802.15.4 MAC
User's Guide
For CC2538

Texas Instruments, Inc.
San Diego, California USA

Version	Description	Date
1.0	Initial release	04/18/2013
1.1	Updated for 1.5.2 release	02/19/2015

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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).

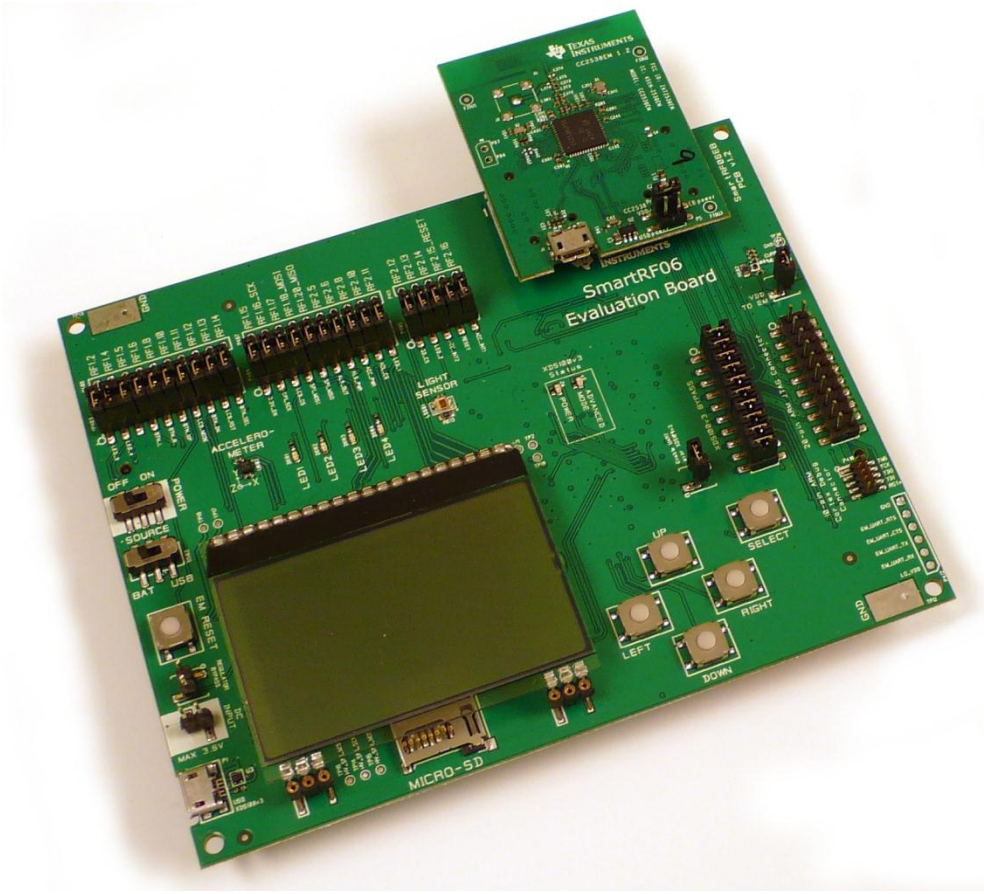


Figure 1: SmartRF06 Evaluation Board with CC2538EM

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.

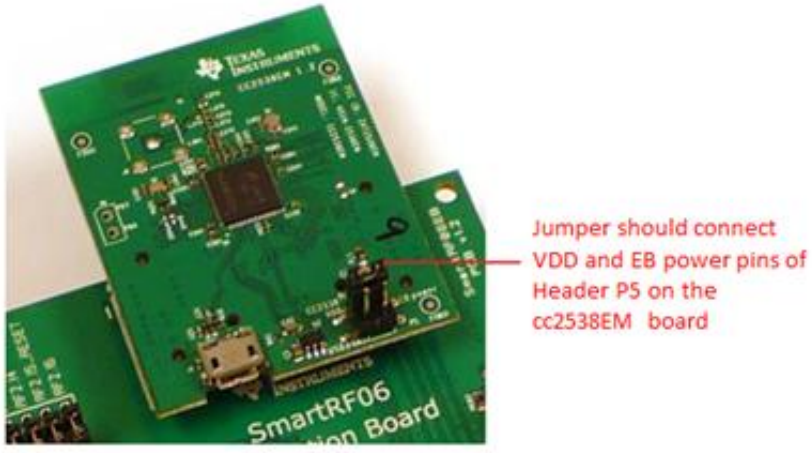


Figure 2: CC2538EM Power Jumper

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:

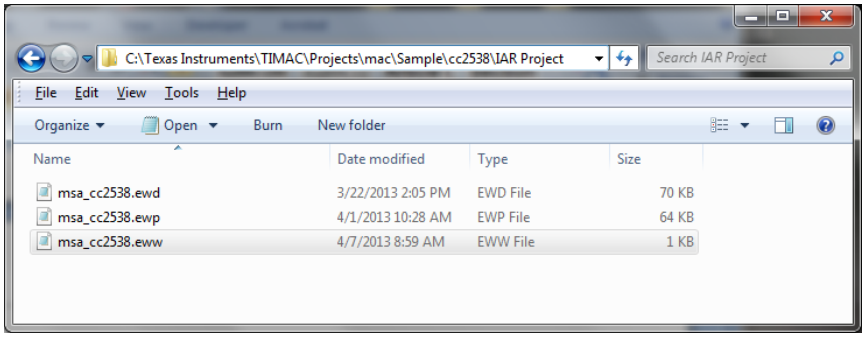


Figure 3: Launch the Sample Application Project

- For PAN Coordinator, select the **Normal-FFD** configuration from the ***Workspace*** pull-down menu. For End Device, select the **Normal-RFD** configuration from the ***Workspace*** pull-down menu. In this example, the non-secure FFD configuration for the ***msa_cc2538*** application is selected:

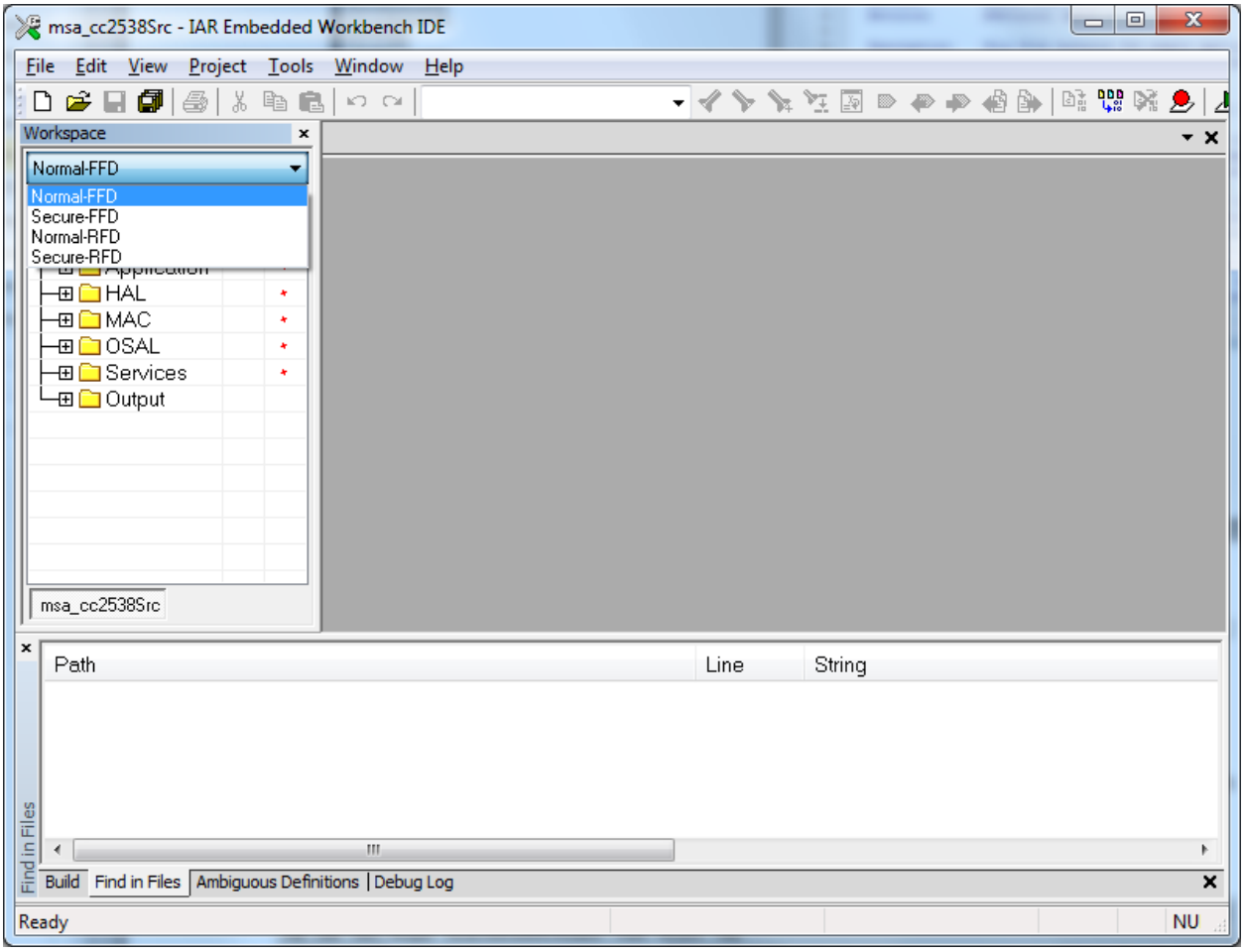


Figure 4: Select a Sample Application Configuration.

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

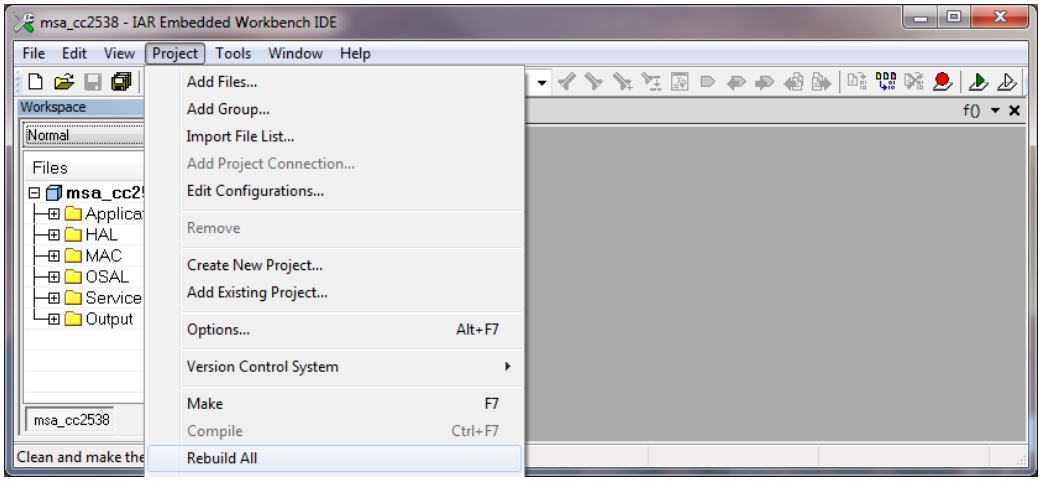


Figure 5: Build the Sample Application

- 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**:

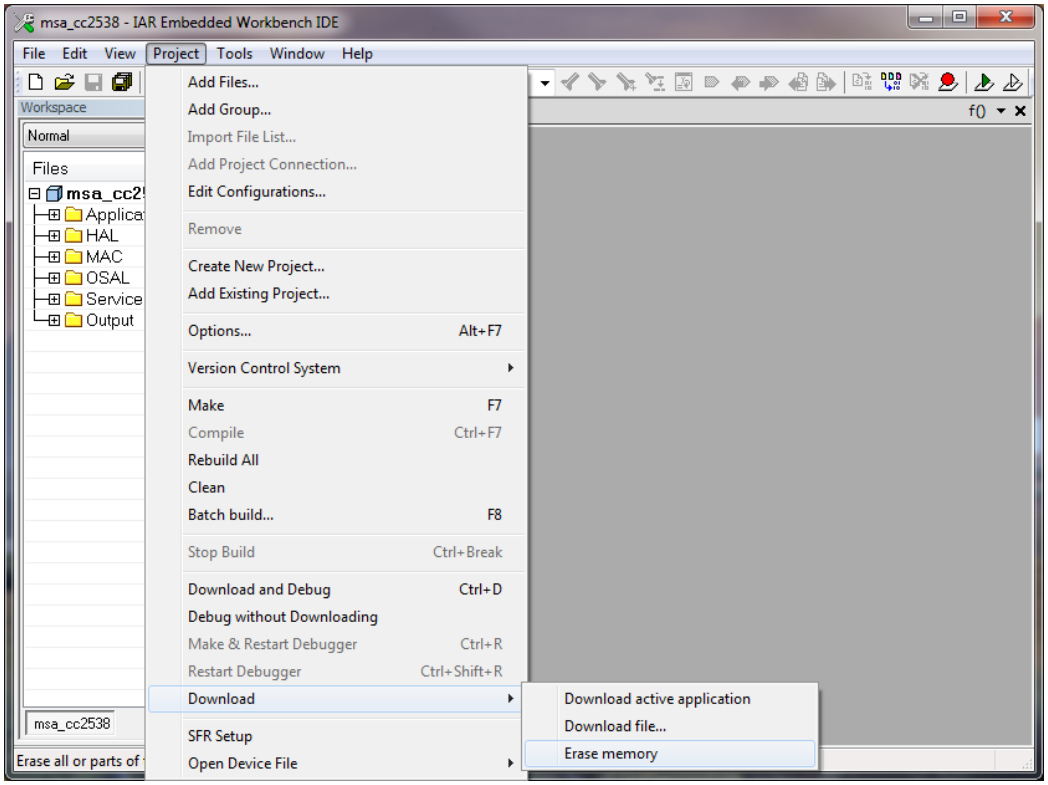


Figure 6: Erase CC2538EM Flash Memory

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

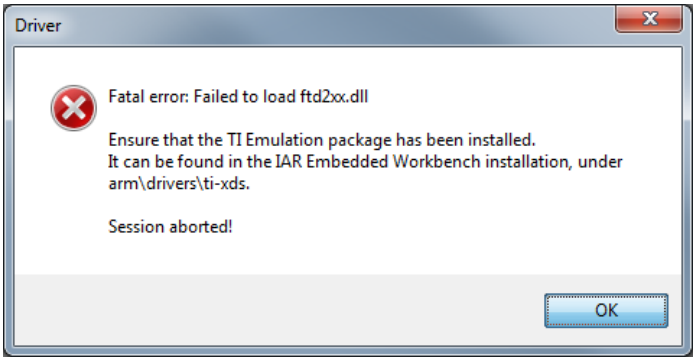


Figure 7: XDS100 Driver Error

  - 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**:

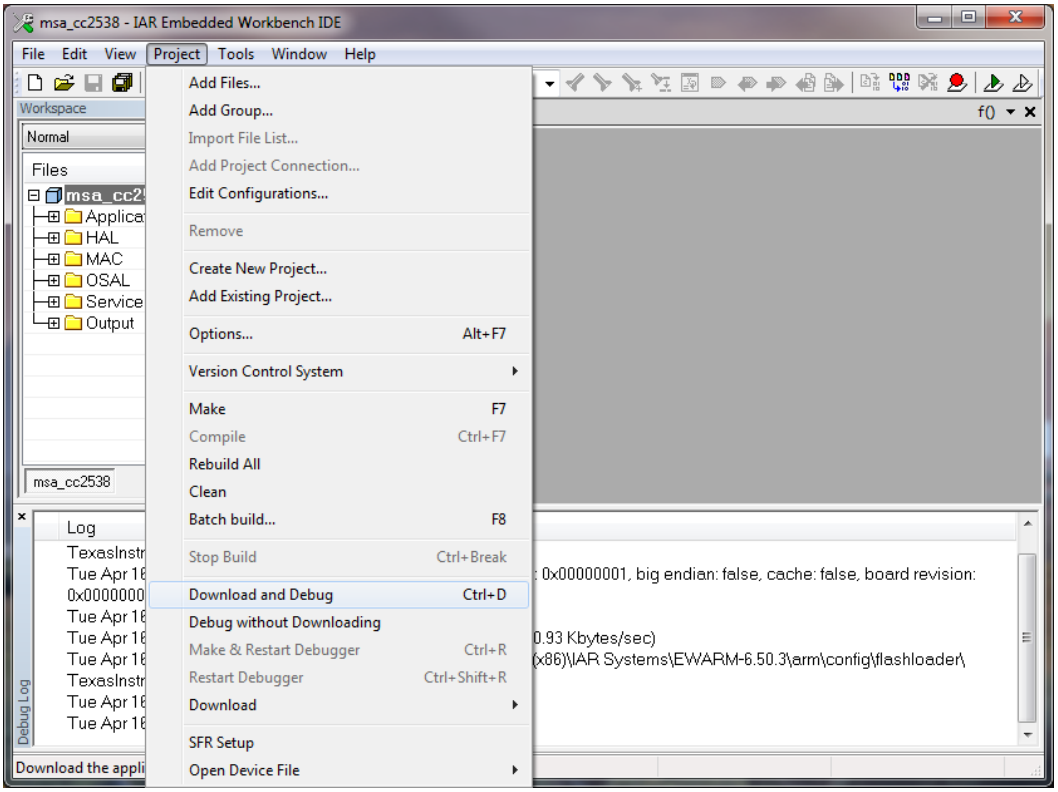


Figure 8: Download the Sample Application

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

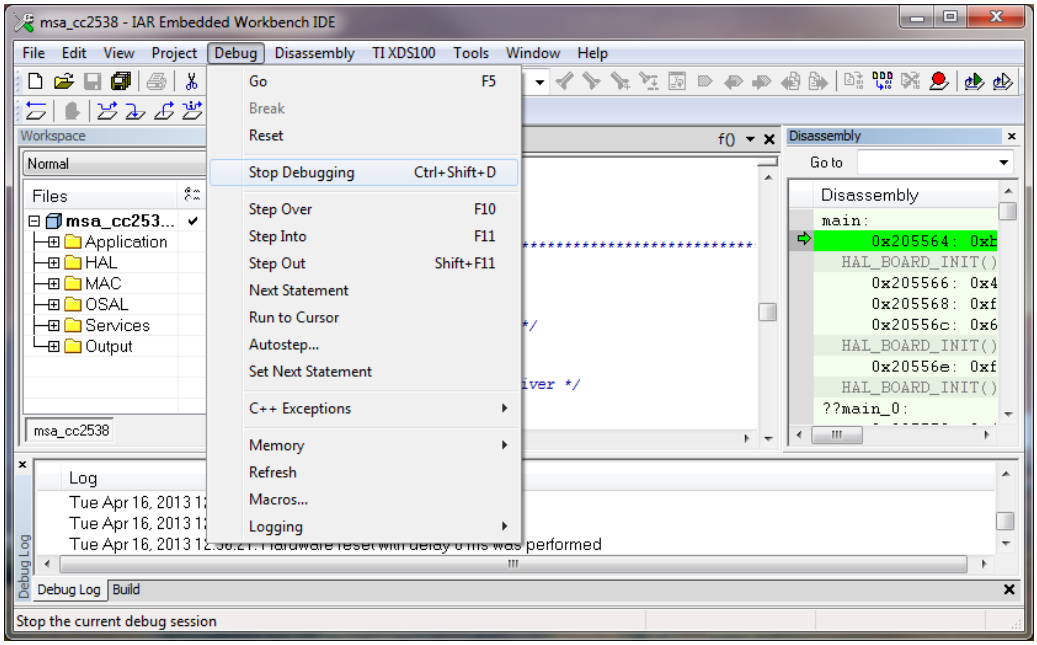


Figure 9: Exit Debugger to Finish Download

- 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 UP on the board flashed with FFD (in the example above Normal-FFD) image. 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 UP on the board on the board flashed with RFD (in the example above Normal-RFD). 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.

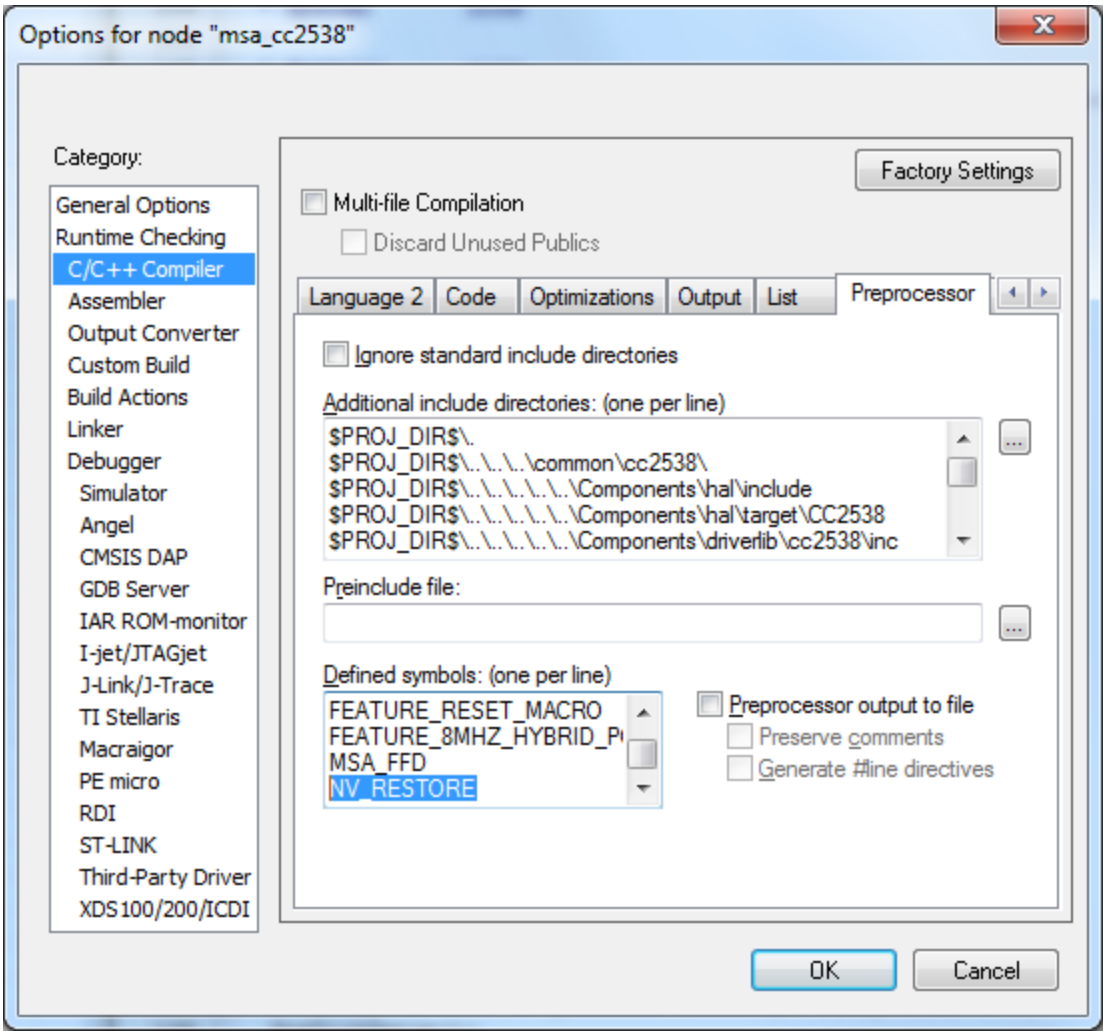
6. Channel Selection

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.

7. Non Volatile Restore

This feature allows the device to remember its settings even when power is turned off and turned back on. This is achieved by storing all the network settings of the device in Non Volatile memory. So, when the device loses power or is powered off and then powered back on, the settings are restored and the device behaves the same way as before.

- To enable this feature, go to Project->Options->C/C++Compiler->Defined Symbols and add NV_RESTORE
- To clear NV, i.e. reset device to default, turn off the device, hold SW_1 key and turn on the device. This should bring the device to its default configuration, before being on the network.



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.