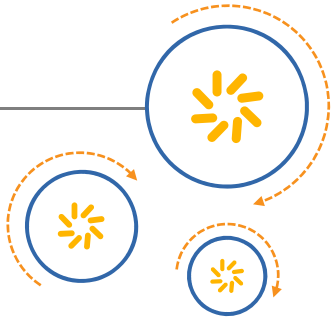
Qualcomm Technologies International, Ltd.



Confidential and Proprietary – Qualcomm Technologies International, Ltd.

(formerly known as Cambridge Silicon Radio Ltd.)

NO PUBLIC DISCLOSURE PERMITTED: Please report postings of this document on public servers or websites to: DocCtrlAgent@qualcomm.com.

Restricted Distribution: Not to be distributed to anyone who is not an employee of either Qualcomm Technologies International, Ltd.or its affiliated companies without the express approval of Qualcomm Configuration Management.

Not to be used, copied, reproduced, or modified in whole or in part, nor its contents revealed in any manner to others without the express written permission of Qualcomm Technologies International, Ltd.

Any software provided with this notice is governed by the Qualcomm Technologies International, Ltd. Terms of Supply or the applicable license agreement at https://www.csrsupport.com/CSRTermsandConditions.

Qualcomm is a trademark of Qualcomm Incorporated, registered in the United States and other countries. All Qualcomm Incorporated trademarks are used with permission. Other product and brand names may be trademarks or registered trademarks of their respective owners.

This technical data may be subject to U.S. and international export, re-export, or transfer (“export”) laws. Diversion contrary to U.S. and international law is strictly prohibited.

Qualcomm Technologies International, Ltd.
Churchill House
Cambridge Business Park
Cambridge, CB4 0WZ
United Kingdom

Push every boundary.™

CSR µEnergy™

CSRmesh™ 2.0 Switch Application

Application Note

Issue 3

Document History

Revision	Date	History
1	21 SEP 2015	Original publication of this document
2	26 OCT 2015	Editorial updates.
3	30 OCT 2015	Editorial updates

Contacts

General information	www.csr.com
Information on this product	sales@csr.com
Customer support for this product	www.csrsupport.com
More detail on compliance and standards	product.compliance@csr.com
Help with this document	comments@csr.com

Trademarks, Patents and Licences

Safety-critical Applications

CSR's products are not designed for use in safety-critical devices or systems such as those relating to: (i) life support; (ii) nuclear power; and/or (iii) civil aviation applications, or other applications where injury or loss of life could be reasonably foreseeable as a result of the failure of a product. The customer agrees not to use CSR's products (or supply CSR's products for use) in such devices or systems.

Performance and Conformance

Refer to www.csrsupport.com for compliance and conformance to standards information.

Contents

Tables and Figures

1. Introduction

This document describes the CSRmesh Switch on-chip application built using the CSR µEnergy SDK.

The application has the following use cases:

- Light Control: The Switch application implements the CSRmesh messages related to the Light Model, Stream Model and the Power Model.
- CSRmesh GATT Bridge: The application also implements the CSR custom Mesh Control Service. This service allows a Bluetooth Smart enabled phone to send and receive CSRmesh commands to many devices with the Switch application acting as a bridge.

The CSRmesh Switch application is part of the CSRmesh release to show CSRmesh light control using an associated switch. It uses the CSRmesh library provided as part of the CSRmesh release. For more information, see the *CSRmesh Library API* documentation.

The CSRmesh Switch application does not support bonding and is not compatible with previous CSRmesh releases.

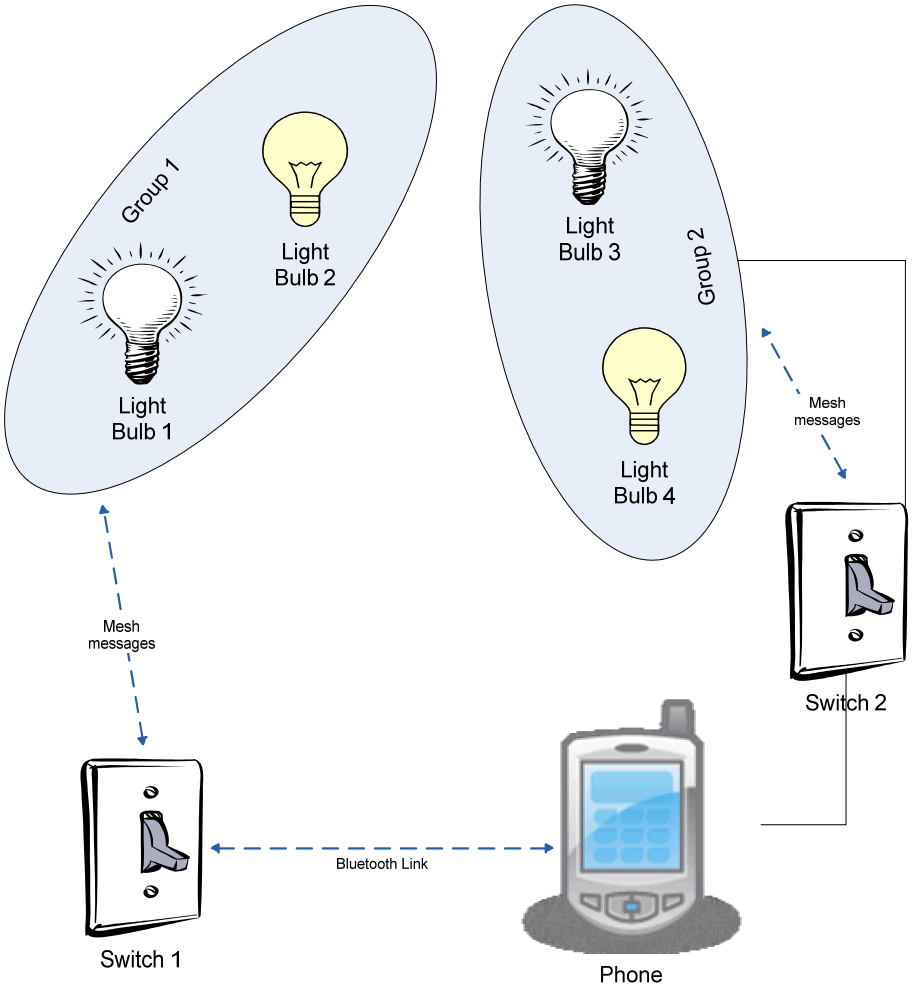


Figure 1.1: CSRmesh Use Case

1.1. Application Overview

The CSRmesh Switch application uses the CSRmesh Library API to communicate with other associated devices in the same CSRmesh network. Additionally it supports a custom GATT profile to allow control of the CSRmesh from a Bluetooth Smart enabled device.

1.1.1. Supported Profiles

The CSR Switch application implements the CSR custom profile in Section 1.1.1.1 to support the use cases.

1.1.1.1. CSRmesh Control Profile

The CSRmesh Control Profile defines the behaviour when:

- A network of devices such as lights, switches and sensors need to be created.
- Controlling the device after a network is created. For example, switching on/off or changing the intensity or colour of a light.
- Reading the status of a device in the network, for example, on/off state, colour or intensity of a light.

Table 1.1 lists the two roles that the CSRmesh Control Profile defines.

Role	Description	Implementation
CSRmesh Bridge Device	Receives commands from the host and sends them over the CSRmesh network. Receives responses from associated devices over the CSRmesh and forwards them to the host over a Bluetooth Smart connection.	On the CSRmesh Switch application
CSRmesh Control Device	Provides the interface to create a network of devices and to control the associated devices. The control commands are sent over a Bluetooth Smart connection to the CSRmesh devices.	On a Bluetooth Smart enabled phone or tablet

Table 1.1: CSRmesh Control Profile Roles

1.1.2. Application Topology

Table 1.2 and Table 1.3 list the topology that the CSRmesh Bridge uses.

Role	Mesh Control Service	GAP Service	GATT Service	CSR OTA Update Application Service
GATT Role	GATT Server	GATT Server	GATT Server	GATT Server
GAP Role	Peripheral	Peripheral	Peripheral	Peripheral

Table 1.2: Application Topology

Role	Responsibility
GATT Server	Accepts incoming commands and requests from a client and sends responses, indications and notifications to the client.
GAP Peripheral	Accepts connections from remote device and acts as a slave in the connection.

Table 1.3: Roles and Responsibilities

For more information about GATT server and GAP peripheral, see the *Bluetooth Core Specification Version 4.1*.

1.1.3. Services Supported in GATT Server Role

The application exposes the following services:

- Mesh Control Service v2.0
- GATT Service
- GAP Service
- CSR OTA Update Application Service v2.0

The Mesh Control Service is mandated by the CSRmesh Control Profile. The GATT and GAP Services are mandated by the *Bluetooth Core Specification Version 4.1*.

Figure 1.2 shows the services supported in the GATT Server Role.

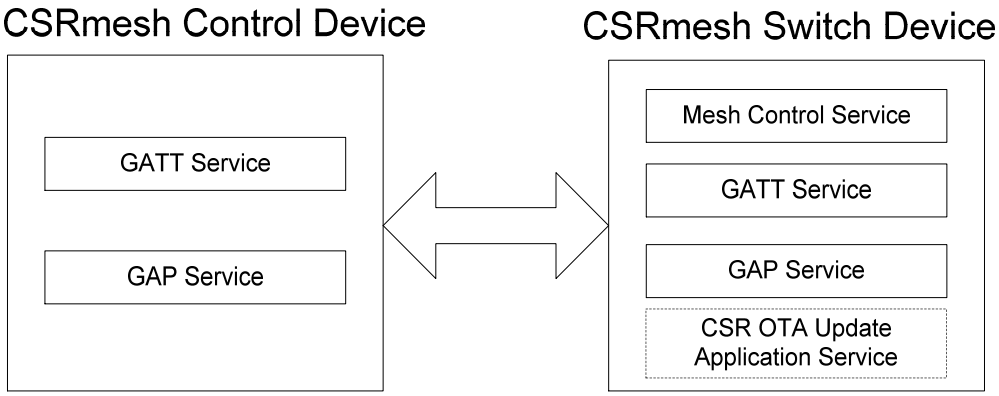


Figure 1.2: Primary Services

1.1.3.1. CSR OTA Update Application Service

The CSR OTA Update Application Service enables wireless update of the application software. A PC or mobile phone application provided by the device manufacturer enables the end-user to keep their device up-to-date with the latest features and bug fixes.

To enable a device for future OTA updates, the application needs to:

- Add OTA Update functionality to the on-chip application.
- Add support for the CSR OTA Update Application Service and GATT Services to an application.
- Configure the on-chip bootloader.

The CSR OTA Update bootloader image must be present on the device and configured to contain the correct device name and optional shared authentication key.

When the device is enabled for OTA Update, the CSR µEnergy Over-the-Air Updater host application included in the SDK can update the device.

For more information about CSR OTA Update, see:

- *CSR µEnergy Over-the-Air (OTA) Update System Application Note*
- *CSR µEnergy Modifying an Application to Support OTA Update Application Note*
- *CSR µEnergy Over-the-Air (OTA) Update Application and Bootloader Services Specification*

For information about CSR OTA Update applications for iOS and Android, see www.csrsupport.com.

2. Using the Application

This section describes how to use the CSRmesh Switch application with the CSRmesh Android application to control devices.

2.1. Demonstration Kit

Table 2.1 lists the components that the application can use for demonstration.

Component	Hardware	Application
Switch Device	CSRmesh Development PCB (DB-CSR1010-10185-1A)	CSRmesh Switch Application v2.0
CSRmesh Android Control Device	Android Bluetooth LE Device	CSRmesh Android Application v2.0
CSRmesh iOS Control Device	iOS Bluetooth LE Device	CSRmesh iOS Application v2.0

Table 2.1: CSRmesh Components

2.1.1. CSRmesh Development Board

The µEnergy SDK is used to download the CSRmesh Switch application on the development boards. For more information, see the *CSR µEnergy xIDE User Guide*.

Ensure that the development board is powered on using the Power On/Off switch. Figure 2.1 shows the switch in the off position.

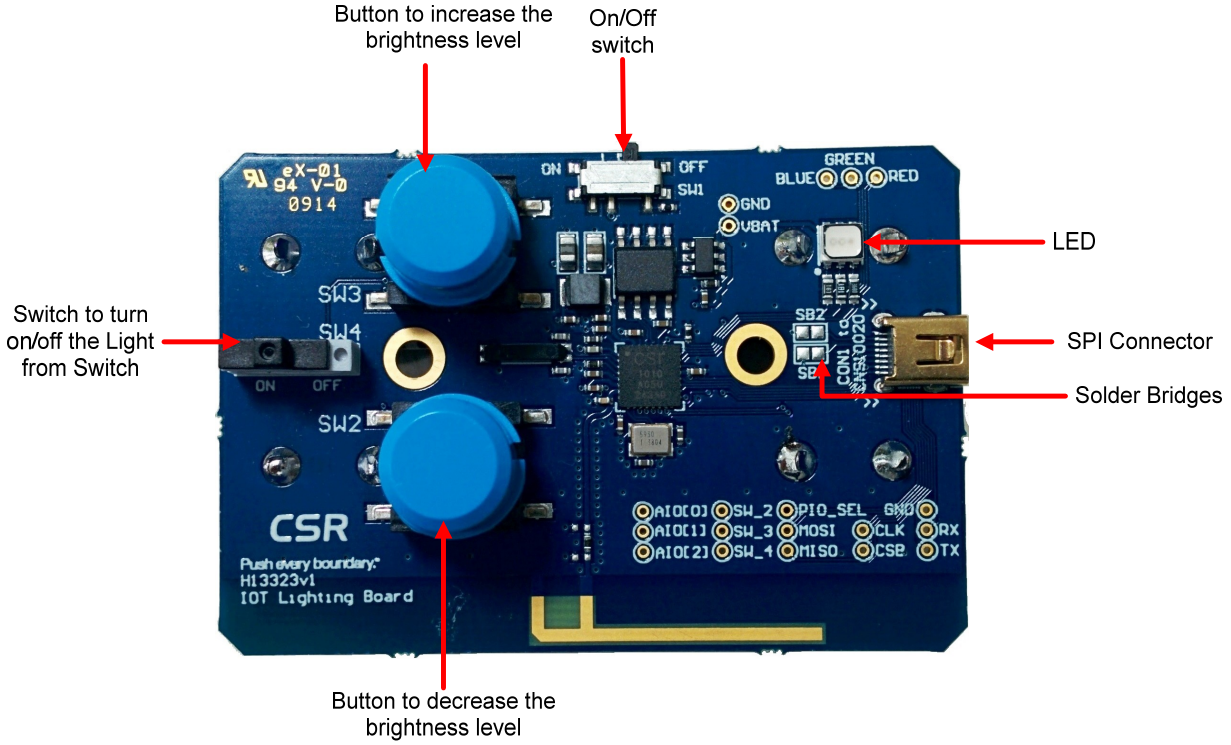


Figure 2.1: CSRmesh Development Board

Note:

When the development board is disconnected from the USB to SPI Adapter, wait at least 1 minute before powering the board on to allow dissipation of any residual charge received from the SPI connector.

Shorting the solder bridges exposes the UART through the CSR SPI connector. The PIOs connected to SW2 and SW3 are also mapped to UART Rx and Tx lines. Pressing any of these buttons shorts the UART lines to ground and corrupts data on the UART. CSR recommends not pressing these buttons during UART communication.

2.1.1.1. User Interface

The application uses the components available on the CSRmesh development board to switch the power on/off and change the brightness of a CSRmesh light or a group of lights.

User Interface Component	Function
Switch SW1	Power slider switch powering on/off the board.
Button SW2	Pressing the button once decreases the brightness by 1 level. Continuously pressing the button results in the following behaviour: ▪ The destination light brightness decreases by 1 level immediately. ▪ The brightness decreases by 5 levels every 1 second until reaching the minimum level.
Button SW3	Pressing the button once increases the brightness by 1 level. Continuously pressing the button results in the following behaviour: ▪ The destination light brightness increases by 1 level immediately. ▪ The destination light brightness increases by 5 levels every 1 second until reaching the maximum level.
Switch SW4	Changes the power state of the assigned CSRmesh light or a group of lights.
RGB LED	▪ Blinks blue until it is not associated with any CSRmesh network. ▪ Blinks yellow when device association is in progress. ▪ Blinks red when device attention is requested. The application turns the light off after association.

Table 2.2:CSRmesh Development Board User Interface

2.1.1.2. CSRmesh Device Tag

The CSRmesh development board is supplied with a CSRmesh Device Tag sticker shown in the Figure 2.2. The sticker contains:

- BT: Device Bluetooth Address
- SN: Serial Number
- XTAL TRIM: Crystal trim value to be set in the CS Config File
- UUID :CSRmesh Device UUID
- AC: CSRmesh Authorisation Code
- QR-Code : Encodes UUID and AC

Figure 2.2: CSRmesh Device Tag Sticker

The device can be programmed with the Bluetooth address and XTAL Trim printed on the sticker by setting these values in the `switch_csr101x_A05.keyr` file.

The Device UUID and the Authorisation Code printed on the sticker can be programmed on the NVM at the offsets defined in Table 5.1 using the USB to SPI adapter.

To program the example UUID `0x0123456789ABCDEFFEDCBA9876543210` and Authorisation Code `0x0123456789ABCDEF` on the NVM:

1. Open a command prompt.
2. Program the device UUID and Authorisation Code to the device EEPROM over the SPI link:
   - If base `NVM_START_ADDRESS` is defined in the `.keyr` file, program the device UUID and Authorisation Code to the device as follows:

     ```
     <CSR_uEnergy_Tools path>\uEnergyProdTest.exe -k
     CSRmeshswitch_csr101x_A05.keyr -m1 0x02 0x3210 0x7654 0xBA98 0xFEDC
     0xCDEF 0x89AB 0x4567 0x0123 0xCDEF 0x89AB 0x4567 0x0123
     ```

     The first value following `-m1` is the NVM offset from `NVM_START_ADDRESS`. The command takes the NVM offset as the byte address. Word offset 1 for device UUID is byte offset 2, see Table 5.1.
   - If the `.keyr` file is not included in the command, program the device UUID and Authorisation Code to the device as follows:

     ```
     <CSR_uEnergy_Tools path>\uEnergyProdTest.exe -m1 0x4102 0x3210 0x7654
     0xBA98 0xFEDC  0xCDEF 0x89AB 0x4567 0x0123 0xCDEF 0x89AB 0x4567
     0x0123
     ```

     The first value following `-m` is the NVM address obtained by adding base address `4100` and word offset 1, see Table 5.1 for device UUID. The command takes the NVM address as the byte address. Word offset 1 is byte offset 2, so the effective address is `0x4102`.

The CSRmesh Control application reads the device Authorisation Code and UUID from the QR-Code printed on the sticker during association. For more information, see the *CSRmesh 2.0 Android Control Application Note* or *CSRmesh 2.0 iOS Control Application Note*. For further information about programming the NVM, see the *CSRmesh 2.0 Production Test Tool User Guide*.

2.1.1.3. Button De-bouncing

Figure 2.3 shows how the application handles button de-bouncing.

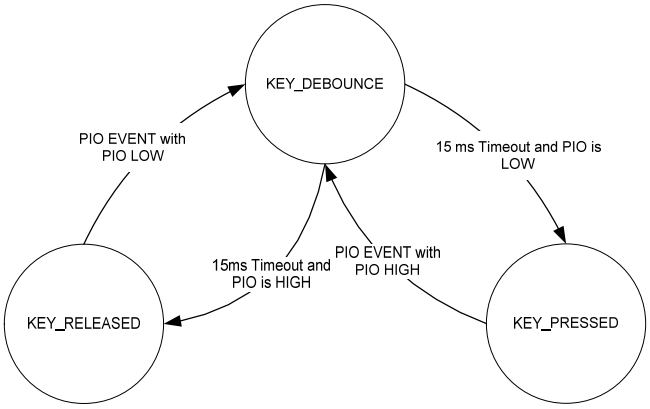


Figure 2.3: Handling Button De-bounce

Note:

The CSRmesh Switch application blinks blue until associated to the CSRmesh network. When getting an association request, the application blinks yellow until the association completes.

2.1.2. CSRmesh Control Application

The CSRmesh Control application runs on an Android or iOS device that supports BLE. It communicates with the CSRmesh devices by connecting to one of the devices that support the CSR custom-defined CSRmesh Control Profile. The application is required for:

- Setting up a network by associating devices.
- Configuring and grouping the network devices.

For instructions about how to use the CSRmesh Control application on an Android device, see the *CSRmesh 2.0 Android Control Application Note*.

For instructions about how to use the CSRmesh Control application on an iOS device, see the *CSRmesh 2.0 iOS Control Application Note*.

For more information about the supported iOS and Android version, see the *CSRmesh 2.0 Mobile Application Release Note*.

3. Application Structure

This section describes the source files, head files and database files.

3.1. Source Files

Table 3.1 lists the source files.

File Name	Description
app_data_stream.c	Handles data stream model events. Implements a protocol to exchange large blocks of data with other CSRmesh devices. See Section 4.5.1 for more information.
app_fw_event_handler.c	Defines the handler functions for firmware events.
app_mesh_event_handler.c	Defines the handler functions for CSRmesh events.
app_watchdog_model.c	Implements the functions to handle watchdog model events.
battery_hw.c	Implements the routines to read battery level.
csr_mesh_switch.c	Implements all the entry functions such as `AppInit()`, `AppProcessSystemEvent()`, `AppProcessCsrMeshEvent()` and `AppProcessLmEvent()`. Handles events received from the hardware, CSRmesh network and firmware first. Contains handling functions for all the LM, CSRmesh and system events.
csr_mesh_switch_gatt.c	Implements routines for triggering advertisement procedures.
csr_mesh_switch_hw.c	Implements the abstract hardware interface to configure and control the peripherals on specific hardware.
csr_mesh_switch_util.c	Implements some utilities functions called by other handlers.
csr_ota_service.c	Implements the routines for handling the read/write access on the CSR custom-defined OTA Update Service.
gap_service.c	Implements routines for GAP Service such as handling read/write access indications on the GAP Service characteristics and reading/writing device name on NVM.
gatt_service.c	Defines routines for using GATT Service.
iot_hw.c	Implements the hardware interface to configure and control the peripherals on the CSRmesh development board.
mesh_control_service.c	Implements routines for handling read/write access on Mesh Control characteristics and for sending notifications of mesh device responses.
nvm_access.c	Implements the NVM read/write routines.

Table 3.1: Source Files

3.2. Header Files

Table 3.2 lists the header files.

File Name	Description
app_data_stream.h	Contains enumerations and function prototypes of the externally referred functions defined in app_data_stream.c
app_debug.h	Contains macro definitions for enabling debug prints.
app_fw_event_handler.h	Contains prototypes of the externally referred functions defined in app_fw_event_handler.c.
app_gatt.h	Contains macro definitions, user-defined data type definitions and function prototypes used across the application.
app_mesh_event_handler.h	Contains prototypes of the externally referred functions defined in app_mesh_event_handler.c.
app_watchdog_model.h	Contains macros and function prototypes for externally referred functions defined in app_watchdog_model.c
appearance.h	Contains the appearance value macro of the application.
battery_hw.h	Contains prototypes of the externally referred functions defined in battery_hw.c.
csr_mesh_switch.h	Contains data structures and prototypes of the externally referred functions defined in the csr_mesh_switch.c file.
csr_mesh_switch_gatt.h	Contains timeout values and prototypes of the externally referred functions defined in the csr_mesh_switch_gatt.c file.
csr_mesh_light_hw.h	Contains the function declarations for controlling the hardware interfaces.
csr_mesh_light_util.h	Contains prototypes of the externally referred functions defined in the csr_mesh_light_util.c file.
csr_ota_service.h	Contains prototypes of the externally referred functions defined in the csr_ota_service.c file.
csr_ota_uuids.h	Contains macros for UUID values for CSR OTA Update Service.
gap_conn_params.h	Contains macro definitions for fast/slow advertising, preferred connection parameters, idle connection timeout values etc.
gap_service.h	Contains prototypes of the externally referred functions defined in the gap_service.c file.
gap_uuids.h	Contains macros for UUID values for GAP Service.
gatt_service_uuids.h	Contains macros for UUID values for GATT Service.
iot_hw.h	Contains the function declarations for controlling the hardware interfaces.
mesh_control_service.h	Contains prototypes of the externally referred functions defined in the mesh_control_service.c file.
mesh_control_service_uuids.h	Contains macros for UUID values for Mesh Control Service.

ota_customisation.h	Customised definitions for the integration of CSR OTA Update functionality with the application.
user_config.h	Contains macros for customising the application.

Table 3.2: Header Files

3.3. Database Files

The SDK uses database files to generate an attribute database for the application. For instructions about how to write database files, see the *GATT Database Generator User Guide*.

Table 3.3 lists the database files.

File Name	Description
app_gatt_db.db	Masters database file including all service specific database files. Is imported by the GATT Database Generator.
csr_ota_db.db	Contains information related to CSR OTA Update Service characteristics, their descriptors and values. For more information about CSR OTA Update Service characteristics, see Table A.3.
gatt_service_db.db	Contains information related to GATT Service characteristics, their descriptors and values. For more information about GATT Service characteristics, see Table A.1.
gap_service_db.db	Contains information related to GAP Service characteristics, their descriptors and values. For more information about GAP Service characteristics, see Table A.2.
mesh_control_service.db	Contains information related to CSRmesh Control Service characteristics, their descriptors and values. For more information about CSRmesh Control Service characteristics, see Table A.4.

Table 3.3: Database Files

4. Code Overview

This sections describes the significant functions of the application.

4.1. Application Entry Points

4.1.1. AppInit()

This function is invoked when the application is powered on or the chip resets. It performs the following initialisation functions:

- Initialises the application timers, hardware and application data structures.
- Configures GATT entity for server role.
- Configures the NVM manager to use I²C EEPROM.
- Initialises all the services.
- Reads the persistent storage. Sets a random device UUID based on Bit[3] of `CS_USER_KEY 1` setting when the application runs for the first time.
- Initialises the CSRmesh stack:
  - Configures CSRmesh bearer parameters and initialises the CSRmesh Scheduler:

    ```
    CSRSchedSetConfigParams(params)
    CSRSchedStart()
    ```
  - Registers an application call-back function for handling core mesh events: `CSRmeshRegisterAppCallback(CSRmeshAppProcessMeshEvent)`
  - Initialises the Core Stack: `CSRmeshInit()`
  - Initialises the supported model server and client modules.
- Registers the attribute database with the firmware.

4.1.2. AppProcessLmEvent()

This function is invoked whenever a LM-specific event is received by the system. Section 4.1.2.1 to section 4.1.2.5 describes the events handled by this function.

4.1.2.1. Database Access

- `GATT_ADD_DB_CFM`: This confirmation event marks the completion of database registration with the firmware. On receiving this event, the application starts advertising.
- `GATT_ACCESS_IND`: This indication event is received when the CSRmesh control device tries to access an ATT characteristic managed by the application.

4.1.2.2. LS Events

- `LS_CONNECTION_PARAM_UPDATE_CFM`: This confirmation event is received in response to the connection parameter update request by the application. The connection parameter update request from the application triggers the L2CAP connection parameter update signalling procedure. See Volume 3, Part A, Section 4.20 of the *Bluetooth Core Specification Version 4.1*.
- `LS_CONNECTION_PARAM_UPDATE_IND`: This indication event is received when the remote central device updates the connection parameters. On receiving this event, the application validates the new connection parameters against the preferred connection parameters and triggers a connection parameter update request if the new connection parameters do not comply with the preferred connection parameters.
- `LS_RADIO_EVENT_IND`: This radio event indication is received when the chip firmware receives an acknowledgement for the Tx data sent by the application. On receiving this event, the application aligns the timer wakeup, which sends data periodically to the collector with the latent connection interval.

4.1.2.3. LM Events

- `LM_EV_ADVERTISING_REPORT`: This event is received when an advertisement packet is received. This can be a CSRmesh advertisement. The application passes the event data to the CSRmesh library to process the packet by calling the `CSRSchedHandleIncomingData()` API.
- `LM_EV_CONNECTION_COMPLETE`: This event is received when the connection with the master is considered to be complete and includes the new connection parameters.
- `LM_EV_DISCONNECT_COMPLETE`: This event is received on link disconnection. Disconnection can be locally triggered or triggered by the remote connected device due to link loss.
- `LM_EV_ENCRYPTION_CHANGE`: This event indicates a change in the link encryption.
- `LM_EV_CONNECTION_UPDATE`: This event indicates that the connection parameters are updated to a new set of values and is generated when the connection parameter update procedure is either initiated by the master or slave. These new values are stored by the application for comparison against the preferred connection parameter, see Section6.1

4.1.2.4. SMP Events

- `SM_SIMPLE_PAIRING_COMPLETE_IND`: This indication event indicates that pairing completes successfully or otherwise. See Volume 3, Part H, Section 2.4 and Section 3.6 of the *Bluetooth Core Specification Version 4.1*.

4.1.2.5. Connection Events

- `GATT_CONNECT_CFM`: This confirmation event indicates that the connection procedure completes. If it does not successfully complete, the application goes to the idle state and waits for a user action. For more information about application states, see Section 0. If the application is bonded to a device with resolvable random address and the connection is established, the application tries to resolve the connected device address using the IRK stored in NVM. If the application fails to resolve the address, it disconnects the link and restarts advertising.
- `GATT_CANCEL_CONNECT_CFM`: This confirmation event confirms the cancellation of the connection procedure. When the application stops advertisements to change advertising parameters or to save power, this signal confirms the successful stopping of advertisements by the CSRmesh application.

4.1.3. AppProcessSystemEvent()

This function handles the system events such as a low battery notification or a PIO change. The CSRmesh applications currently handle the following system events:

- `sys_event_pio_changed`: This event indicates a change in PIO value. Whenever the user presses or releases the button, the corresponding PIO value changes and the application receives a PIO changed event and takes the appropriate action.

4.1.4. CSRmeshAppProcessMeshEvent ()

This function handles the CSRmesh core stack events received from the CSRmesh network or caused by internal state change. Section 4.1.4.1 to Section 4.1.4.5 describes the events handled by the CSRmesh Switch application.

4.1.4.1. Network Association Messages

- `CSR_MESH_ASSOC_STARTED_EVENT`: This event is received when a CSRmesh Control application sends an association request to a light that is ready for association. The application starts blinking yellow to indicate that the association is in progress.
- `CSR_MESH_KEY_DISTRIBUTION`: This event is received when the CSRmesh Control device provides the network key used for all future messages to communicate on the network. The application switches the state to associate, switches the LED to indicate association completion and stores the association status on the NVM.
- `CSR_MESH_ASSOC_COMPLETE_EVENT/CSR_MESH_SEND_ASSOC_COMPLETE_EVENT`: One of these events is received when the association completes. The application updates the network association

state and stops the ready for association LED display. It disables the promiscuous state so that the device relays only known network messages.

- CSR_MESH_ASSOCIATION_ATTENTION_EVENT: This event is received when a CSRmesh Control application seeks the attention of the device. The application starts blinking green to display attention. The attention display is continued till timeout or the association state changes.
- CSR_MESH_CONFIG_RESET_DEVICE_EVENT: This event is received when a configuring device removes the device. The association with the network is removed and the application uses this event to clean up the model data and sets the device in ready for association state.
- CSR_MESH_BEARER_STATE_EVENT: This message is received when a configuring device sends a bearer state change message.

4.1.4.2. Device Configuration messages

- CSR_MESH_CONFIG_RESET_DEVICE_EVENT: This message is received when a configuring device wants to remove all CSRmesh network information from device. The application resets all the assigned model group IDs.

4.1.4.3. Device Information Messages

- CSR_MESH_OPERATION_REQUEST_FOR_INFO is received by the application for the following messages. It has sub events related to device information.
- CSR_MESH_GET_VID_PID_VERSTION_EVENT: This message is received when configuring device requests for Vendor Identifier, Product Identifier and Version number information from the device. The application sends this information to the library for transmission.
- CSR_MESH_GET_DEVICE_APPEARANCE_EVENT: This message is received when configuring device requests for device appearance information from the device. The application sends this information to the library for transmission.

4.1.4.4. Group Model Messages

- CSR_MESH_GROUP_SET_MODEL_GROUPID_EVENT: This message is received when the control device sets a new group ID to a supported model. The CSRmesh Switch application stores the assigned Group IDs in the Group ID list for the Model and saves it on the NVM.

4.1.4.5. Bearer Model Messages

- CSR_MESH_BEARER_STATE_EVENT: The application enables or disables the relay and promiscuous mode set in the message when this message is received

4.1.5. AppLightClientHandler

This function handles the CSRmesh Light responses received from the CSRmesh network, such as getting the light status or any other responses for Light model commands received over CSRmesh.

- CSRMESH_LIGHT_STATE: This response is received from the light device on a state change.

4.1.6. AppPowerClientHandler

This function handles the CSRmesh Power model events received from the CSRmesh network, such as setting the power state or any other responses for Power model commands sent over CSRmesh.

- CSRMESH_POWER_STATE: This response is received from the light device on a state change.

4.1.7. AppBatteryEventHandler

This function handles the CSRmesh Battery model events received from the CSRmesh network, such as getting the battery state or any other responses for Battery model commands sent over CSRmesh.

- CSRMESH_BATTERY_GET_STATE: This message is received when the control device queries the battery status. The application returns the current battery status.

4.1.8. AppAttentionEventHandler

This function handles the CSRmesh Attention model events received from the CSRmesh network, such as setting the attention state or any other responses for Attention model commands sent over CSRmesh.

- `CSRMESH_ATTENTION_SET_STATE`: This message is received when a control device requests the attention of a device in the network. The application blinks red when Attention state is set and resumes the last set light colour when the Attention state is reset.

4.1.9. AppDataServerHandler

This function handles the CSRmesh Data Stream model events received from the CSRmesh network when the device is in server role.

- `CSRMESH_DATA_STREAM_FLUSH`: This message is received when a Data stream Client wants to start sending a data stream or to indicate complete transmission of data in the current stream.
- `CSRMESH_DATA_STREAM_SEND`: This message is received when the next stream data block is received from the data stream client. The application verifies the type of message streamed and stores it to the device info string.
- `CSRMESH_DATA_BLOCK_SEND`: This message is received when a data stream client sends a single block of data.

4.1.10. AppDataClientHandler

This function handles the CSRmesh Data Stream model events received from the CSRmesh network when the device is in client role.

- `CSRMESH_DATA_STREAM_RECEIVED`: This message is received when the data stream server acknowledges the reception of a stream data block sent by the device using the `StreamSendData` function

4.1.11. AppWatchdogEventHandler

This function handles the CSRmesh Watchdog model events received from the CSRmesh network.

- `CSRMESH_WATCHDOG_SET_INTERVAL`: The application changes the watchdog message interval and listening duration after sending the watchdog message when this message is received.

4.2. Internal State Machine for GATT Connection

Figure 4.1 shows the different state transition in the application during connection.

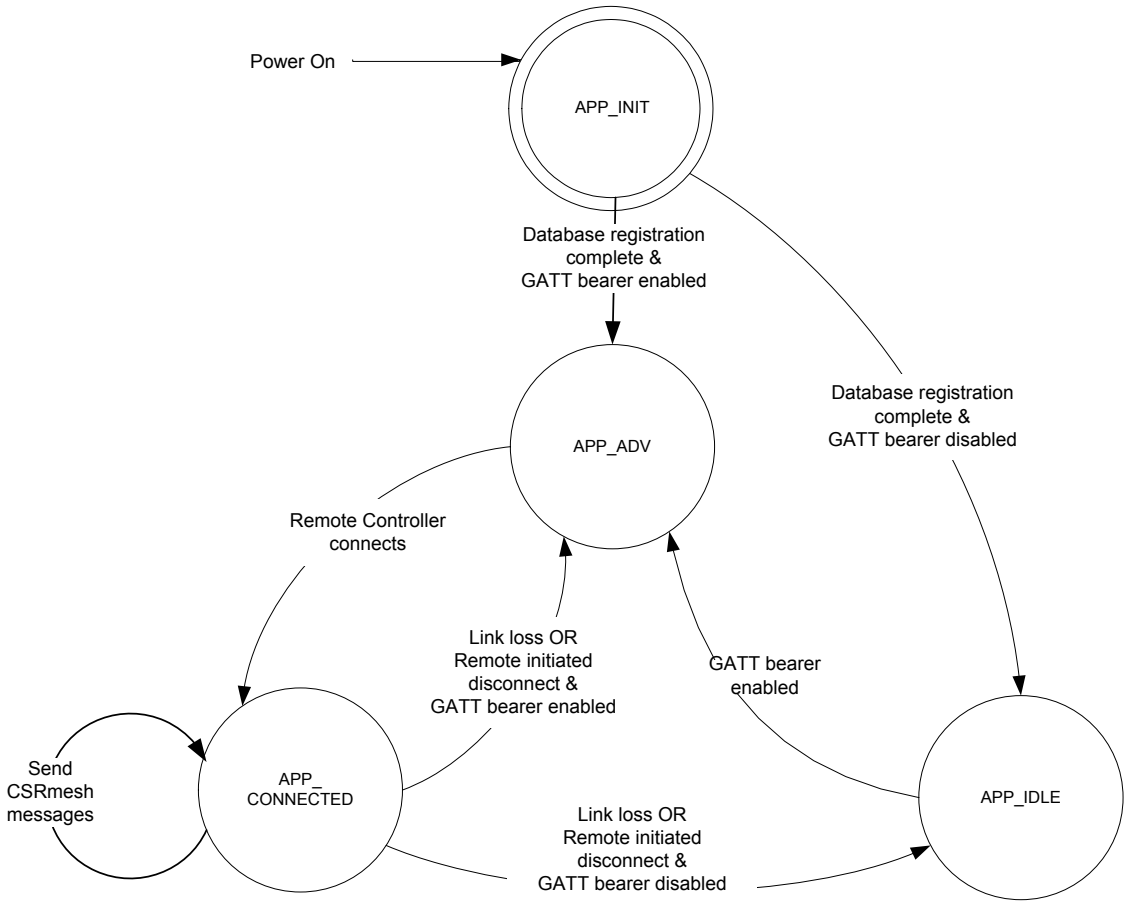


Figure 4.1: Internal GATT State Machine

4.2.1. app_state_init

When the application is powered on or the chip resets, it enters the `app_state_init` state. The application registers the service database with the firmware and waits for confirmation. On a successful database registration the application starts advertising if the GATT bearer is enabled. If GATT bearer is disabled, the application switches to the `app_state_idle` state.

4.2.2. app_state_advertising

The application starts in the `app_state_advertising` state and transmits connectable advertising events at an interval defined by `ADVERT_INTERVAL`. When a central device connects to it, the advertisements are stopped and the application enters the `app_state_connected` state. For more information about advertisement timers, see Section 6.1. If the GATT bearer is disabled in this state, the application switches to the `app_state_idle` state.

4.2.3. app_state_idle

The CSRmesh application enters the `app_state_idle` state when the GATT bearer is disabled and the application is not in the `app_state_connected` state.

4.2.4. app_state_connected

In the `app_state_connected` state, the CSRmesh application is connected to a CSRmesh Control device using connection intervals specified in Table 6.2. It can receive commands from Control device or send responses received over CSRmesh to control device.

- If link loss occurs and the GATT bearer is enabled, the application switches to the `app_state_advertising` state, otherwise it switches to the `app_state_idle` state.
- In the case of a remote triggered disconnection, the application switches to the `app_state_advertising` state if the GATT bearer is enabled, otherwise it switches to the `app_state_idle` state.

4.2.5. app_state_disconnecting

The CSRmesh application never triggers a disconnection on its own.

- If the disconnection is triggered, the application enters the `app_state_advertising` state if the GATT bearer is enabled, otherwise it switches to the `app_state_idle` state.

4.3. CSRmesh Association

The device needs to be associated with a CSRmesh network to communicate with other devices in the network. In CSRmesh 2.0, the application does not send device identification messages periodically by default. The UUID and AC of the device can be programmed to the device using the uEnergy Production Test Tool. The CSRmeshQRCodeScanner application generates the QR code corresponding to the known UUID and Authorization Code, see Figure 4.3. The CSRmesh mobile applications can be used to scan the QR code for initiating association with the device. For more information about device association, see *CSRmesh 2.0 Android Control Application Note* or *CSRmesh 2.0 iOS Control Application Note*.

Figure 4.2 shows the application association state machine.

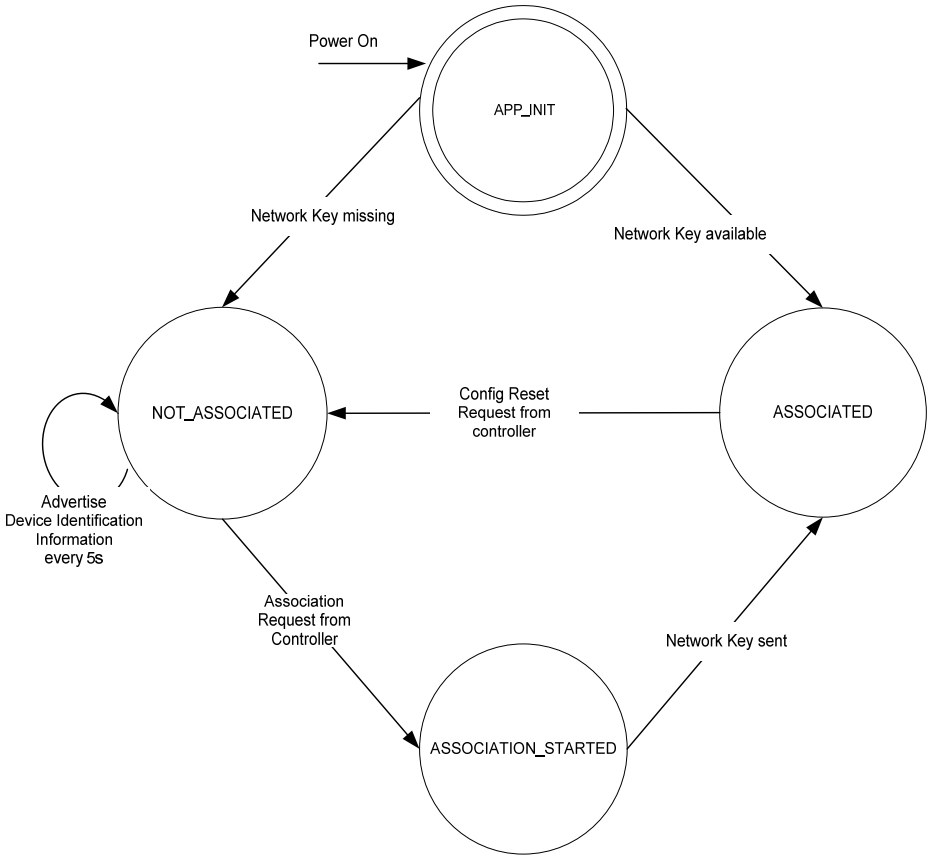


Figure 4.2: CSRmesh Association State Machine

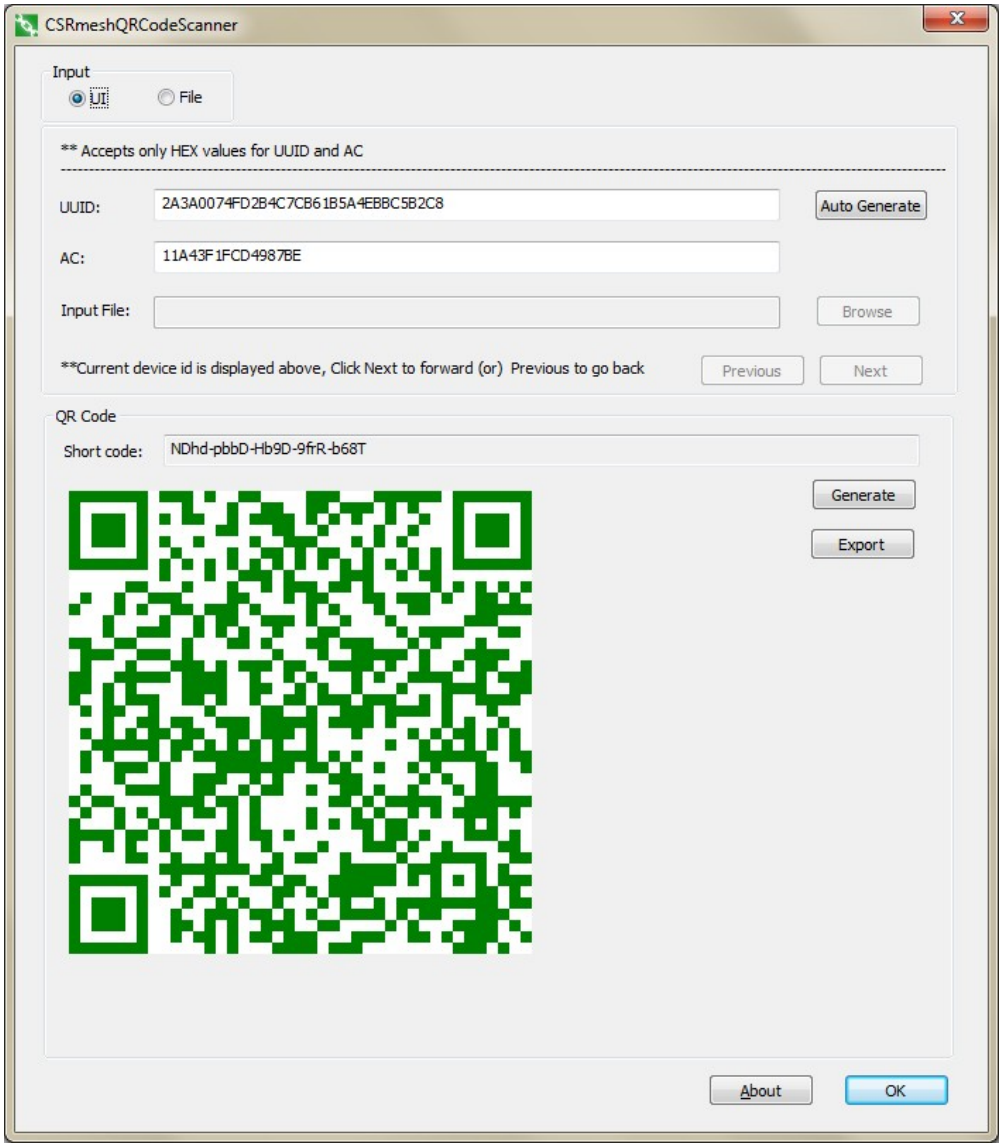


Figure 4.3: CSRmesh QR Code Scanner Application

4.3.1. app_state_not_associated

The first time the application is flashed on the device, it is in the `app_state_not_associated` state. The application is ready to associate with a CSRmesh network and sends the CSRmesh device UUID advertisements every 5 seconds.

4.3.2. app_state_association_started

The application enters the `app_state_association_started` state when receiving an association request from the control device.

4.3.3. app_state_associated

The application enters the `app_state_associated` state when association completes. The application disables the promiscuous mode on the BLE bearer once the association completes. The application saves the association state on the NVM and continues to be associated even after power cycle. The application switches to `app_state_not_associated` when receiving a `CSR_MESH_CONFIG_RESET_DEVICE`.

4.4. CSRmesh Models Supported

Table 4.1 lists the CSRmesh models that the Switch application supports.

CSRmesh Model	Application Action
Light Model	Sets the light level when the button is pressed.
Power Model	Sends power set commands to the assigned target device when the switch SW4 is toggled. Handles the `POWER_STATE` message received from the target device.
Battery Model	Upon receiving the `CSR_MESH_GET_BATTERY_STATE` message, the application reads the battery level and responds with the current battery level and state. The application is implemented with reference to the CSRmesh development boards that run on AA Batteries. So the application sets the `BATTERY_MODEL_STATE_POWERING_DEVICE` indicating that the device is battery powered. If the battery level is below the threshold, it sets the `BATTERY_MODEL_STATE_NEEDS_REPLACEMENT` bit.
Switch Model	Enables the Switch model. This allows the Control application to identify the device as a switch and to assign group IDs.
Watchdog Model	Enables a device to save power by periodically listening to CSRmesh network for a specified period of time. It also sends a message at the start of listening to notify other CSRmesh devices.
Data Stream Model	Enables the application to send and receive stream of bytes from another CSRmesh device.

Table 4.1: CSRmesh Models Supported

Note:

The CSRmesh Switch application supports groups for Switch, Data Stream and Watchdog models. It statically allocates memory to store the assigned group IDs and saves them on the NVM.

4.5. Synchronising with CSRmesh Activity

The CSRmesh Switch application can connect to the CSRmesh Control application in a bridge device role. The application must synchronise with the CSRmesh library to avoid collision of the advertisements and connection events with the CSRmesh activity. The application calls the CSRmesh APIs to synchronise the connection radio events and connectable advertisements with the CSRmesh library.

4.5.1. Application Connectable Advertising

The application sends connectable advertisements at regular intervals when the device is powered and not connected. The interval at which the advertising events are sent is defined by `ADVERT_INTERVAL`.

The application calls `CSRSchedSendUserAdv()` rather than the firmware API to send connectable adverts. This function schedules an application advertising event when called.

4.5.2. Connection Events

The application must notify the CSRmesh stack of the GATT connection events to schedule the CSRmesh activity:

- The application calls the `CSRSchedNotifyGattEvent(ucid, conn_interval)` to synchronise the CSRmesh library with the connection events. It is called in the following event handlers:
  - `LM_EV_CONNECTION_COMPLETE`
  - `LS_CONNECTION_PARAM_UPDATE_IND`
  - `LM_EV_DISCONNECT_COMPLETE`

4.6. Bearer State Management

The CSRmesh Switch application supports 2 bearers:

- GATT Bearer
- BLE Advertising Bearer

The application adopts the following policy with regard to the supported bearer state:

- Relay is always enabled on both the bearers unless disabled by the `CSR_MESH_BEARER_STATE_EVENT` message or by the CS User Key configuration, see section 6.7.
- When the device is not associated, the promiscuous mode is enabled on both bearers. This helps in relaying the messages authenticated by the network key that are addressed to other associated devices.
- Both relay and promiscuous modes are enabled when the device is connected as a GATT bridge. This means any message sent from the Control application over a GATT connection is relayed on the mesh promiscuously. This is useful because any device in the vicinity that supports bridge role, regardless of the association status and the network to which it is associated to, can be used as a bridge by the control device.
- The last configured bearer state is restored when the connection is terminated.

4.7. Application Data Stream Protocol

The application implements a protocol to transfer large blocks of data with another CSRmesh device on the network. Table 4.2 lists a message format that the application uses to exchange messages.

Message Code (1 octet)	Length (1 or 2 octets)	Data (0 – 32767 octets)
Identifies type of message. See Table 4.3 for supported messages.	Length of the data. ▪ If the MSB of the first octet is `0` then the length is only 7-bit value. ▪ If the MSB of the first octet is `1` then the length is a 15-bit value.	Data associated with the message

Table 4.2: Application Data Stream Message Format

Message	Code	Length	Data	Description
`CSR_DEVICE_INFO_REQ`	`0x01`	`0`	None	Requests device information. Can be sent as stream or a datagram message.
`CSR_DEVICE_INFO_RSP`	`0x02`	Variable (`1` to `32767`)	Device info	A text string containing information about device. Is sent over a stream. The application sends a text string containing information about supported CSRmesh features.
`CSR_DEVICE_INFO_SET`	`0x03`	Variable `(1 to 32767)`	Device info	A text/binary data stored on the device as device info. The application stores the data associated with this message as the device information and responds with this data for any further device info requests.
`CSR_DEVICE_INFO_RESET`	`0x04`	`0`	None	Resets the device info. The application returns the default string to any further device info requests.
	`0x05` to `0xff`			Undefined

Table 4.3: Application Data Stream Messages

5. NVM Map

Table 5.1 lists the parameters that the application stores in the NVM to prevent loss in the event of powering off or a chip panic.

Entity Name	Type	Size of Entity (Words)	NVM Offset (Words)
CSRmesh Stack NVM	uint16 array	32	0
CSRmesh Device UUID (This is part of 31 words of Stack NVM)	uint16 array	8	1
CSRmesh Device Authorisation Code (This is part of 31 words of Stack NVM)	uint16 array	4	9
Sanity Word	uint16	1	32
App NVM Version	uint16	1	33
CSRmesh Association State	boolean	1	34
Switch Level	uint16	1	35
Destination Device Address	uint16	1	36
Data Model Group IDs	Uint16 array	4	37
Watchdog Model Data	structure	2	41

Table 5.1: NVM Map for Application

Entity Name	Type	Size of Entity (Words)	NVM Offset (Words)
GAP Device Name Length	uint16	1	43
GAP Device Name	uint8 array	20	44

Table 5.2: NVM Map for GAP Service

Note:

The application does not pack data before writing it to the NVM. This means that writing a `uint8` takes one word of NVM memory.

5.1. Application NVM Version

Before reading the parameters in Table 5.1 and Table 5.2 from the NVM, the application reads the NVM version at word offset 1. In the case of an application update when the version number stored on the NVM does not match the defined `APP_NVM_VERSION`, the application re-initialises the NVM starting from Switch Level and stores the defined `APP_NVM_VERSION` at word offset 1.

Note:

The Device UUID, Authorisation Code, CSRmesh library data and association information are not reset, ensuring that the contents of the NVM are valid for the NVM offsets defined in the application. In case the NVM offsets of the parameters change upon an application update, this value can be incremented to invalidate the contents of the NVM.

6. Customising the Application

This section describes how to customise some parameters of the CSRmesh applications.

The developer can customise the application by modifying the following parameter values described in sections 6.1 to 6.7.

6.1. Advertisement Timers

The CSRmesh Switch application sends connectable advertisements when powered on and not connected. The application uses a timer to send a connectable advertising event at regular intervals. The advertising interval is defined in the `csr_mesh_switch_gatt.h` file.

Timer Name	Timer Value
`ADVERT_INTERVAL`	1250 ms ± (0~10) ms

Table 6.1: Advertisement Timers

6.2. Connection Parameters

The CSRmesh Switch application uses the connection parameters in Table 6.2 by default. The macros for these values are defined in the `gap_conn_params.h` file. These values are chosen by considering the overall current consumption of the device and optimum performance of the device in the CSRmesh network. CSR recommends not modifying these parameters. If the connection interval is set to less than 13 ms, the device is not able to scan for CSRmesh messages from the associated network but only messages received from the GATT connection. See the *Bluetooth Core Specification Version 4.1* for the connection parameter range.

Parameter Name	Parameter Value
Minimum Connection Interval	90 ms
Maximum Connection Interval	120 ms
Slave Latency	0 intervals
Supervision Timeout	6000 ms

Table 6.2: Connection Parameters

6.3. Device Name

The device name for the application can be changed. The default name is `CSRmesh` set in the `gap_service.c` file. The maximum length of the device name is 20 octets.

6.4. Device Address

The application uses a public address by default. The `USE_STATIC_RANDOM_ADDRESS` macro in the `user_config.h` file enables the support for static random addresses. If enabled, the application sets a new random address during the application initialisation during a power on reset.

6.5. Non-volatile Memory

The application uses one of the following macros to store and retrieve persistent data in either the EEPROM or Flash-based memory.

- `NVM_TYPE_EEPROM` for I²C EEPROM
- `NVM_TYPE_FLASH` for SPI Flash

Note:

The macros are enabled by selecting the NVM type using the Project Properties in xIDE. This macro is defined during compilation to let the application know which NVM type it is being built for. If EEPROM is selected, `NVM_TYPE_EEPROM` is defined. If SPI Flash is selected, the `NVM_TYPE_FLASH` is defined. Follow the comments in the `.keyr` file.

6.6. Application Features

Table 6.3 lists how to customise some parameters on the CSRmesh Switch application. The application can be configured by uncommenting the required definition in the `user_config.h` header file.

Configuration	Description
ENABLE_GATT_OTA_SERVICE	Enables the CSR OTA Update Service. If this feature is enabled, you can request for firmware update over the air using the CSR OTA Update tool.
DEBUG_ENABLE	Enables application debug logging on UART. The debug messages can be viewed on a HyperTerminal or any other terminal application by connecting the device to the PC and opening the corresponding COM Port with 2400-8-N-1 configuration. **Note:** If this feature is enabled, the brightness control function of the buttons SW2 and SW3 is disabled.
USE_AUTHORISATION_CODE	Enforces Authorisation code check on device during association. If this feature is enabled, the associating control device must have the same authorization code to associate the device to network. Enabled by default.
ENABLE_DEVICE_UUID_ADVERTS	If this feature is enabled, the application sends UUID adverts periodically with an interval defined in `DEVICE_ID_ADVERT_TIME`. Otherwise the device UUID adverts are not sent. Disabled by default.
ENABLE_DATA_MODEL	Enables data stream model to send/receive stream of octets to/from another CSRmesh device. If this features is enabled, the application supports streaming of device information string over the data model. The application uses a simple protocol to send and receive messages. See section 4.5.1 for more information.
ENABLE_WATCHDOG_MODEL	Enables watchdog model in the application. If this feature is enabled, the device listens only for a certain interval periodically to save power.
USE_STATIC_RANDOM_ADDRESS	If this features is enabled, the application uses static random address for sending connectable adverts.

Table 6.3: Application Configuration

6.7. Configuring the CSRmesh Parameters

The CS User Keys can be defined in the `.keyr` file to override the default CSRmesh parameters. The CSRmesh library sets the parameters based on the CS User Key values. Table 6.4 lists the recommended values for optimal performance of the devices over the CSRmesh network.

CS User Key Index	Parameter	Recommended Value	Description
0	CSRmesh Configuration Bitmask	`0000` to `0007`	Bit[0]: CSRmesh Relay Enable `1`: Enables relay of CSRmesh messages. `0`: Disables relay of CSRmesh messages. Bit[1]: CSRmesh Bridge Enable `0`: Disables connectable advertisements. `1`: Enables connectable advertisements. Disabling bridge leaves the device non connectable on any service. The connectable adverts can be enabled by sending a `CSR_MESH_BEARER_SET_STATE` message with the LE GATT server bearer bit set. Bit[2]: CSRmesh Random Device UUID Enable `1`: Enables generation of random device UUID. `0`: Reads the UUID from NVM. If this bit is set to 1, the application generates a random UUID and stores it in the NVM when running for the first time. This can be used to avoid having the same UUID on multiple devices without explicitly programming a UUID on each device. Bits[3:15] are ignored.

Table 6.4: Configuring CSRmesh Parameters

Appendix A CSRmesh Application GATT Database

A.1 GATT Service Characteristics

Characteristic Name	Database Handle	Access Permissions	Managed By	Security Permissions	Value
Service Changed	0x0003	Indicate	Application	Security Mode 1 and Security Level 1	Service Changed handle value
Service Changed Client Characteristic Configuration Descriptor	0x0004	Read, Write	Application	Security Mode 1 and Security Level 1	Current client configuration for Service Changed characteristic

Table A.1: GATT Service Characteristics

A.2 GAP Service Characteristics

Characteristic Name	Database Handle	Access Permissions	Managed By	Security Permissions	Value
Device Name	0x0007	Read Write	Application	Security Mode 1 and Security Level 1	Device name Default value: CSRmesh
Appearance	0x0009	Read	Firmware	Security Mode 1 and Security Level 1	Unknown: 0x0000
Peripheral Preferred Connection Parameters	0x000b	Read	Firmware	Security Mode 1 and Security Level 1	Connection interval: Minimum 90 ms Maximum 120 ms Slave latency: 0 Connection timeout: 6 s

Table A.2: GAP Service Characteristics

For more information about GAP Service and security permissions, see the *Bluetooth Core Specification Version 4.1*.

A.3 CSR OTA Update Application Service Characteristics

Characteristic Name	Database Handle	Access Permissions	Managed By	Security Permissions	Value
Current Application	0x000e	Read Write	Application	Security Mode 1 and Security Level 2	Current live application 0x0: OTA Update Bootloader 0x1: Identifies application 1 0x2: Identifies application 2
Read CS Block	0x0010	Write	Application	Security Mode 1 and Security Level 2	Format: uint16[2] Index 0: An offset in 16-bit words into the CS defined in the SDK documentation. Index 1: Size of the CS block expected in octets.
Data Transfer	0x0012	Read Notify	Application	Security Mode 1 and Security Level 2	This characteristic is ATT_MTU-3 (20)-bytes long. The format of the 20-bytes is defined by the message context.
Data Transfer Client Characteristic Configuration	0x0013	Read Write	Application	Security Mode 1 and Security Level 2	Current client configuration for Data Transfer characteristic
Version	0x0015	Read	Firmware	Security Mode 1 and Security Level 2	Service version Format: uint8

Table A.3: CSR OTA Update Application Service Characteristics

A.4 Mesh Control Service Characteristics

Characteristic Name	Database Handle	Access Permissions	Managed By	Security Permissions	Value
Network Key	0x0018	Write	Application	Security Mode 1 and Security Level 1	0
Device UUID	0x001a	Read	Application	Security Mode 1 and Security Level 1	22e4-b12c-5042-11e3-9618-ce3f-5508-acd9
Device ID	0x001c	Read Write	Application	Security Mode 1 and Security Level 1	0x8001
MTL Continuation Control Point	0x001e	Write	Application	Security Mode 1 and Security Level 1	Dynamic
MTL Continuation Control Point Client Characteristic Configuration	0x001f	Read Write	Application	Security Mode 1 and Security Level 1	Current client configuration for MTL Continuation Control Point characteristic
MTL Complete Control Point	0x0021	Write Notify	Application	Security Mode 1 and Security Level 1	Dynamic
MTL Complete Control Point Client Characteristic Configuration	0x0022	Read Write	Application	Security Mode 1 and Security Level 1	Current client configuration for MTL Complete Control Point characteristic
MTL TTL	0x0024	Read Write	Application	Security Mode 1 and Security Level 1	50
MESH Appearance	0x0026	Read Write	Application	Security Mode 1 and Security Level 1	0

Table A.4: Mesh Control Service Characteristics

Document References

Document	Reference
Bluetooth Core Specification Version 4.1	www.bluetooth.org/
CSR µEnergy Modifying an Application to Support OTA Update Application Note	CS-304564-AN
CSR µEnergy Over-the-Air (OTA) Update System Application Note	CS-316019-AN
CSR µEnergy xIDE User Guide	CS-212742-UG
CSRmesh 2.0 Android Controller Application Note	CS-337680-AN
CSRmesh 2.0 Gateway SB User Guide	CS-332701-UG
CSRmesh 2.0 iOS Controller Application Note	CS-337682-AN
CSRmesh 2.0 Mobile Application User Guide	CS-337051-UG
CSRmesh 2.0 Production Test Tool User Guide	CS-335123-UG
CSRmesh 2.0 Node API Guide	www.csrsupport.com
CSRmesh 2.0 Node Release Note	CS-339050-RN
CSRmesh Application 1.x to 2.0 Porting Guide	CS-335300-DC
GATT Database Generator	CS-219225-UG
Installing the CSR Driver for the Profile Demonstrator Application	CS-235358-UG
Over-the-Air Update Application and Bootloader Services Specification	CS-316220–SP
Service Characteristics And Descriptions	developer.bluetooth.org

Terms and Definitions

API	Application Programmer's Interface
BLE	Bluetooth Low Energy (now known as Bluetooth Smart)
Bluetooth®	Set of technologies providing audio and data transfer over short-range radio connections
CS	Configuration Store
CSR	Cambridge Silicon Radio
CSRmesh™	A CSR protocol that enables peer-to-peer-like networking of Bluetooth Smart devices
EEPROM	Electrically Erasable Programmable Read Only Memory
GAP	Generic Access Profile
GATT	Generic Attribute Profile
I^2C	Inter-Integrated Circuit
IoT	Internet of Things
IRK	Identity Resolving Key
LED	Light Emitting Diode
LM	Link Manager
MTL	Message Transport Layer
NVM	Non Volatile Memory
OTA	Over The Air
PC	Personal Computer
PCB	Printed Circuit Board
PIO	Programmable Input Output
PWM	Pulse Width Modulation
Rx	Receive
SDK	Software Development Kit
SPI	Serial Peripheral Interface
Tx	Transmit
USB	Universal Serial Bus
UUID	Universally Unique Identifier