



**802.15.4 MAC
User's Guide
For CC2538**

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1. Introduction

1.1. Scope

This document is a user's guide for Texas Instruments' TIMAC™ software and accompanying sample application. TIMAC is an implementation of the IEEE 802.15.4 MAC specification. The sample application demonstrates how devices can associate and transmit application data using the Texas Instruments TIMAC.

2. Product Package Description

2.1. Installation Package Contents

The downloaded TIMAC installation package contains all of the documentation and software required to install, configure, and develop applications using TIMAC. The package employs a Microsoft Windows™-based installation application which guides the installation process.

2.2. Development Boards

Two Texas Instruments [SmartRF06EB](#) evaluation boards, each fitted with a [CC2538EM](#) radio module, may be used to demonstrate or develop IEEE 802.15.4 applications based on the TIMAC software package. These boards provide a versatile development platform, including a graphical LCD display and various I/O devices (LEDs, buttons, light sensor, etc).

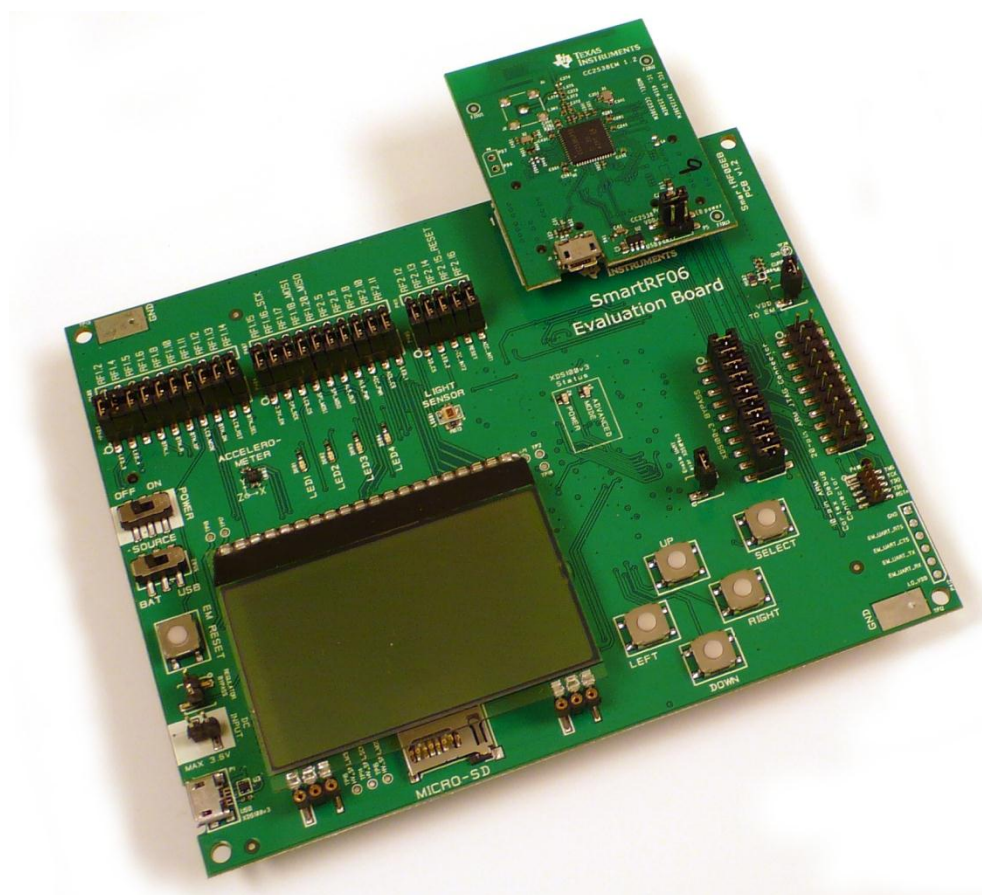


Figure 1: SmartRF06 Evaluation Board with CC2538EM

3. Installation Requirements

3.1. Development System Requirements

The TIMAC sample application projects for the CC2538 are used with the IAR Embedded Workbench (EWARM) suite of software development tools. These tools support project management, compiling, assembling, linking, downloading, and debugging for Cortex M3 based devices, including the CC2538SF53. Required support for TIMAC target software development:

- Texas Instruments [TIMAC](#)
- Two SmartRF06 Evaluation Boards [SmartRF06 Evaluation Board](#)
- Two CC2538EM radio modules [CC2538 Evaluation Module Kit](#)
- IAR Embedded Workbench for ARM <http://www.iar.com>

4. Product Installation Procedures

4.1. Install TIMAC Package

Install the Texas Instruments TIMAC files and programs from the downloaded package. Run the windows-based installation program, *TIMAC-x.x.x.exe* (substitute *x.x.x* for the version of installer that was downloaded), which will create the required directory structure and load all software and documentation files. Review the Release Notes file for a summary of new features and changes with this release.

4.2. Install IAR EWARM Package

Install the *Embedded Workbench for ARM* from IAR Systems: <http://www.iar.com>. The project and library files included in this release of TIMAC were built and tested with the EWARM version listed in the Release Notes. When considering use of a different version of EWARM, it will be necessary to verify that installed project and library files are compatible with those development tools.

4.3. CC2538EM Power Jumper

For normal operation of CC2538EM boards, a jumper should be placed on the VDD-EB Power pins (P5) as shown below. To measure the power consumption of the board, replace the jumper with a low value resistor, such as 2.2 ohms, and measure the voltage drop across the resistor.

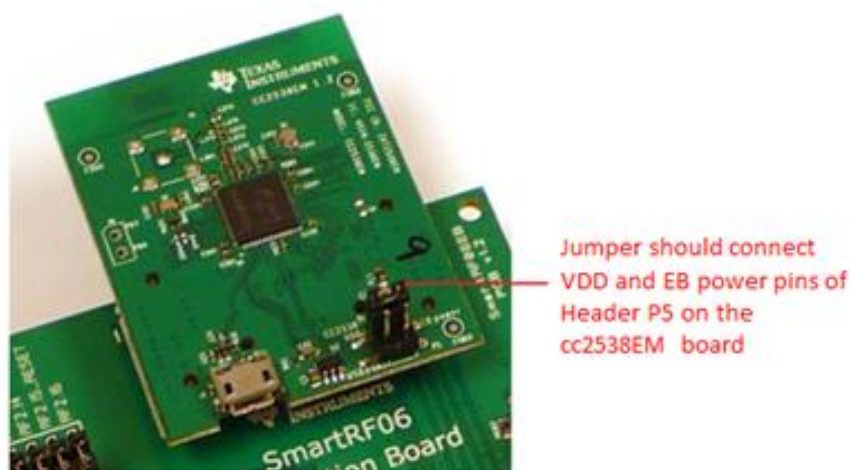


Figure 2: CC2538EM Power Jumper

4.4. Configuring a CC2531EM-based Packet Sniffer

A [CC2531EM](#) USB dongle can be used with Wireshark and TiWsPc and for capturing over the air packets for development and debug purposes. Wireshark is a widely used network protocol analyzer application that runs on various platforms, including Windows and Linux. TiWsPc is Packet Converter, when used with Wireshark, allows analysis of IEEE 802.15.4 packets used by the TIMAC product.

4.4.1. Programming Firmware on a CC2531EM

The CC2531EM comes pre-programmed with Packet Sniffer firmware from TI. If the sniffer firmware on the CC2531EM needs to be replaced, you will need a [CC-Debugger](#) and [SmartRF Flash Programmer](#) to program the CC2531EM. To obtain a copy of the CC2531 packet sniffer firmware, install [SmartRF Studio](#) -- after installation, the sniffer firmware will be located at:

C:\Program Files (x86)\Texas Instruments\SmartRF Tools\Packet Sniffer\bin\general\firmware file sniffer_fw_cc2531.hex.

4.4.2. Installing Wireshark and TiWsPc

- Install Wireshark from <http://www.gridmerge.com/download.html>
- TiWsPc gets installed as part of the TIMAC installation – the installer files are found at: *C:\Texas Instruments\TIMAC-x.x.x\Accessories\TiWsPc*
- It is very important to follow the instructions step by step in the TiWsPc Readme file: *Start->All Programs->Texas Instruments->TiWsPc->Readme*. These steps will enable Wireshark to capture over-the-air packets using TiWsPc and CC2531. The recommended data transfer method will be Pipe

4.4.3. Start TiWsPc before Wireshark

- It is required to start TiWsPc before starting Wireshark
- After starting TiWsPc, the window shown below will open. Select the **Use Pipe** option if you have selected the data transfer type to be Pipe (recommended). Otherwise, select the appropriate data transfer type:

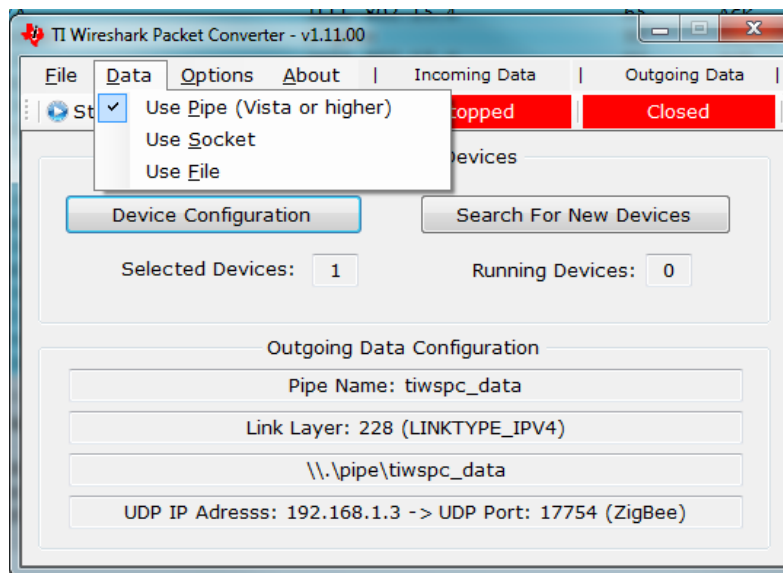


Figure 3: Select TiWsPc Data Transfer Option

- Press the **Device Configuration** button to display the window shown below. From the list, select the sniffer device(s) and associated channel(s). Then press **Start** for each selected device and then press **Done**

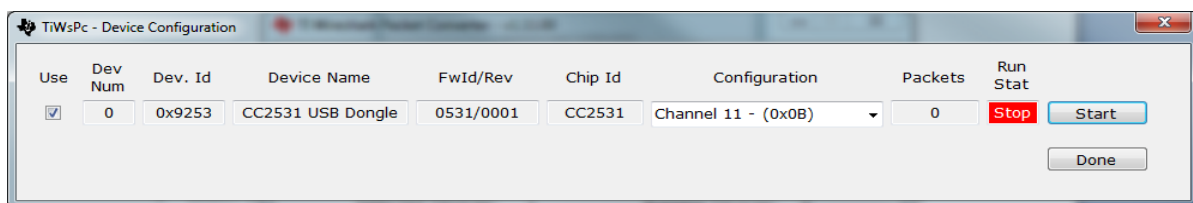


Figure 4: Configure TiWSPc Device

- After installing Wireshark (as explained in the TiWSPc Readme), create a new Wireshark shortcut on the PC desktop, and modify the "target:" adding " -i\\.\pipe\tiwspc_data -k" to the end. (Do not copy the quote marks!). Example target entry:
"C:\<your path here>\wireshark.exe" -i\\.\pipe\tiwspc_data -k
- Start WireShark by double-clicking the desktop shortcut
- When the network is started, as explained in the section 5, you should see the TIMAC over-the-packets displayed as shown below:

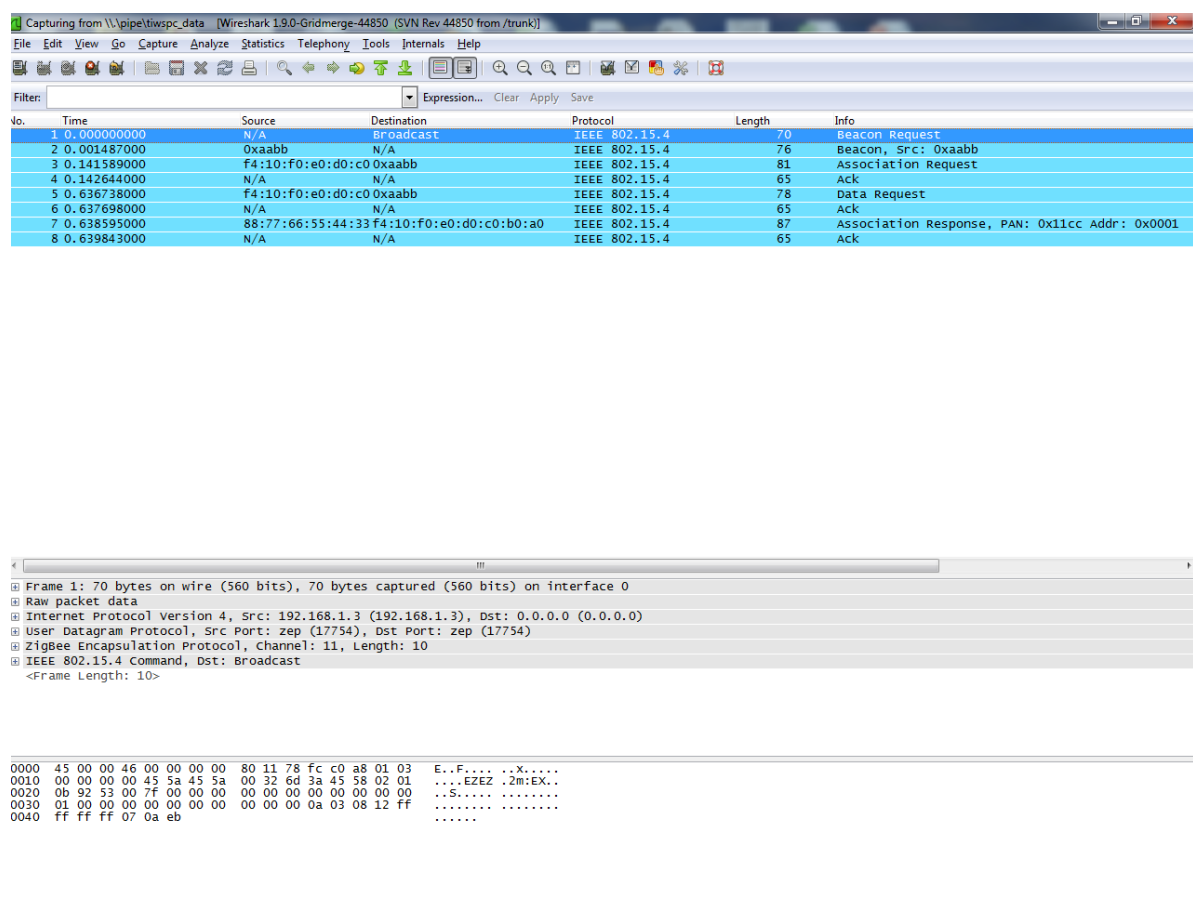


Figure 5: Wireshark Display of TIMAC Association Process Messages

5. Using the TIMAC Sample Application

The remainder of this document describes building and running the TIMAC sample application. The sample application demonstrates association between two IEEE 802.15.4 devices in a non-beaconed network and transmitting application data between the associated devices. The sample application supports 2 configurations – “Normal” and “Secure”. The “Normal” configuration can be used when message encryption is not necessary and the “Secure” configuration provides IEEE 802.15.4 security features. For proper operation of the sample application described in this document, all devices must be programmed to use the same IEEE 802.15.4 channel (see Section 6) and security configuration. In the tutorial that follows, the “Normal” configuration is shown but the user can substitute “Secure” if desired.

5.1. Building the Sample Application

- Make sure all software and tools have been installed (Sections 4.1 and 4.2)
- Navigate to the sample application project directory:
C:\Texas Instruments\TIMAC-x.x.x\Projects\mac\sample\cc2538\IAR Project

PLEASE NOTE: The ‘x.x.x’ in ‘TIMAC-x.x.x’ above must be substituted with the version of the installer that was downloaded.

- Launch the IAR Embedded Workshop and select the **msa_cc2538.eww** file:

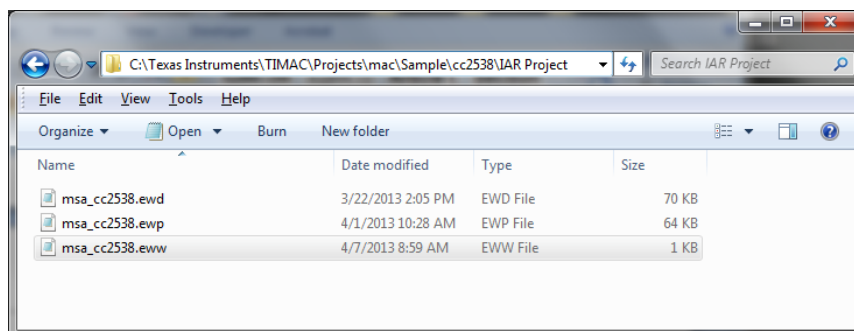


Figure 6: Launch the Sample Application Project

- Select the **Normal** configuration from the **Workspace** pull-down menu. In this example, the non-secure configuration for the **msa_cc2538** application is selected:

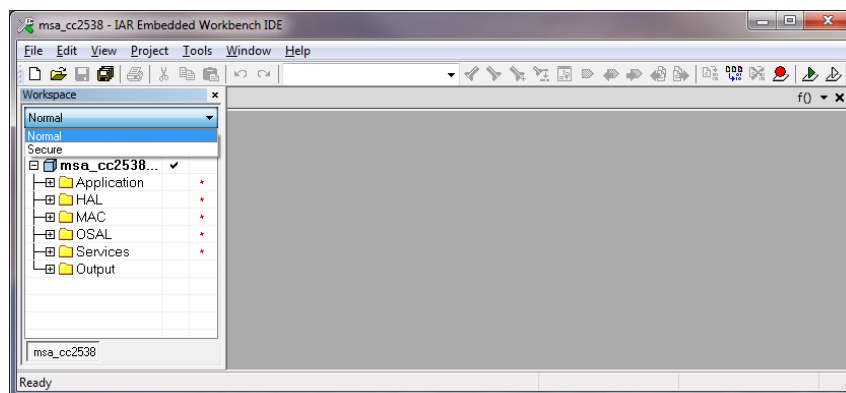


Figure 7: Select a Sample Application Configuration

- Build the application - pull down the **Project** menu and click on **Rebuild All**:

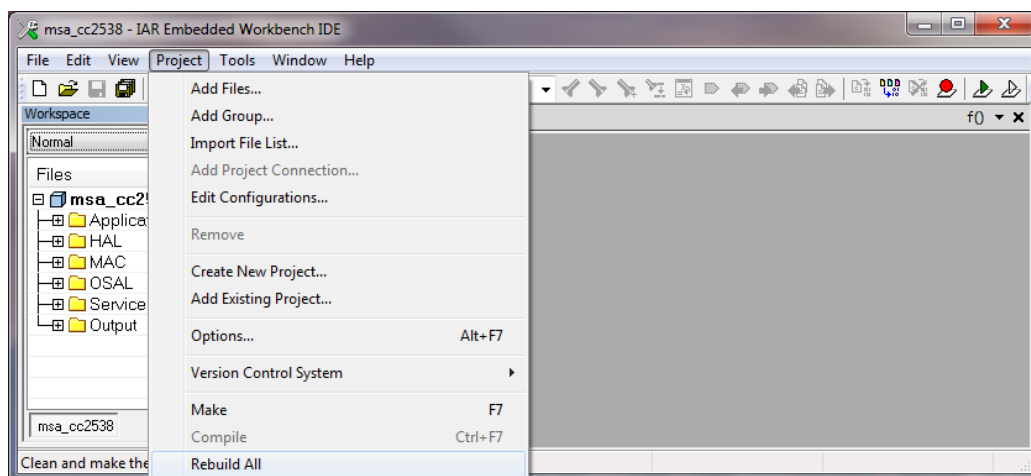


Figure 8: Build the Sample Application

- Connect the SmartRF06 Evaluation Board to the development PC with a USB cable - plug the cable into the USB connector (P1) located at the lower left corner (next to the LCD).
- If this is the first time TIMAC is being downloaded to the CC2538EM, erase the flash memory - pull down the **Project** menu and click on **Download->Erase Memory**:

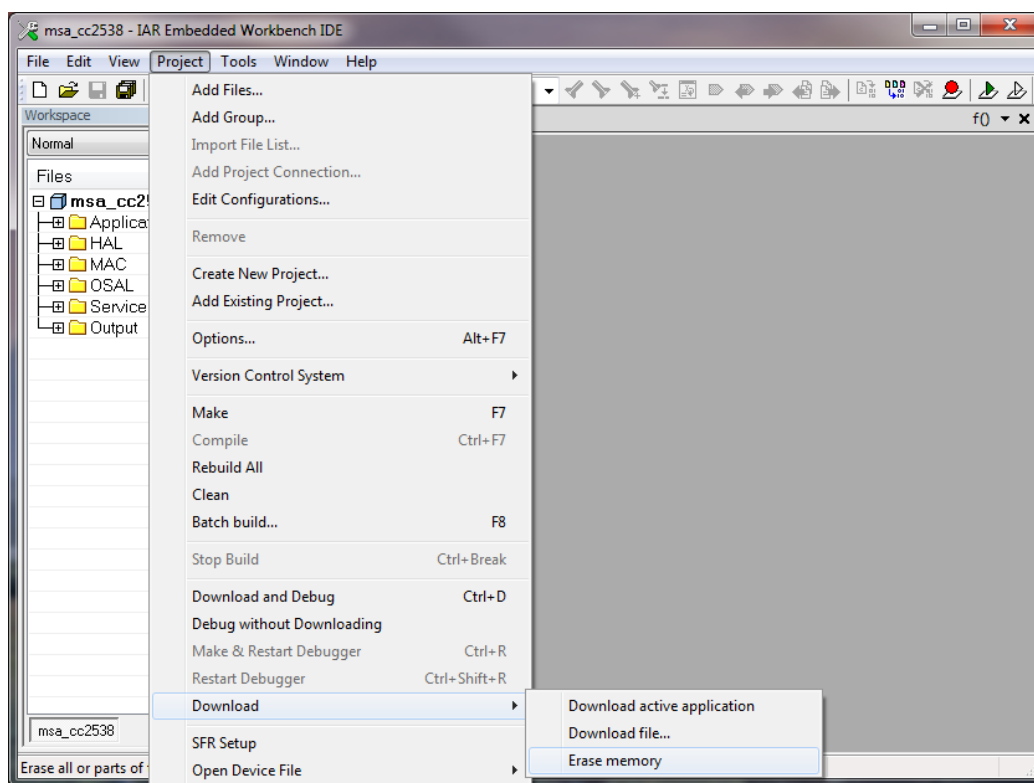


Figure 9: Erase CC2538EM Flash Memory

- The first time that EWARM is used to with a CC2538EM, the following error may be seen:

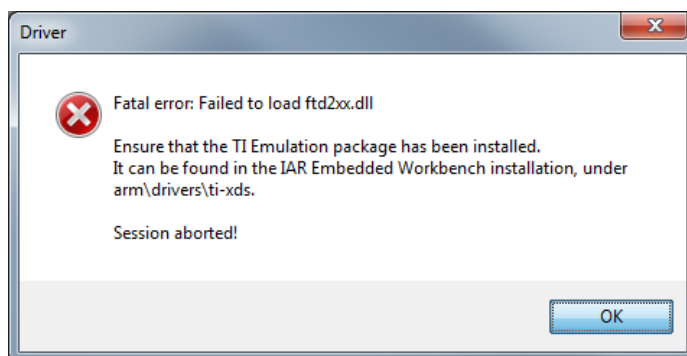


Figure 10: XDS100 Driver Error

- Hit the **OK** button to clear the error
 - Go to: *C:\Program Files (x86)\IAR Systems\Embedded Workbench 6.5\arm\drivers\ti-xds*
 - Run the TI Emulation Package installer, **ti_emupack_setup.exe**
 - Repeat the attempt to erase the CC2538EM flash memory
- Download the application - pull down the **Project** menu and click **Download and Debug**:

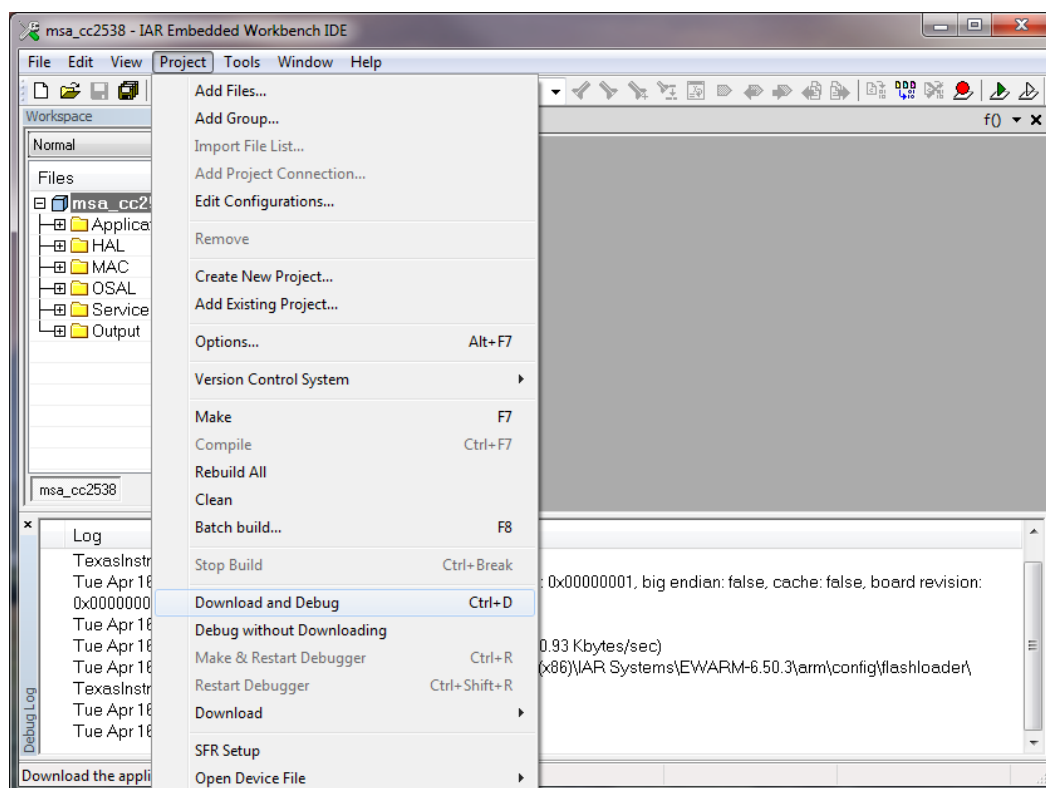


Figure 11: Download the Sample Application

- After downloading is complete, exit the debugger by pulling down the **Debug** menu and clicking on **Stop Debugging**:

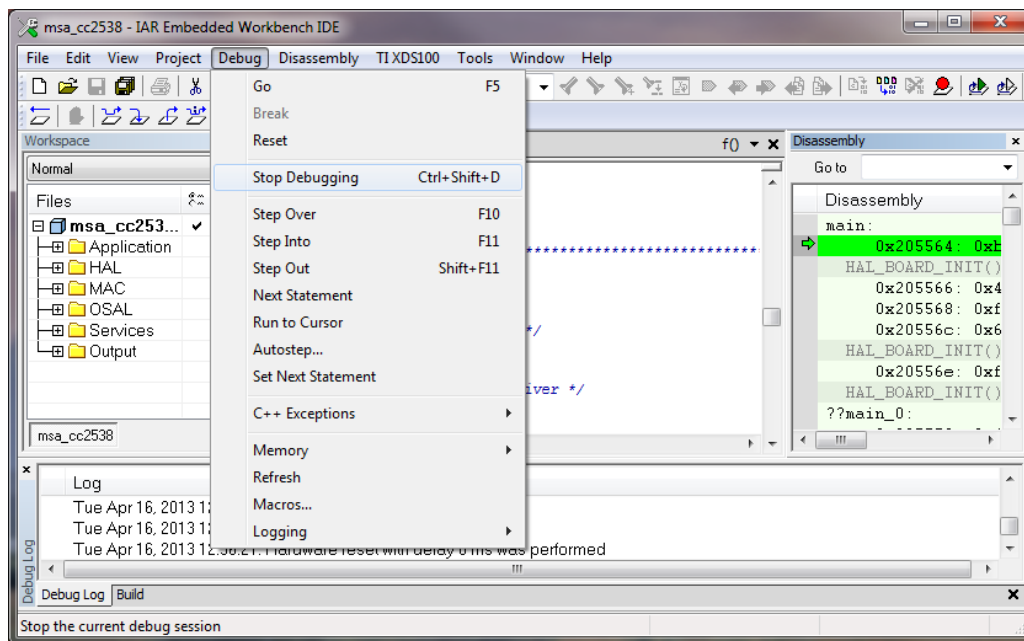


Figure 12: Exit Debugger to Finish Download

- Disconnect the SmartRF06+CC2538EM from the development PC and set it aside.
- Repeat the previous six steps to program more SmartRF06+CC2538EM boards.

5.2. Running the Sample Application

To begin execution of the TIMAC sample application, apply power to each programmed board and press the EM RESET button on each board. LED4 on each board should blink several times per second to indicate that it is waiting to start or join a network.

5.2.1. Starting a Network

Press the UP button on one of the boards. LED4 should stop blinking and stay lit. This device is now configured as IEEE 802.15.4 Coordinator. Label this board as the 'Coordinator'. If LED4 begins blinking, the device found an existing network to join and did not become a Coordinator. Press EM RESET again to reset the board and retry. If the problem persists, reprogram the boards to use a different radio channel (see Section 6).

5.2.2. Associating Devices

Press the UP button on the remaining boards. Their LED4 should begin blinking about once per second to indicate that they have associated to the Coordinator as End-Devices. Label these boards as 'End-Device'. At this point, a simple "star" network has been formed, with all devices waiting to send and/or receive data with their associated device.

5.2.3. Sending Application Data

After all devices have successfully associated, data can be transmitted between the Coordinator and End-Devices. To begin transmitting data, press the RIGHT button on the Coordinator. LED1

on the Coordinator toggles quickly, indicating that data is being transmitted. LED3 on the End-Devices toggles a little slower, indicating that data is being received.

Pressing the RIGHT button on a device while it is transmitting data stops the transmission. Press RIGHT on the Coordinator. LED1 stops blinking on the Coordinator (no data transmitted) and LED3 stops blinking on the End-Devices (no data received).

To transmit data to the Coordinator, press the RIGHT button on one End-Device. LED1 on that End-Device toggles quickly to indicate that data is being transmitted. LED3 on the Coordinator toggles a little slower to indicate that data is being received. Press RIGHT on remaining End-Devices to start data transmission – LED3 on the Coordinator toggles faster, indicating increased received data.

6. Channel Selection

The 802.15.4 specification defines 16 channels in the 2.4 GHz frequency range. These channels are assigned numbers 11 through 26. The TIMAC Sample Application defaults to channel 11, but the user can select a different channel by changing the `MSA_MAC_CHANNEL` in the **msa.h** header file. `MSA_MAC_CHANNEL` can be set to `MAC_CHAN_XX` where `XX` is a number from 11-26 indicating the desired channel.

Applicable Documents

TIMAC Documents

1. 802.15.4 MAC API, TI Document SWRA192
2. MAC Sample Application Design, TI Document SWRA200

Other Documents

3. IEEE Std 802.15.4-2006, Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs), September 8, 2006.