transmitted from one device to another across the network. One of the attributes of a characteristic is whether it is readable, writeable, or both. We will use the notify indication to stream data from the embedded object to the smart phone. Characteristics have a **universally unique identifier** (UUID), which is a 128-bit (16-byte) number that is unique. BLE can use either 16-bit or 32-bit UUIDs. A specific UUID is used within the network to identify a specific characteristic. Often a characteristic has one or more descriptors. Descriptors may be information like its name and its units. We will also see **handles**, which are a mechanism to identify characteristics within the device. A handle is a pointer to an internal data structure within the GATT that contains all the information about that characteristic. Handles are not passed across the Bluetooth network; rather, handles are used by the host and controller to keep track of characteristics. UUIDs are passed across the network.

Simple Network Processor (SNP) is TI's name for the application that runs on the CC2650 when using the CC2650 with another microcontroller such as the MSP432. In this configuration the controller and host are implemented together on the CC2650, while the profiles and application are implemented on an external MCU. The application and profiles communicate with the CC2650 via the Application Programming Interface (API) that simplifies the management of the BLE network processor. The SNP API communicates with the BLE device using the Network Protocol Interface (NPI) over a serial (SPI or UART) connection. In this module, we will use a UART interface. This configuration is useful for applications that wish to add Bluetooth functionality to an existing device. In this paradigm, the application runs on the existing microcontroller, and BLE runs on the CC2650.

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated