



Digi XBee3[®] DigiMesh 2.4

RF Module

User Guide

Revision history—90002277

Revision	Date	Description
A	April 2018	Initial release.
B	September 2018	Added features for S2C parity.
C	April 2019	Added sleep support, file system, OTA file system updates, and several MicroPython features.

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- Firmware version
- Operating system/browser (if applicable)
- Logs (from time of reported issue)
- Trace (if possible)
- Description of issue
- Steps to reproduce

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About the XBee3 DigiMesh RF Module

The XBee3 DigiMesh RF Module consists of DigiMesh 2.4 firmware loaded on the XBee3 hardware. This user guide covers the firmware. For information about XBee3 hardware, see the [XBee3 RF Module Hardware Reference Manual](#).

Digi XBee3 devices offer the flexibility to switch between multiple frequencies and wireless protocols as needed. These devices use the DigiMesh networking protocol using a globally deployable 2.4 GHz transceiver. This peer-to-peer mesh network offers users added network stability through self-healing, dense network operation, extending the operational life of battery dependent networks and provides an upgrade path to IEEE 802.15.4 or ZigBee mesh protocols, if desired.

Digi's XBee3 DigiMesh RF Module is an easy-to-use USB to XBee Wireless Personal Area Network (WPAN) adapter, providing local connectivity to wireless networks. Simply plug the XBee3 DigiMesh RF Module into the USB port of a laptop or PC for instant access to an Digi XBee network and its connected devices. This compact, USB-powered wireless adapter enables local network configuration, diagnostics or device monitoring.

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Applicable firmware and hardware

This manual supports the following firmware:

- v.30xx DigiMesh

It supports the following hardware:

- XBee3

Change the firmware protocol

You can switch the firmware loaded onto the XBee3 hardware to run any of the following protocols:

- Zigbee
- 802.15.4
- DigiMesh

To change protocols, use the **Update firmware** feature in XCTU and select the firmware. See the [XCTU User Guide](#).

Regulatory information

See the [Regulatory information](#) section of the [XBee3 RF Module Hardware Reference Manual](#) for the XBee3 hardware's regulatory and certification information.

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Verify kit contents

The XBee3 DigiMesh RF Module development kit contains the following components:

Part	
XBee3 Zigbee SMT module (3)	
XBee Grove development board (3)	
Micro USB cable (3)	
Antenna - 2.4 GHz, half-wave dipole, 2.1 dBi, U.FL female, articulating (3)	
XBee stickers	

Assemble the hardware

This guide walks you through the steps required to assemble and disassemble the hardware components of your kit.

- [Plug in the XBee3 DigiMesh RF Module](#)
- [Unplug an XBee3 DigiMesh RF Module](#)

The kit includes several XBee Grove Development Boards. For more information about this hardware, see the [XBee Grove Development Board](#) documentation.

Plug in the XBee3 DigiMesh RF Module

Follow these steps to connect the XBee devices to the boards included in the kit:

1. Plug one XBee3 DigiMesh RF Module into the XBee Grove Development Board. When you connect the development board to a PC for the first time, the PC automatically installs drivers, which may take a few minutes to complete.

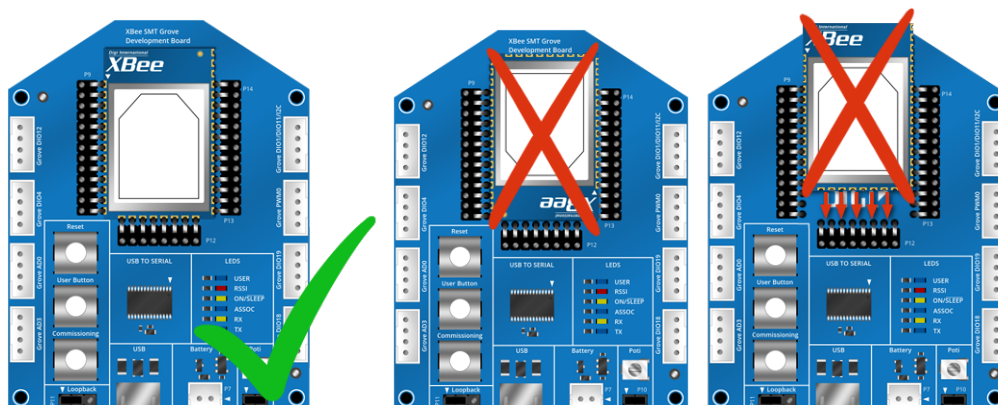


Make sure the board is NOT powered (either by the micro USB or a battery) when you plug in the XBee module.

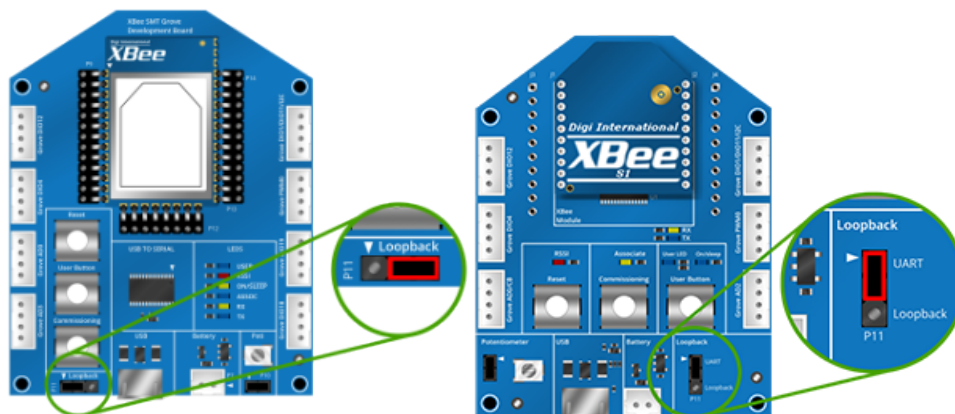
For XBee SMT modules, align all XBee pins with the spring header and carefully push the module until it is hooked to the board.



WARNING! Never insert or remove the XBee device while the power is on!



2. Once the XBee module is plugged into the board (and not before), connect the board to your computer using the micro USB cables provided.
3. Ensure the loopback jumper is in the UART position.



Unplug an XBee3 DigiMesh RF Module

To disconnect a device from the XBee Grove Development Board:

1. Disconnect the micro USB cable from the board so it is not powered.
2. Remove the device from the board socket, taking care not to bend any of the pins. The surface mount device uses spring pins rather than a socket and has a rectangular board cutout designed to help in removing the XBee3 DigiMesh RF Module.



CAUTION! Make sure the board is **not** powered when you remove the XBee3 DigiMesh RF Module.

Configure the device using XCTU

XBee Configuration and Test Utility ([XCTU](#)) is a multi-platform program that enables users to interact with Digi radio frequency (RF) devices through a graphical interface. The application includes built-in tools that make it easy to set up, configure, and test Digi RF devices.

For instructions on downloading and using XCTU, see the [XCTU User Guide](#).

Configure remote devices

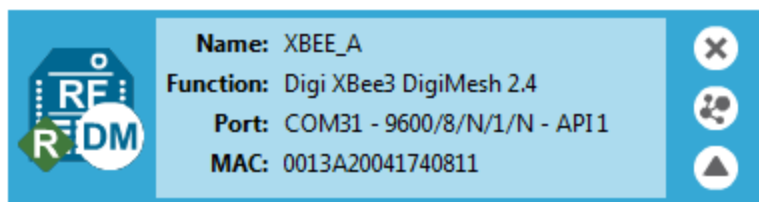
You can communicate with remote devices over the air through a corresponding local device.


Note Using API mode on the local device allows you to send remote API commands.

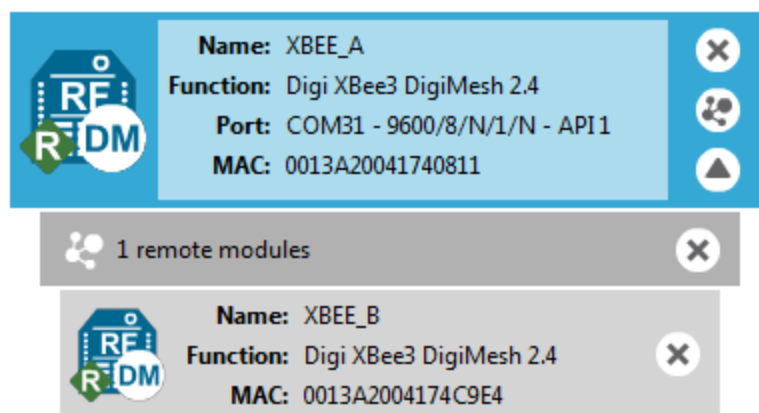
These instructions show you how to configure a remote device parameter on a remote device.

1. Add two XBee devices to XCTU.
2. Load XBee3 DigiMesh 2.4 firmware onto each device if it is not already loaded. See [How to update the firmware of your modules](#) in the *XCTU User Guide* for more information.
3. Configure the first device in API mode and name it **XBEE_A** by configuring the following parameters:
 - **ID:** 2018
 - **NI:** XBEE_A
 - **AP:** API enabled [1]
4. Configure the second device in either API or Transparent mode, and name it **XBEE_B** by configuring the following parameters:
 - **ID:** 2018
 - **NI:** XBEE_B
 - **AP:** 0 or 1

4. Disconnect XBEE_B from your computer and remove it from XCTU.
5. Connect XBEE_B to a power supply (or laptop or portable battery).
The **Radio Modules** area should look something like this.



6. Select **XBEE_A** and click the **Discover radio nodes in the same network** button .
7. Click **Add selected devices** in the **Discovering remote devices** dialog. The discovered remote device appears below XBEE_A.



9. Select the remote device **XBEE_B** to display its current configuration settings. If you want to modify a command parameter, use the radio configuration pane.
10. Click the **Write radio settings** button to apply any changes and write it to the remote device.

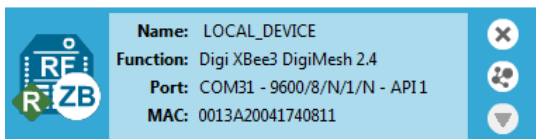
Configure the devices for a range test


1. Add two devices to XCTU.
2. Select the first module and click the **Load default firmware settings** button.
3. Configure the following parameters:
 - ID:** 2018
 - NI:** LOCAL_DEVICE
 - AP:** API Mode Enabled [1]
4. Click the **Write radio settings** button.
5. Select the other module and click the **Default firmware settings** button.
6. Configure the following parameters:
 - ID:** 2018
 - NI:** REMOTE_DEVICE

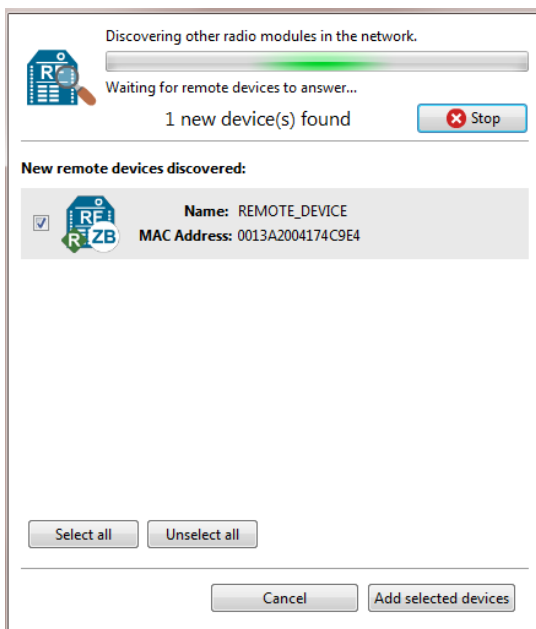
7. Click the **Write radio settings** button.
After you write the radio settings for each device, their names appear in the **Radio Modules** area. The Port indicates that the LOCAL_DEVICE is in API mode.
8. Disconnect REMOTE_DEVICE from the computer, remove it from XCTU, and connect it to a power supply, laptop, or portable battery.
9. Leave LOCAL_DEVICE connected to the computer.

Perform a range test


1. Go to the XCTU display for radio 1.

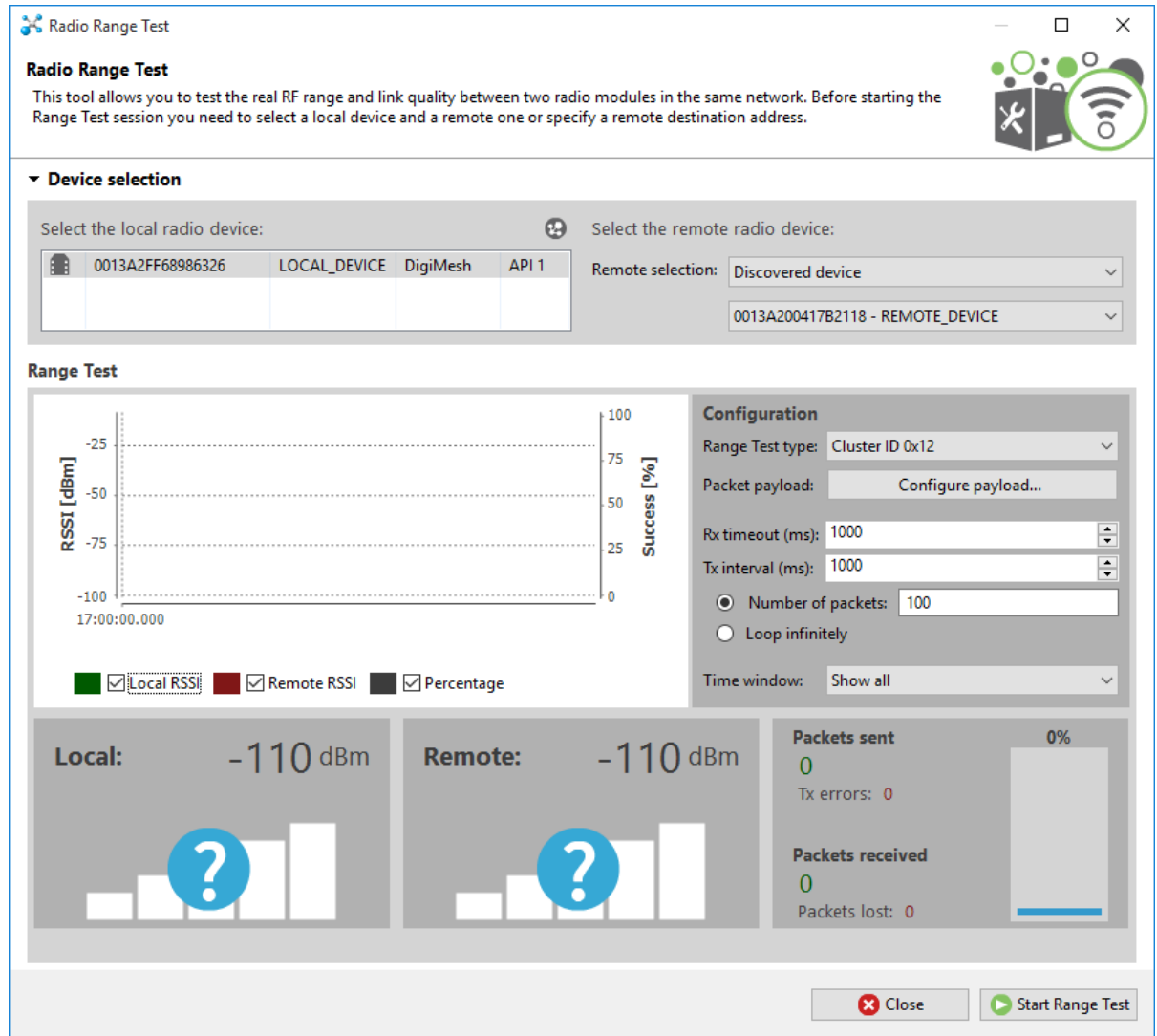


2. Click  to discover remote devices within the same network. The **Discover remote devices** dialog appears.



3. Click **Add selected devices**.

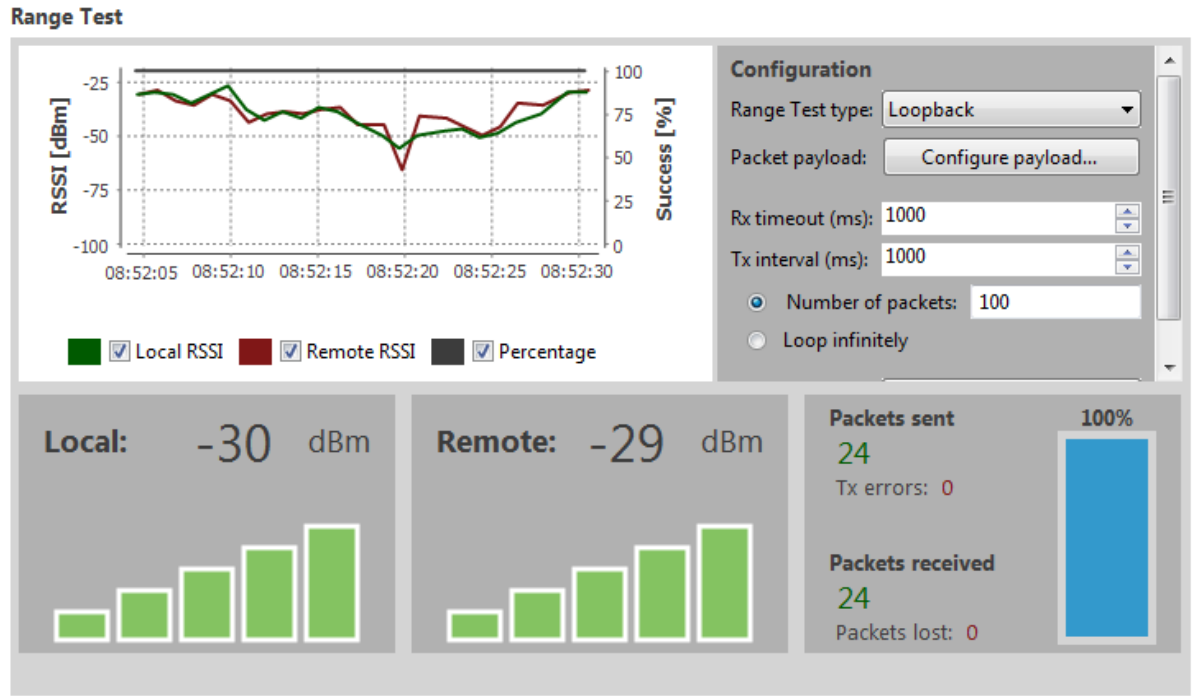
- Click  and select **Range test**. The **Radio Range Test** dialog appears.



- In the **Select the local radio device** area, select radio 1. XCTU automatically selects the **Discovered device** option, and the **Start Range Test** button is active.

6. Click **Start Range Test** to begin the range test.

If the test is running properly, the packets sent should match the packets received. You will also see the received signal strength indicator (RSSI) update for each radio after each reception.

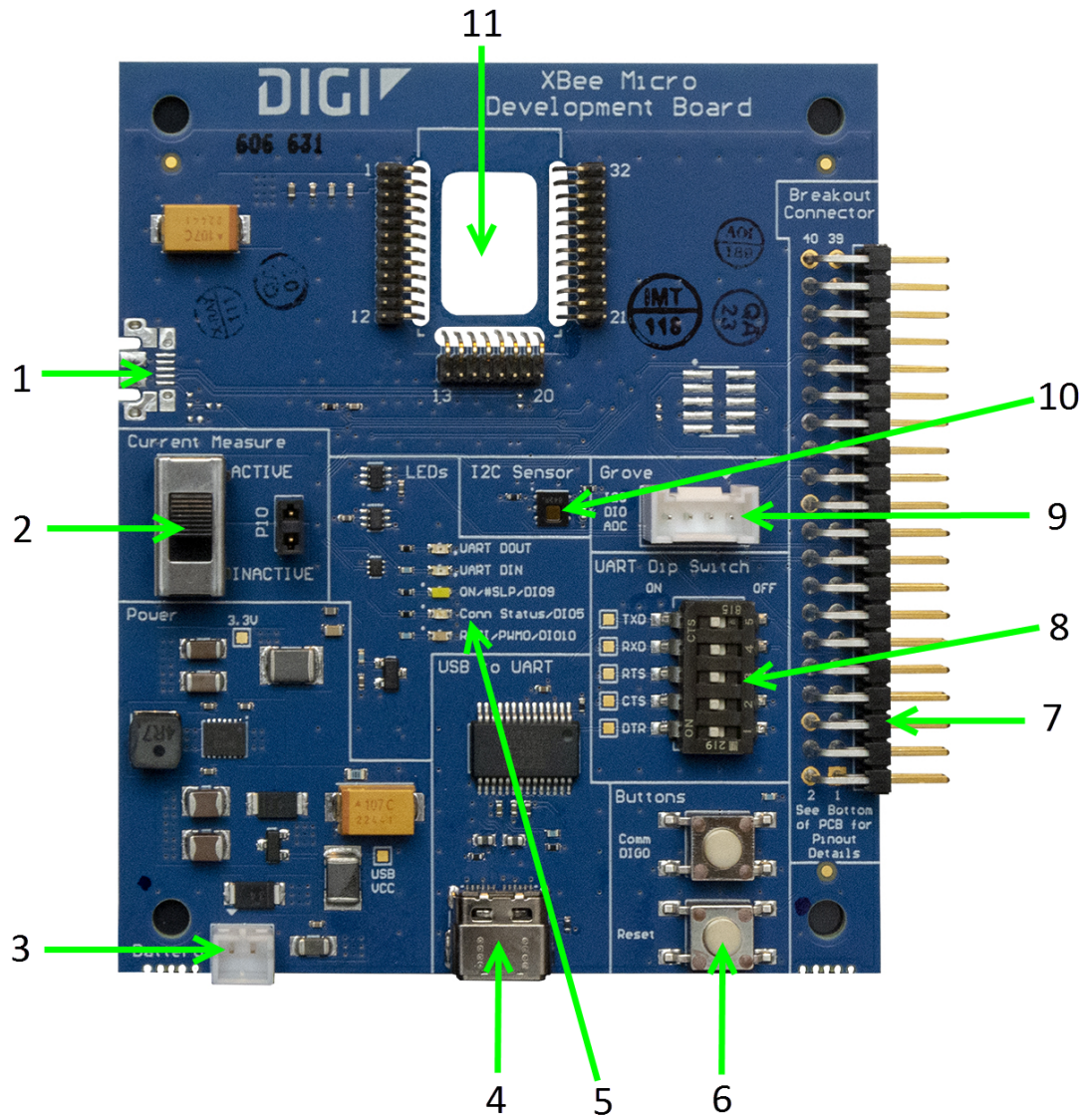


7. Move Radio 1 around to see the resulting signal strength at different distances. You can also test different power levels by reconfiguring the [PL \(TX Power Level\)](#) parameter on both devices.

XBIB-C Micro Mount reference

This picture shows the XBee-C Micro Mount development board and the table that follows explains the callouts in the picture.

Note This board is sold separately.

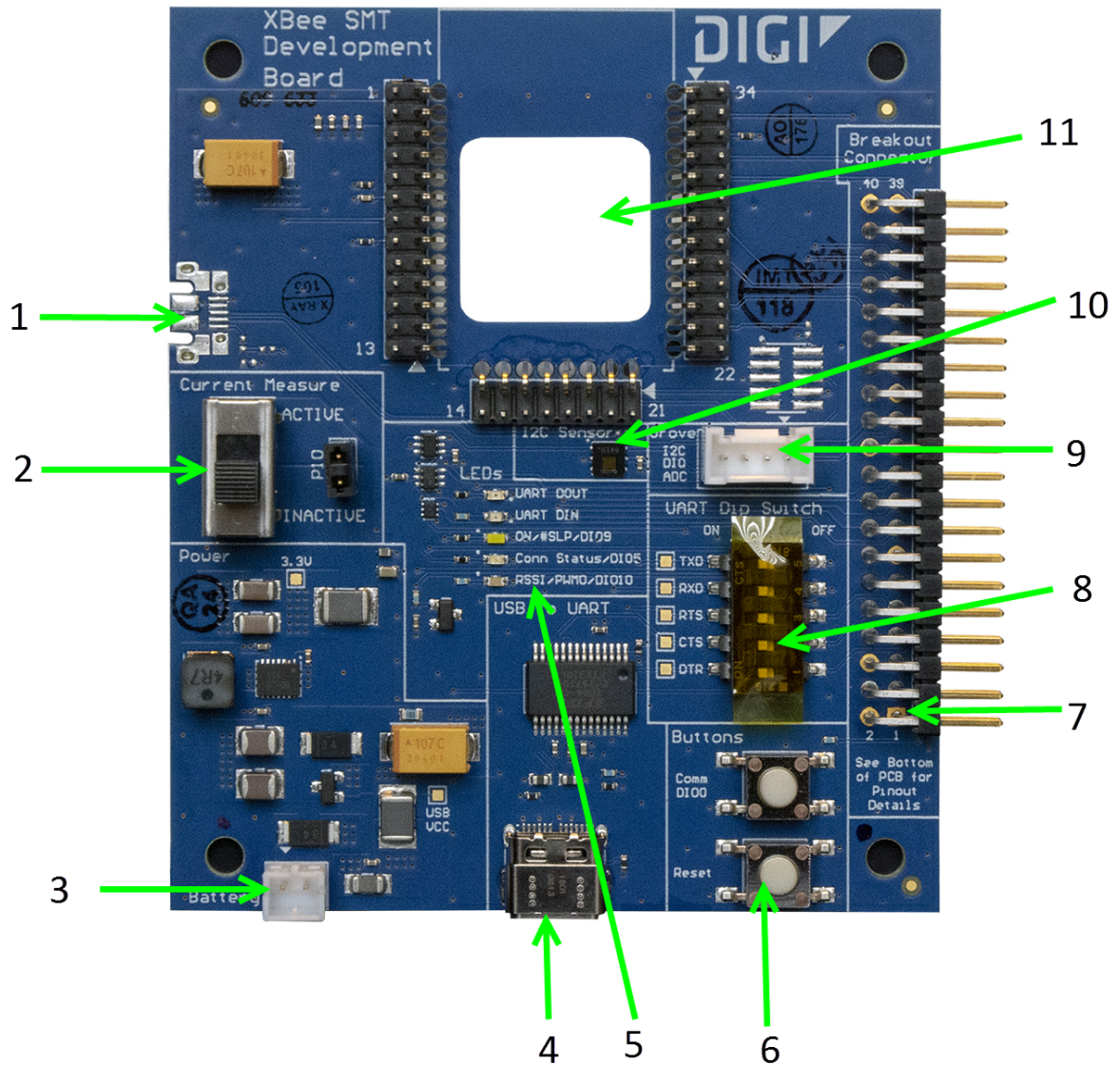


Number	Item	Description
1	Secondary USB (USB MICRO B)	Secondary USB Connector for possible future use. Not used.
2	Current Measure	Large switch controls whether current measure mode is active or inactive. When inactive, current can freely flow to the VCC pin of the XBee. When active, the VCC pin of the XBee is disconnected from the 3.3 V line on the development board. This allows current measurement to be conducted by attaching a current meter across the jumper P10.
3	Battery Connector	If desired, you can attach a battery to provide power to the development board. The voltage can range from 2 V to 5 V. The positive terminal is on the left.
4	USB-C Connector	Connects to your computer. This is connected to a USB to UART conversion chip that has the five UART lines passed to the XBee device. The UART Dip Switch can be used to disconnect these UART lines from the XBee.
5	LED indicator	Red: UART DOUT (modem sending serial/UART data to host) Green: UART DIN (modem receiving serial/UART data from host) White: ON/SLP/DIO9 Blue: Connection Status/DIO5 Yellow: RSSI/PWM0/DIO10
6	User Buttons	Comm DIO0 Button connects the Commissioning/DIO0 pin on the XBee Connector through to a 10 Ω resistor to GND when pressed. RESET Button Connects to the RESET pin on the XBee Connector to GND when pressed.
7	Breakout Connector	This 40-pin connector can be used to connect to various XBee pins as shown on the silkscreen on the bottom of the board.
8	UART Dip Switch	This dip switch allows the user to disconnect any of the primary UART lines on the XBee from the USB to UART conversion chip. This allows for testing on the primary UART lines without the USB to UART conversion chip interfering. Push Dip switches to the right to disconnect the USB to UART conversion chip from the XBee.
9	Grove Connector	This connector can be used to attach I2C enabled devices to the development board. Note that I2C needs to be available on the XBee in the board to use this functionality. Pin 1: I2C_CLK/XBee DIO1 Pin2: I2C_SDA/XBee DIO11 Pin3: VCC Pin4: GND
10	Temp/Humidity Sensor	This as a Texas Instruments HDC1080 temperature and humidity sensor. This part is accessible through I2C. Be sure that the XBee that is inserted into the development board has I2C if access to this sensor is desired.
11	XBee Socket	This is the socket for the XBee (Micro form factor).

XBIB-C SMT reference

This picture shows the XBee-C SMT development board and the table that follows explains the callouts in the picture.

Note This board is sold separately.

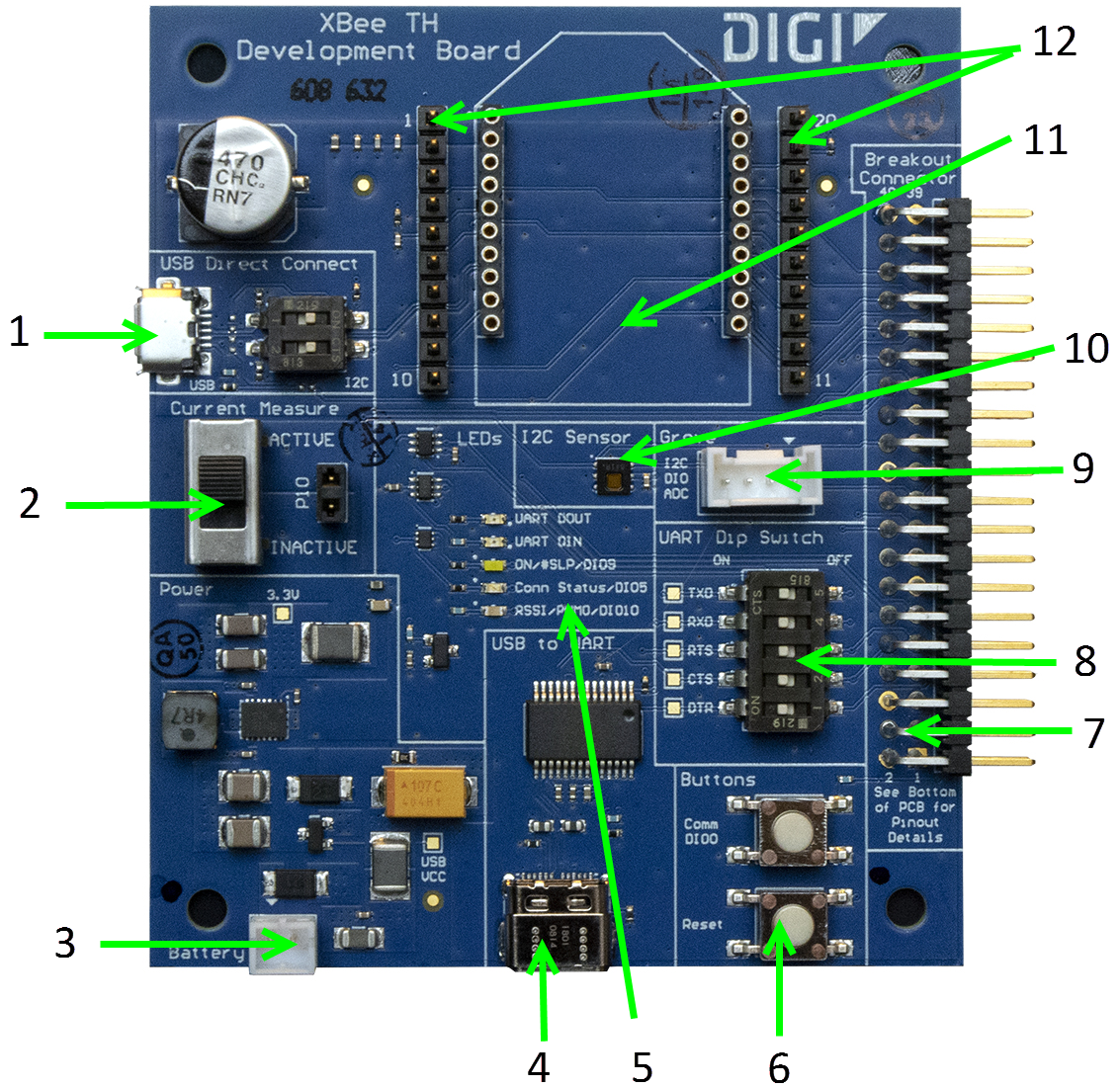



Number	Item	Description
1	Secondary USB (USB MICRO B)	Secondary USB Connector for possible future use. Not used.
2	Current Measure	Large switch controls whether current measure mode is active or inactive. When inactive, current can freely flow to the VCC pin of the XBee. When active, the VCC pin of the XBee is disconnected from the 3.3 V line on the dev board. This allows current measurement to be conducted by attaching a current meter across the jumper P10.
3	Battery Connector	If desired, you can attach a battery to provide power to the development board. The voltage can range from 2 V to 5 V. The positive terminal is on the left.
4	USB-C Connector	Connects to your computer. This is connected to a USB to UART conversion chip that has the five UART lines passed to the XBee. The UART Dip Switch can be used to disconnect these UART lines from the XBee.
5	LED indicator	Red: UART DOUT (modem sending serial/UART data to host) Green: UART DIN (modem receiving serial/UART data from host) White: ON/SLP/DIO9 Blue: Connection Status/DIO5 Yellow: RSSI/PWM0/DIO10
6	User Buttons	Comm DIO0 Button connects the Commissioning/DIO0 pin on the XBee Connector through to a 10 Ω resistor to GND when pressed. RESET Button Connects to the RESET pin on the XBee Connector to GND when pressed.
7	Breakout Connector	This 40-pin connector can be used to connect to various XBee pins as shown on the silkscreen on the bottom of the board.
8	UART Dip Switch	This dip switch allows the user to disconnect any of the primary UART lines on the XBee from the USB to UART conversion chip. This allows for testing on the primary UART lines without the USB to UART conversion chip interfering. Push Dip switches to the right to disconnect the USB to UART conversion chip from the XBee.
9	Grove Connector	This connector can be used to attach I2C enabled devices to the development board. Note that I2C needs to be available on the XBee in the board to use this functionality. Pin 1: I2C_CLK/XBee DIO1 Pin2: I2C_SDA/XBee DIO11 Pin3: VCC Pin4: GND
10	Temp/Humidity Sensor	This as a Texas Instruments HDC1080 temperature and humidity sensor. This part is accessible through I2C. Be sure that the XBee that is inserted into the Dev Board has I2C if access to this sensor is desired.
11	XBee Socket	This is the socket for the XBee (SMT form factor)

XBIB-CU TH reference

This picture shows the XBee-CU TH development board and the table that follows explains the callouts in the picture.

Note This board is sold separately.



Number	Item	Description
1	Secondary USB (USB MICRO B) and DIP Switch	<p>Secondary USB Connector for direct programming of modules on some XBee units. Flip the Dip switches to the right for I2C access to the board; flip Dip switches to the left to disable I2C access to the board. The USB_P and USB_N lines are always connected to the XBee, regardless of Dip switch setting. This USB port is not designed to power the module or the board. Do not plug in a USB cable here unless the board is already being powered through the main USB-C connector. Do not attach a USB cable here if the Dip switches are pushed to the right.</p> <hr/> <div style="display: flex; align-items: center;">  <p>WARNING! Direct input of USB lines into XBee units or I2C lines not designed to handle 5V can result in the destruction of the XBee or I2C components. Could cause fire or serious injury. Do not plug in a USB cable here if the XBee device is not designed for it and do not plug in a USB cable here if the Dip switches are pushed to the right.</p> </div> <hr/>
2	Current Measure	Large switch controls whether current measure mode is active or inactive. When inactive, current can freely flow to the VCC pin of the XBee. When active, the VCC pin of the XBee is disconnected from the 3.3 V line on the development board. This allows current measurement to be conducted by attaching a current meter across the jumper P10.
3	Battery Connector	If desired, a battery can be attached to provide power to the development board. The voltage can range from 2 V to 5 V. The positive terminal is on the left. If the USB-C connector is connected to a computer, the power will be provided through the USB-C connector and not the battery connector.
4	USB-C Connector	Connects to your computer and provides the power for the development board. This is connected to a USB to UART conversion chip that has the five UART lines passed to the XBee. The UART Dip Switch can be used to disconnect these UART lines from the XBee.
5	LED indicator	<p>Red: UART DOUT (modem sending serial/UART data to host) Green: UART DIN (modem receiving serial/UART data from host) White: ON/SLP/DIO9 Blue: Connection Status/DIO5 Yellow: RSSI/PWM0/DIO10</p>
6	User Buttons	<p>Comm DIO0 Button connects the Commissioning/DIO0 pin on the XBee Connector through to a 10 Ω resistor to GND when pressed.</p> <p>RESET Button Connects to the RESET pin on the XBee Connector to GND when pressed.</p>
7	Breakout Connector	This 40 pin connector can be used to connect to various XBee pins as shown on the silkscreen on the bottom of the board.

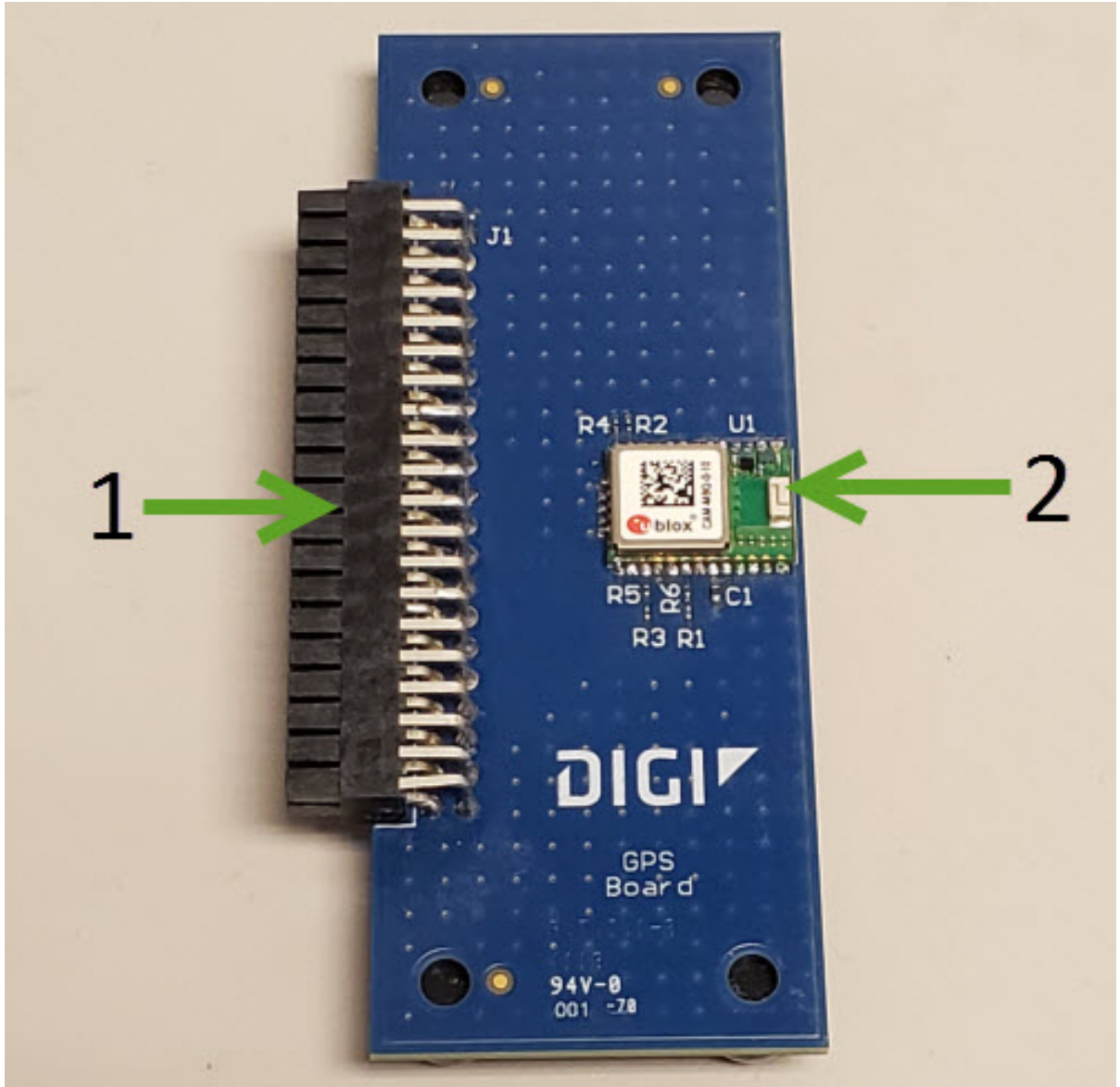
Number	Item	Description
8	UART Dip Switch	This dip switch allows the user to disconnect any of the primary UART lines on the XBee from the USB to UART conversion chip. This allows for testing on the primary UART lines without the USB to UART conversion chip interfering. Push Dip switches to the right to disconnect the USB to UART conversion chip from the XBee.
9	Grove Connector	This connector can be used to attach I2C enabled devices to the development board. Note that I2C needs to be available on the XBee in the board for this functionality to be used. Pin 1: I2C_CLK/XBee DIO1 Pin2: I2C_SDA/XBee DIO11 Pin3: VCC Pin4: GND
10	Temp/Humidity Sensor	This as a Texas Instruments HDC1080 temperature and humidity sensor. This part is accessible through I2C. Be sure that the XBee that is inserted into the development board has I2C if access to this sensor is desired.
11	XBee Socket	This is the socket for the XBee (TH form factor).
12	XBee Test Point Pins	Allows easy access for probes for all 20 XBee TH pins. Pin 1 is shorted to Pin 1 on the XBee and so on.

XBIB-C-GPS reference

This picture shows the XBIB-C-GPS module and the table that follows explains the callouts in the picture.

Note This board is sold separately. You must also have purchased an XBIB-C through-hole, surface-mount, or micro-mount development board.

Note For a demonstration of how to use MicroPython to parse some of the GPS NMEA sentences from the UART, print them and report them to Digi Remote Manager, see [Run the MicroPython GPS demo](#).



Number	Item	Description
1	40-pin header	This header is used to connect the XBIB-C-GPS board to a compatible XBIB development board. Insert the XBIB-C-GPS module slowly with alternating pressure on the upper and lower parts of the connector. If added or removed improperly, the pins on the attached board could bend out of shape.
2	GPS unit	This is the CAM-M8Q-0-10 module made by u-blox. This is what makes the GPS measurements. Proper orientation is with the board laying completely flat, with the module facing towards the sky.

Interface with the XBIB-C-GPS module

The XBee3 DigiMesh RF Module can interface with the XBIB-C-GPS board through the large 40-pin header. This header is designed to fit into XBIB-C development board. This allows the XBee3 DigiMesh RF Module in the XBIB-C board to communicate with the XBIB-C-GPS board—provided the XBee device used has MicroPython capabilities (see [this link](#) to determine which devices have MicroPython capabilities). There are two ways to interface with the XBIB-C-GPS board: through the host board’s Secondary UART or through the I2C compliant lines.

The following picture shows a typical setup:



I²C communication

There are two I2C lines connected to the host board through the 40-pin header, SCL and SDA. I2C communication is performed over an I2C-compliant Display Data Channel. The XBIB-C-GPS module operates in slave mode. The maximum frequency of the SCL line is 400 kHz. To access data through the I2C lines, the data must be queried by the connected XBee3 DigiMesh RF Module.

For more information about I2C Operation see the **I2C** section of the [Digi Micro Python Programming Guide](#).

For more information on the operation of the XBIB-C-GPS board see the [CAM-M8 datasheet](#). Other CAM-M8 documentation is located [here](#).

UART communication

There are two UART pins connected from the XBIB-C-GPS to the host board by the 40-pin header: RX and TX. By default, the UART on the XBIB-C-GPS board is active and sends GPS readings to the connected device's secondary UART pins. Readings are transmitted once every second. The baud rate of the UART is 9600 baud.

For more information about using Micro Python to communicate to the XBIB-C-GPS module, see [Class UART](#).

Run the MicroPython GPS demo

The Digi MicroPython github repository contains a GPS demo program that parses some of the GPS NMEA sentences from the UART, prints them and also reports them to Digi Remote Manager.

Note If you are unfamiliar with MicroPython on XBee you should first run some of the tutorials earlier in this manual to familiarize yourself with the environment. See [Get started with MicroPython](#). For more detailed information, refer to the [Digi MicroPython Programming Guide](#).

Step 1: Create a Remote Manager developer account

You must have a Remote Manager developer account to be able to use this program. Make sure you know the user name and password for this account.

If you don't currently have a Remote Manager developer account, you can [create a free developer account](#).

Step 2: Download or clone the XBee MicroPython repository

1. Navigate to: <https://github.com/digidotcom/xbee-micropython/>
2. Click **Clone or download**.
3. You must either clone or download a zip file of the repository. You can use either method.
 - **Clone:** If you are familiar with GIT, follow the standard GIT process to clone the repository.
 - **Download**
 - a. Click **Download zip** to download a zip file of the repository to the download folder of your choosing.
 - b. Extract the repository to a location of your choosing on your hard drive.

Step 3: Edit the MicroPython file

1. Navigate to the location of the repository zip file that you created in Step 2.
2. Navigate to: **samples/gps**
3. Open the MicroPython file: *gpsdemo1.py*
4. Using the editor of your choice, edit the MicroPython file. At the top of the file, enter the user name and password for your Remote Manager developer account. The correct location is indicated in the comments in the file.

Step 4: Run the program

1. Rename the file you edited in Step 3 from *gpsdemo1.py* to *main.py*.
2. Copy the renamed file onto your device's root filesystem directory.
3. Copy the following three modules from the locations specified below into your device's **/lib** directory:
 - From the **/lib** directory of the Digi xbee-micropython repository: *urequest.py* and *remotemanager.py*
 - From the **/lib/sensor** directory of the Digi xbee-micropython repository: *hdc1080.py*

Note These modules are required to be able to run the *gpsdemo1.py*.

4. Open [XCTU](#) and use the MicroPython Terminal to run the demo.
5. Type <CTRL>-R from the MicroPython prompt to run the code.

Get started with MicroPython

This user guide provides an overview of how to use MicroPython with the XBee3 DigiMesh RF Module. For in-depth information and more complex code examples, refer to the [Digi MicroPython Programming Guide](#). Continue with this user guide for simple examples to get started using MicroPython on the XBee3 DigiMesh RF Module.

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About MicroPython

MicroPython is an open-source programming language based on Python 3.0, with much of the same syntax and functionality, but modified to fit on small devices with limited hardware resources, such as an XBee3 DigiMesh RF Module.

For more information about MicroPython, see www.micropython.org.

For more information about Python, see www.python.org.

MicroPython on the XBee3 DigiMesh RF Module

The XBee3 DigiMesh RF Module has MicroPython running on the device itself. You can access a MicroPython prompt from the XBee3 DigiMesh RF Module when you install it in an appropriate development board (XBDB or XBIB), and connect it to a computer via a USB cable.

Note MicroPython is only available through the UART interface and does not work with SPI.

Note MicroPython programming on the device requires firmware version 3002 or newer.

The examples in this user guide assume:


- You have [XCTU](#) on your computer. See [Configure the device using XCTU](#).
- You have a serial terminal program installed on your computer. For more information, see [Use the MicroPython Terminal in XCTU](#). This requires XCTU 6.3.10 or higher.
- You have an XBee3 DigiMesh RF Module installed on an appropriate development board such as an XBIB-U-DEV or an XBDB-U-ZB.
- The XBee3 DigiMesh RF Module is connected to the computer via a USB cable and XCTU recognizes it.

Use XCTU to enter the MicroPython environment

To use the XBee3 DigiMesh RF Module in the MicroPython environment:



1. Use XCTU to add the device(s); see [Configure the device using XCTU](#) and [Add devices to XCTU](#).
2. The XBee3 DigiMesh RF Module appears as a box in the **Radio Modules** information panel. Each module displays identifying information about itself.
3. Click this box to select the device and load its current settings.

Note To ensure that MicroPython is responsive to input, Digi recommends setting the XBee UART baud rate to 115200 baud. To set the UART baud rate, select **115200 [7]** in the **BD** field and click the **Write** button. We strongly recommend using hardware flow control to avoid data loss, especially when pasting large amounts of code or text. For more information, see [UART flow control](#).

4. To put the XBee3 DigiMesh RF Module into MicroPython mode, in the **AP** field select **MicroPython REPL [4]** and click the **Write** button .
5. Note which COM port the XBee3 DigiMesh RF Module is using, because you will need this information when you use the MicroPython terminal.

Use the MicroPython Terminal in XCTU

You can use the MicroPython Terminal to communicate with the XBee3 DigiMesh RF Module when it is in MicroPython mode.¹ This requires XCTU 6.3.10 or higher. To enter MicroPython mode, follow the steps in [Use XCTU to enter the MicroPython environment](#). To use the MicroPython Terminal:

1. Click the **Tools** drop-down menu  and select **MicroPython Terminal**. The terminal window opens.
2. Click **Open** to open the Serial Port Configuration window.
3. In the **Select the Serial/USB port** area, click the COM port that the device uses.
4. Verify that the baud rate and other settings are correct.
5. Click **OK**. The **Open** icon changes to **Close** , indicating that the device is properly connected.

If the `>>>` prompt appears, you are connected properly. You can now type or paste MicroPython code in the terminal.

MicroPython examples

This section provides examples of how to use some of the basic functionality of MicroPython with the XBee3 DigiMesh RF Module.

Example: hello world

1. At the MicroPython `>>>` prompt, type the Python command: `print("Hello, World!")`
2. Press **Enter** to execute the command. The terminal echos back **Hello, World!**

Example: enter MicroPython paste mode

In the following examples it is helpful to know that MicroPython supports [paste mode](#), where you can copy a large block of code from this user guide and paste it instead of typing it character by character. To use paste mode:

1. Copy the code you want to run. For example, copy the following code that is the code from the "Hello world" example:

```
print("Hello World")
```

Note You can easily copy and paste code from the [online version of this guide](#). Use caution with the PDF version, as it may not maintain essential indentations.

2. In the terminal, at the MicroPython `>>>` prompt type **Ctrl-+E** to enter paste mode. The terminal displays **paste mode; Ctrl-C to cancel, Ctrl-D to finish**.
3. Right-click in the MicroPython terminal window and click **Paste** or press **Ctrl+Shift+V** to paste.
4. The code appears in the terminal occupying one line. Each line starts with its line number and three "=" symbols. For example, line 1 starts with **1===**.

¹See [Other terminal programs](#) if you do not use the MicroPython Terminal in XCTU.

5. If the code is correct, press **Ctrl+D** to run the code; “Hello World” should print.

Note If you want to exit paste mode without running the code, or if the code did not copy correctly, press **Ctrl+C** to cancel and return to the normal MicroPython `>>>` prompt).

Example: using the time module

The time module is used for time-sensitive operations such as introducing a delay in your routine or a timer.

The following time functions are supported by the XBee3 DigiMesh RF Module:

- **ticks_ms()** returns the current millisecond counter value. This counter rolls over at 0x40000000.
- **ticks_diff()** compares the difference between two timestamps in milliseconds.
- **sleep()** delays operation for a set number of seconds.
- **sleep_ms()** delays operation for a set number of milliseconds.
- **sleep_us()** delays operation for a set number of microseconds.

Note The standard **time.time()** function cannot be used, because this function produces the number of seconds since the epoch. The XBee3 module lacks a realtime clock and cannot provide any date or time data.

The following example exercises the various sleep functions and uses **ticks_diff()** to measure duration:

```
import time

start = time.ticks_ms() # Get the value from the millisecond counter

time.sleep(1)           # sleep for 1 second
time.sleep_ms(500)     # sleep for 500 milliseconds
time.sleep_us(1000)    # sleep for 1000 microseconds

delta = time.ticks_diff(time.ticks_ms(), start)

print("Operation took {} ms to execute".format(delta))
```

Example: AT commands using MicroPython

AT commands control the XBee3 DigiMesh RF Module. The "AT" is an abbreviation for "attention", and the prefix "AT" notifies the module about the start of a command line. For a list of AT commands that can be used on the XBee3 DigiMesh RF Module, see [AT commands](#).

MicroPython provides an **atcmd()** method to process AT commands, similar to how you can use [Command mode](#) or API frames.

The **atcmd()** method accepts two parameters:

1. The two character AT command, entered as a string.
2. An optional second parameter used to set the AT command value. If this parameter is not provided, the AT command is queried instead of being set. This value is an integer, bytes object, or string, depending on the AT command.

Note The `xbee.atcmd()` method does not support the following AT commands: **IS**, **AS**, **ED**, **ND**, or **DN**.

The following is example code that queries and sets a variety of AT commands using `xbee.atcmd()`:

```
import xbee

# Set the NI string of the radio
xbee.atcmd("NI", "XBee3 module")

# Configure a destination address using two different data types
xbee.atcmd("DH", 0x0013A200)          # Hex
xbee.atcmd("DL", b'\x12\x25\x89\xf5') # Bytes

# Read some AT commands and display the value and data type:
print("\nAT command parameter values:")
commands = ["DH", "DL", "NI", "CK"]
for cmd in commands:
    val = xbee.atcmd(cmd)
    print("{}: {:20} of type {}".format(cmd, repr(val), type(val)))
```

This example code outputs the following:

```
AT command parameter values:
DH: b'\x00\x13\xa2\x00' of type <class 'bytes'>
DL: b'\x12%\x89\xf5'   of type <class 'bytes'>
NI: 'XBee3 module'   of type <class 'str'>
CK: 65535             of type <class 'int'>
```

Note Parameters that store values larger than 16-bits in length are represented as bytes. Python attempts to print out ASCII characters whenever possible, which can result in some unexpected output (such as the "%" in the above output). If you want the output from MicroPython to match XCTU, you can use the following example to convert bytes to hex:

```
dl_value = xbee.atcmd("DL")
hex_dl_value = hex(int.from_bytes(dl_value, 'big'))
```

MicroPython networking and communication examples

This section provides networking and communication examples for using MicroPython with the XBee3 DigiMesh RF Module.

DigiMesh networks with MicroPython

For small networks, it is suitable to use MicroPython on every node. However, there are some inherent limitations that may prevent you from using MicroPython on some heavily trafficked nodes:

- When running MicroPython, any received messages will be stored in a small receive queue. This queue only has room for 4 packets and must be regularly read to prevent data loss. For networks that will be generating a lot of traffic, the data aggregator may need to operate in API mode in order to capture all incoming data.

For the examples in this section, the devices should be pre-configured with identical network settings so that RF communication is possible. To follow the upcoming examples, we need to configure a second XBee3 DigiMesh RF Module to use MicroPython.

XCTU only allows a single MicroPython terminal. We will be running example code on both modules, which requires a second terminal window.

Open a second instance of XCTU, and configure a different XBee3 module for MicroPython following the steps in [Use XCTU to enter the MicroPython environment](#).

Example: network Discovery using MicroPython

The `xbee.discover()` method returns an iterator that blocks while waiting for results, similar to executing an **ND** request. For more information, see [ND \(Network Discover\)](#).

Each result is a dictionary with fields based on an **ND** response:

- **sender_nwk**: 16-bit network address.
- **sender_eui64**: 8-byte bytes object with EUI-64 address.
- **parent_nwk**: Set to 0xFFFFE on the coordinator and routers; otherwise, this is set to the network address of the end device's parent.
- **node_id**: The device's **NI** value (a string of up to 20 characters, also referred to as Node Identification).
- **node_type**: Value of 0, 1 or 2 for coordinator, router, or end device.
- **device_type**: The device's 32-bit **DD** value, also referred to as Digi Device Type; this is used to identify different types of devices or hardware.
- **rsi**: Relative signal strength indicator (in dBm) of the node discovery request packet received by the sending node.

Note When printing the dictionary, fields for **device_type**, **sender_nwk** and **parent_nwk** appear in decimal form. You can use the MicroPython `hex()` method to print an integer in hexadecimal. Check the function code for `format_eui64` from the [Example: communication between two XBee3 DigiMesh modules](#) topic for code to convert the `sender_eui64` field into a hexadecimal string with a colon between each byte value.

Use the following example code to perform a network discovery:

```
import xbee, time

# Set the network discovery options to include self
xbee.atcmd("NO", 2)
xbee.atcmd("AC")
time.sleep(.5)

# Perform Network Discovery and print out the results
print ("Network Discovery in process...")
nodes = list(xbee.discover())
if nodes:
    for node in nodes:
        print("\nRadio discovered:")
        for key, value in node.items():
            print("\t{<12} : {}".format(key, value))

# Set NO back to the default value
xbee.atcmd("NO", 0)
xbee.atcmd("AC")
```

This produces the following output from two discovered nodes:

```
Radio discovered:
    rssi          : -63
    node_id       : Coordinator
```

```

device_type : 1179648
parent_nwk  : 65534
sender_nwk  : 0
sender_eui64 : b'\x00\x13\xa2\xff h\x98T'
node_type   : 0

Radio discovered:
 rssi       : -75
node_id     : Router
device_type : 1179648
parent_nwk  : 65534
sender_nwk  : 23125
sender_eui64 : b'\x00\x13\xa2\xffh\x98c&'
node_type   : 1

```

Examples: transmitting data

This section provides examples for transmitting data using MicroPython. These examples assume you have followed the above examples and the two radios are on the same network.

Example: transmit message

Use the **xbee** module to transmit a message from the XBee3 Zigbee device. The **transmit()** function call consists of the following parameters:

1. The Destination Address, which can be any of the following:
 - Integer for 16-bit addressing
 - 8-byte bytes object for 64-bit addressing
 - Constant **xbee.ADDR_BROADCAST** to indicate a broadcast destination
 - Constant **xbee.ADDR_COORDINATOR** to indicate the coordinator
2. The Message as a character string.

If the message is sent successfully, **transmit()** returns **None**. If the transmission fails due to an ACK failure or lack of free buffer space on the receiver, the sent packet will be silently discarded.

Example: transmit a message to the network coordinator

1. From the router, access the MicroPython environment.
2. At the MicroPython >>> prompt, type **import xbee** and press **Enter**.
3. At the MicroPython >>> prompt, type **xbee.transmit(xbee.ADDR_COORDINATOR, "Hello World!")** and press **Enter**.
4. On the coordinator, you can issue an **xbee.receive()** call to output the received packet.

Example: transmit custom messages to all nodes in a network

This program performs a network discovery and sends the message **'Hello <Destination Node Identifier>!'** to individual nodes in the network. For more information, see [Example: network Discovery using MicroPython](#).

```

import xbee

# Perform a network discovery to gather destination address:
print("Discovering remote nodes, please wait...")
node_list = list(xbee.discover())
if not node_list:

```

```

        raise Exception("Network discovery did not find any remote devices")

for node in node_list:
    dest_addr = node['sender_eui64']
    dest_node_id = node['node_id']
    payload_data = "Hello, " + dest_node_id + "!"

    try:
        print("Sending \"{}\" to {}".format(payload_data, dest_addr))
        xbee.transmit(dest_addr, payload_data)
    except Exception as err:
        print(err)

print("complete")

```

Receiving data

Use the `receive()` function from the `xbee` module to receive messages. When MicroPython is active on a device (**AP** is set to 4), all incoming messages are saved to a receive queue within MicroPython. This receive queue is limited in size and only has room for 4 messages. To ensure that data is not lost, it is important to continuously iterate through the receive queue and process any of the packets within.

If the receive queue is full and another message is sent to the device, it will not acknowledge the packet and the sender generates a failure status of 0x24 (Address not found).

The `receive()` function returns one of the following:

- None: No message (the receive queue is empty).
- Message dictionary consisting of:
 - **sender_nwk**: 16-bit network address of the sending node.
 - **sender_eui64**: 64-bit address (as a "bytes object") of the sending node.
 - **source_ep**: source endpoint as an integer.
 - **dest_ep**: destination endpoint as an integer.
 - **cluster**: cluster id as an integer.
 - **profile**: profile id as an integer.
 - **broadcast**: True or False depending on whether the frame was broadcast or unicast.
 - **payload**: "Bytes object" of the payload. This is a bytes object instead of a string, because the payload can contain binary data.

Example: continuously receive data

In this example, the `format_packet()` helper formats the contents of the dictionary and `format_eui64()` formats the bytes object holding the EUI-64. The `while` loop shows how to poll for packets continually to ensure that the receive buffer does not become full.

```

def format_eui64(addr):
    return ':'.join('%02X' % b for b in addr)

def format_packet(p):
    type = 'Broadcast' if p['broadcast'] else 'Unicast'
    print("%s message from EUI-64 %s (network 0x%04X)" % (type,
        format_eui64(p['sender_eui64']), p['sender_nwk']))
    print("    from EP 0x%02X to EP 0x%02X, Cluster 0x%04X, Profile 0x%04X:" %
        (p['source_ep'], p['dest_ep'], p['cluster'], p['profile']))
    print(p['payload'])

```

```
import xbee, time
while True:
    print("Receiving data...")
    print("Press CTRL+C to cancel.")
    p = xbee.receive()
    if p:
        format_packet(p)
    else:
        time.sleep(0.25) # wait 0.25 seconds before checking again
```

If this node had previously received a packet, it outputs as follows:

```
Unicast message from EUI-64 00:13:a2:00:41:74:ca:70 (network 0x6D81)
  from EP 0xE8 to EP 0xE8, Cluster 0x0011, Profile 0xC105:
b'Hello World!'
```

Note Digi recommends calling the **receive()** function in a loop so no data is lost. On modules where there is a high volume of network traffic, there could be data lost if the messages are not pulled from the queue fast enough.

Example: communication between two XBee3 DigiMesh modules

This example combines all of the previous examples and represents a full application that configures a network, discovers remote nodes, and sends and receives messages.

First, we will upload some utility functions into the flash space of MicroPython so that the following examples will be easier to read.

Complete the following steps to compile and execute utility functions using flash mode on both devices:

1. Access the MicroPython environment.
2. Press **Ctrl + F**.
3. Copy the following code:

```
import xbee, time
# Utility functions to perform XBee3 DigiMesh operations
def format_eui64(addr):
    return ':'.join('%02x' % b for b in addr)

def format_packet(p):
    type = 'Broadcast' if p['broadcast'] else 'Unicast'
    print("%s message from EUI-64 %s" %
          (type, format_eui64(p['sender_eui64'])))
    print("from EP 0x%02X to EP 0x%02X, Cluster 0x%04X, Profile 0x%04X:" %
          (p['source_ep'], p['dest_ep'], p['cluster'], p['profile']))
    print(p['payload'], "\n")
```

4. At the MicroPython 1^^^ prompt, right-click and select the **Paste** option.
5. Press **Ctrl+D** to finish. The code is uploaded to the flash memory and then compiled. At the "Automatically run this code at startup" [Y/N]?" prompt, select **Y**.
6. Press **Ctrl+R** to run the compiled code; this provides access to these utility functions for the next examples.



WARNING! MicroPython code stored in flash is saved in the file system as **main.py**. If the file system has not been formatted, then the following error is generated:

OSError: [Errno 7019] ENODEV

The file system can be formatted in one of three ways:

In XCTU by using the [File System Manager](#).

In Command mode using the **ATFS FORMAT confirm** command—see [FS \(File System\)](#).

In MicroPython by issuing the following code:

```
import os
os.format()
```

Example code on the aggregator module

The following example code configures DigiMesh network settings, performs a network discovery to find the remote node, and continuously prints out any incoming data.

1. Access the MicroPython environment.
2. Copy the following sample code:

```
print("Configuring DigiMesh network settings...")
xbee.atcmd("NI", "Aggregator")
network_settings = {"CH": 0x13, "ID": 0x1111, "EE": 0}
for command, value in network_settings.items():
    xbee.atcmd(command, value)
xbee.atcmd("AC") # Apply changes
time.sleep(1)

print("Waiting for a remote node to join...")
node_list = []
while len(node_list) == 0:
    # Perform a network discovery until the router joins
    node_list = list(xbee.discover())
print("Remote node found, transmitting data")

for node in node_list:
    dest_addr = node['sender_eui64'] # using 64-bit addressing
    dest_node_id = node['node_id']
    payload_data = "Hello, " + dest_node_id + "!"

    print("Sending \"{}\" to {}".format(payload_data, repr(dest_addr)))
    xbee.transmit(dest_addr, payload_data)

# Start the receive loop
print("Receiving data...")
print("Hit CTRL+C to cancel")
while True:
    p = xbee.receive()
    if p:
        format_packet(p)
    else:
        time.sleep(0.25)
```

3. Press **Ctrl+E** to enter paste mode.
4. At the **MicroPython >>>** prompt, right-click and select the **Paste** option. Once you paste the code, it executes immediately.

Example code on the router module

The following example code joins the Zigbee network from the previous example, and continuously prints out any incoming data. This device also sends its temperature data every 5 seconds to the coordinator address.

1. Access the MicroPython environment.
2. Copy the following sample code:

```
print("Configuring network settings...")
xbee.atcmd("NI", "Remote")
network_settings = {"CH": 0x13, "ID": 0x1111, "EE": 0}
for command, value in network_settings.items():
    xbee.atcmd(command, value)
xbee.atcmd("AC") # Apply changes
time.sleep(1)

print("Network configured\n")


last_sent = time.ticks_ms()
interval = 5000 # How often to send a message



# Start the transmit/receive loop
print("Sending temp data every {} seconds".format(interval/1000))
while True:
    p = xbee.receive()
    if p:
        format_packet(p)
    else:
        # Transmit temperature if ready
        if time.ticks_diff(time.ticks_ms(), last_sent) > interval:
            temp = "Temperature: {}C".format(xbee.atcmd("TP"))
            print("\tsending " + temp)
            try:
                xbee.transmit(xbee.ADDR_BROADCAST, temp)
            except Exception as err:
                print(err)
            last_sent = time.ticks_ms()
        time.sleep(0.25)
```

3. Press **Ctrl+E** to enter paste mode.
4. At the **MicroPython >>>** prompt, right-click and select the **Paste** option. Once you paste the code, it executes immediately.

Exit MicroPython mode

To exit MicroPython mode:

1. In the XCTU MicroPython terminal, click the green **Close** button .
2. Click **Close** at the bottom of the terminal to exit the terminal.

- In XCTU's Configuration working mode , change **AP API Enable** to another mode and click the **Write** button . We recommend changing to Transparent mode [0], as most of the examples use this mode.

Other terminal programs

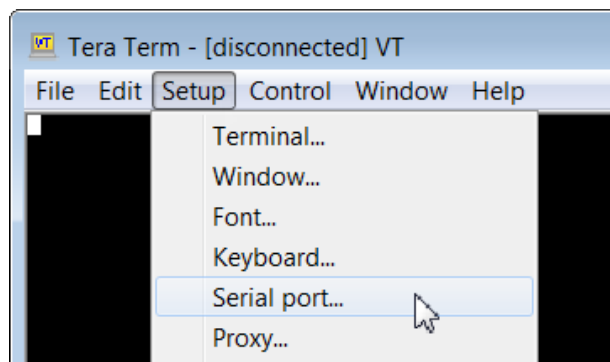
If you do not use the MicroPython terminal in XCTU, you can use other terminal programs to communicate with the XBee3 DigiMesh RF Module. If you use Microsoft Windows, follow the instructions for Tera Term; if you use Linux, follow the instructions for picocom. To download these programs:

- Tera Term for Windows, see ttssh2.osdn.jp/index.html.en.
- Picocom for Linux, see developer.ridgerun.com/wiki/index.php/Setting_up_Picocom_-_Ubuntu
- Source code and in-depth information, see github.com/npat-efault/picocom.

Tera Term for Windows

With the XBee3 DigiMesh RF Module in MicroPython mode (**AP = 4**), you can access the MicroPython prompt using a terminal.

- Open Tera Term. The **Tera Term: New connection** window appears.
- Click the **Serial** radio button to select a serial connection.
- From the **Port:** drop-down menu, select the COM port that the XBee3 DigiMesh RF Module is connected to.
- Click **OK**. The **COMxx - Tera Term VT** terminal window appears and Tera Term attempts to connect to the device at a baud rate of 9600 bps. The terminal will not allow communication with the device since the baud rate setting is incorrect. You must change this rate as it was previously set to 115200 bps.
- Click **Setup** and **Serial Port**. The **Tera Term: Serial port setup** window appears.



- In the **Tera Term: Serial port setup** window, set the parameters to the following values:
 - **Port:** Shows the port that the XBee3 DigiMesh RF Module is connected on.
 - **Baud rate:** 115200
 - **Data:** 8 bit
 - **Parity:** none

- **Stop:** 1 bit
 - **Flow control:** hardware
 - **Transmit delay:** N/A
7. Click **OK** to apply the changes to the serial port settings. The settings should go into effect right away.
 8. To verify that local echo is not enabled and that extra line-feeds are not enabled:
 - a. In Tera Term, click **Setup** and select **Terminal**.
 - b. In the **New-line** area of the **Tera Term: Serial port setup** window, click the **Receive** drop-down menu and select **AUTO** if it does not already show that value.
 - c. Make sure the **Local echo** box is not checked.
 9. Click **OK**.
 10. Press **Ctrl+B** to get the MicroPython version banner and prompt.

```
MicroPython v1.9.3-716-g507d0512 on 2018-02-20; XBee3 DigiMesh with EFR32MG
Type "help()" for more information.
>>>
```

Now you can type MicroPython commands at the `>>>` prompt.

Use picocom in Linux

With the XBee3 DigiMesh RF Module in MicroPython mode (**AP = 4**), you can access the MicroPython prompt using a terminal.

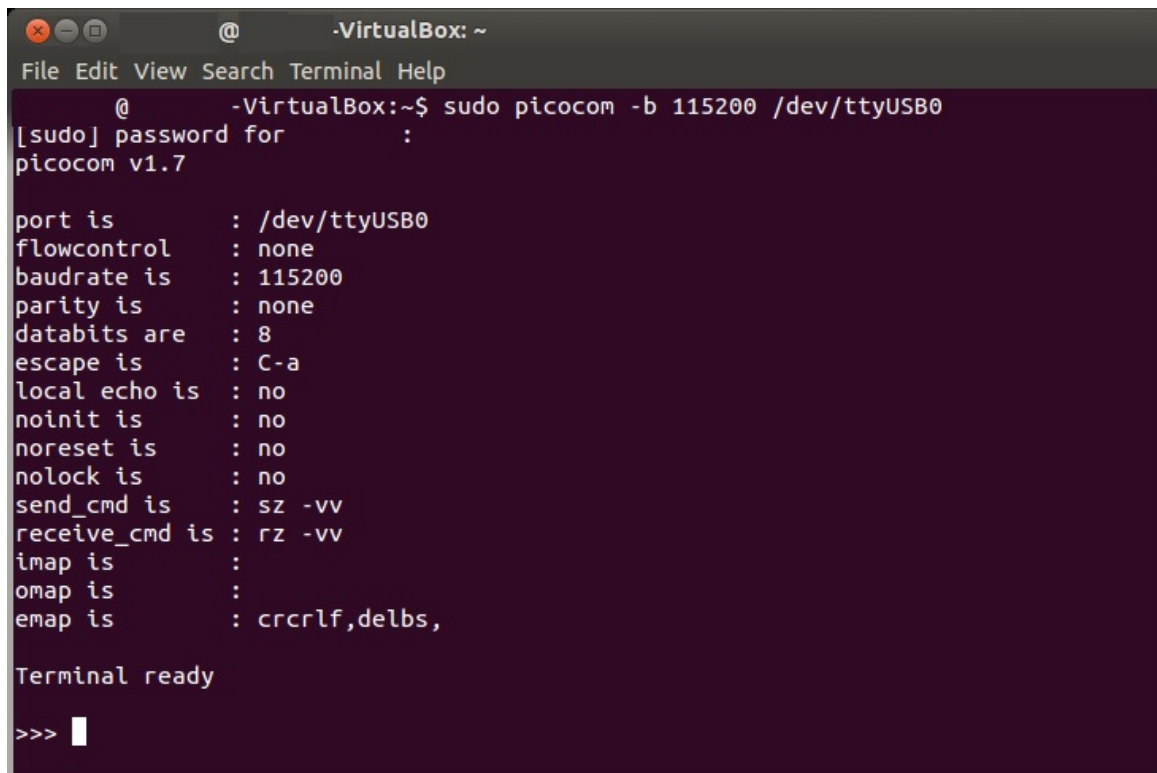
Note The user must have read and write permission for the serial port the XBee3 DigiMesh RF Module is connected to in order to communicate with the device.

1. Open a terminal in Linux and type **picocom -b 115200 /dev/ttyUSB0**. This assumes you have no other USB-to-serial devices attached to the system.
2. Press **Ctrl+B** to get the MicroPython version banner and prompt. You can also press **Enter** to bring up the prompt.

If you do have other USB-to-serial devices attached:

1. Before attaching the XBee3 DigiMesh RF Module, check the directory **/dev/** for any devices named **ttyUSBx**, where **x** is a number. An easy way to list these is to type: **ls /dev/ttyUSB***. This produces a list of any device with a name that starts with **ttyUSB**.
2. Take note of the devices present with that name, and then connect the XBee3 DigiMesh RF Module.
3. Check the directory again and you should see one additional device, which is the XBee3 DigiMesh RF Module.
4. In this case, replace **/dev/ttyUSB0** at the top with **/dev/ttyUSB<number>**, where **<number>** is the new number that appeared.

It connects and shows "Terminal ready".



You can now type MicroPython commands at the >>> prompt.

Micropython help ()

When you type the **help()** command at the prompt, it provides a link to online help, control commands and also usage examples.

```
>>> help()
Welcome to MicroPython!
For online docs please visit http://docs.micropython.org/.
Control commands:
CTRL-A      -- on a blank line, enter raw REPL mode
CTRL-B      -- on a blank line, enter normal REPL mode
CTRL-C      -- interrupt a running program
CTRL-D      -- on a blank line, reset the REPL
CTRL-E      -- on a blank line, enter paste mode
CTRL-F      -- on a blank line, enter flash upload mode
For further help on a specific object, type help(obj)
For a list of available modules, type help('modules')
-----
-----
```

When you type **help('modules')** at the prompt, it displays all available Micropython modules.

```
-----
>>> help('modules')
__main__      io          time          uos
array         json        ubinascii     ustruct
binascii     machine    uerrno        utime
-----
```

builtins	micropython	uhashlib	xbee
errno	os	uio	
gc	struct	ujson	
hashlib	sys	umachine	

Plus any modules on the filesystem

When you import a module and type **help()** with the module as the object, you can query all the functions that the object supports.

```

-----
>>> import sys
>>> help(sys)
object <module 'sys'> is of type module
__name__ -- sys
path -- ['', '/flash', '/flash/lib']
argv -- []
version -- 3.4.0
version_info -- (3, 4, 0)
implementation -- ('micropython', (1, 10, 0))
platform -- xbee3-DigiMesh
byteorder -- little
maxsize -- 2147483647
exit -- <function>
stdin -- <io.FileIO 0>
stdout -- <io.FileIO 1>
stderr -- <io.FileIO 2>
modules -- {}
print_exception -- <function>
-----

```

File system

For detailed information about using MicroPython on the XBee3 DigiMesh RF Module refer to the [Digi MicroPython Programming Guide](#).

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Overview of the file system



CAUTION! You need to format the file system if upgrading a device that originally shipped with older firmware. You can use XCTU, AT commands or MicroPython for that initial format or to erase existing content at any time.

Note To use XCTU with file system, you need XCTU 6.4.0 or newer.

See **FS FORMAT confirm** in [FS \(File System\)](#) and ensure that the format is complete.

Directory structure

The XBee3 DigiMesh RF Module's internal flash appears in the file system as **/flash**, the only entry at the root level of the file system. Files and directories other than **/flash** cannot be created within the root directory, only within **/flash**. By default **/flash** contains a lib directory intended for MicroPython modules.

Paths

The XBee3 DigiMesh RF Module stores all of its files in the top-level directory **/flash**. On startup, the **ATFS** commands and MicroPython each use that directory as their current working directory. When specifying the path to a file or directory, it is interpreted as follows:

- Paths starting with a forward slash are "absolute" and must start with **/flash** to be valid.
- All other paths are relative to the current working directory.
- The directory **..** refers to the parent directory, so an operation on **../filename.txt** that takes place in the directory **/flash/test** accesses the file **/flash/filename.txt**.
- The directory **.** refers to the current directory, so the command **ATFS ls .** lists files in the current directory.
- Names are case-insensitive, so **FILE.TXT**, **file.txt** and **File.Txt** all refer to the same file.
- File and directory names are limited to 64 characters, and can only contain letters, numbers, periods, dashes and underscores. A period at the end of the name is ignored.
- The full, absolute path to a file or directory is limited to 255 characters.

Limitations

The file system on the XBee3 DigiMesh RF Module has a few limitations when compared to conventional file systems:

- When a file on the file system is deleted, the space it was using is not reclaimed. The only way to reclaim space that has been used is by formatting the file system. The **FS INFO** command shows how much space is available and how much space is being used by deleted files.
- The file system can only have one file open for writing at a time.
- The file system cannot create new directories while a file is open for writing.
- Files cannot be renamed.

- The contents of the file system will be lost when any firmware update is performed. See [OTA file system upgrades](#) for information on how to put files on a device after an OTA firmware update.

XCTU interface

XCTU releases starting with 6.4.0 include a **File System Manager** in the **Tools** menu. You can upload files to and download files from the device, in addition to renaming and deleting existing files and directories. See the [File System manager tool](#) section of the *XCTU User Guide* for details of its functionality.

Configure the XBee3 DigiMesh RF Module

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Software libraries

One way to communicate with the XBee3 DigiMesh RF Module is by using a software library. The libraries available for use with the XBee3 DigiMesh RF Module include:

- [XBee Java library](#)
- [XBee Python library](#)

The XBee Java Library is a Java API. The package includes the XBee library, its source code and a collection of samples that help you develop Java applications to communicate with your XBee devices. The XBee Python Library is a Python API that dramatically reduces the time to market of XBee projects developed in Python and facilitates the development of these types of applications, making it an easy process.

Over-the-air (OTA) firmware update

The XBee3 DigiMesh RF Module supports OTA firmware updates using XCTU version 6.3.0 or higher. For instructions on performing an OTA firmware update with XCTU, see [How to update the firmware of your modules](#) in the XCTU User Guide.

Custom defaults

Custom defaults allow you to preserve a subset of the device configuration parameters even after returning to default settings using [RE \(Restore Defaults\)](#). This can be useful for settings that identify the device—such as [NI \(Network Identifier\)](#)—or settings that could make remotely recovering the device difficult if they were reset—such as [ID \(Network ID\)](#).

Note You must send these commands as local AT commands, they cannot be set using [Remote AT Command Request frame - 0x17](#).

Set custom defaults

Use [%F \(Set Custom Default\)](#) to set custom defaults. When the XBee3 DigiMesh RF Module receives [%F](#) it takes the next command it receives and applies it to both the current configuration and the custom defaults.

To set custom defaults for multiple commands, send a [%F](#) before each command.

Restore factory defaults

[!C \(Clear Custom Defaults\)](#) clears all custom defaults, so that [RE \(Restore Defaults\)](#) will restore the device to factory defaults. Alternatively, [R1 \(Restore Factory Defaults\)](#) restores all parameters to factory defaults without erasing their custom default values.

Limitations

There is a limitation on the number of custom defaults that can be set on a device. The number of defaults that can be set depends on the size of the saved parameters and the devices' firmware version. When there is no more room for custom defaults to be saved, any command sent immediately after a [%F](#) returns an error.

Setting a custom default that has already been set or setting a custom default to the factory default value will not reclaim the space used by the previous value. The new value takes effect but the old

value still occupies space in memory, reducing the number of custom defaults that can be set. This can be remedied by using **!C (Clear Custom Defaults)** to clear all custom defaults when changing custom default values, and by only setting custom defaults that differ from the factory defaults.

Custom configuration: Create a new factory default

You can create a custom configuration that is used as a new factory default. This feature is useful if, for example, you need to maintain certain settings for manufacturing or want to ensure a feature is always enabled. When you use **RE (Restore Defaults)** to perform a factory reset on the device, the custom configuration is set on the device after applying the original factory default settings.

For example, by default Bluetooth is disabled on devices. You can create a custom configuration in which Bluetooth is enabled by default. When you use **RE** to reset the device to the factory defaults, the Bluetooth configuration set to the custom configuration (enabled) rather than the original factory default (disabled).

The custom configuration is stored in non-volatile memory. You can continue to create and save custom configurations until the XBee3 DigiMesh RF Module's memory runs out of space. If there is no space left to save a configuration, the device returns an error.

You can use **!C (Clear Custom Defaults)** to clear or overwrite a custom configuration at any time.

Set a custom configuration

1. Open XCTU and load your device.
2. [Enter Command mode](#).
3. Perform the following process for each configuration that you want to set as a factory default.
 - a. Send the [Set Custom Default](#) command, **AT%F**. This command enables you to enter a custom configuration.
 - b. Send the custom configuration command. For example: **ATBT 1**. This command sets the default for Bluetooth to enabled.

Clear all custom configuration on a device

After you have set configurations using [%F \(Set Custom Default\)](#), you can return all configurations to the original factory defaults.

1. Open XCTU and load the device.
2. [Enter Command mode](#).
3. Send **AT!C**.

XBee bootloader

You can update firmware on the XBee3 DigiMesh RF Module serially. This is done by invoking the XBee3 bootloader and transferring the firmware image using XMODEM.

This process is also used for updating a local device's firmware using XCTU.

XBee devices use a modified version of Silicon Labs' Gecko [bootloader](#). This bootloader [version](#) supports a custom entry mechanism that uses module pins DIN, DTR/SLEEP_RQ, and RTS.

To invoke the bootloader, do the following:

1. Set $\overline{\text{DTR/SLEEP_RQ}}$ low (CMOS0V) and RTS high.
2. Send a serial break to the DIN pin and power cycle or reset the module.
3. When the device powers up, set $\overline{\text{DTR/SLEEP_RQ}}$ and DIN to low (CMOS0V) and $\overline{\text{RTS}}$ should be high.
4. Terminate the serial break and send a carriage return at 115200 baud to the device.
5. If successful, the device sends the Silicon Labs' Gecko bootloader menu out the DOUT pin at 115200 baud.
6. You can send commands can be sent to the bootloader at 115200 baud.

Note Disable hardware flow control when entering and communicating with the bootloader.

All serial communications with the module use 8 data bits, no parity bit, and 1 stop bit.

Send a firmware image

After invoking the bootloader, a menu is sent out the UART at 115200 baud. To upload a firmware image through the UART interface:

1. Look for the bootloader prompt **BL >** to ensure the bootloader is active.
2. Send an ASCII **1** character to initiate a firmware update.
3. After sending a **1**, the device waits for an XModem CRC upload of a .gbl image over the serial line at 115200 baud. Send the .gbl file to the device using standard XMODEM-CRC.

If the firmware image is successfully loaded, the bootloader outputs a “complete” string. Invoke the newly loaded firmware by sending a **2** to the device.

If the firmware image is not successfully loaded, the bootloader outputs an "aborted string". It return to the main bootloader menu. Some causes for failure are:

- Over 1 minute passes after the command to send the firmware image and the first block of the image has not yet been sent.
- A power cycle or reset event occurs during the firmware load.
- A file error or a flash error occurs during the firmware load.

XBee Network Assistant

The XBee Network Assistant is an application designed to inspect and manage RF networks created by Digi XBee devices. Features include:

- Join and inspect any nearby XBee network to get detailed information about all the nodes it contains.
- Update the configuration of all the nodes of the network, specific groups, or single devices based on configuration profiles.
- Geo-locate your network devices or place them in custom maps and get information about the connections between them.
- Export the network you are inspecting and import it later to continue working or work offline.
- Use automatic application updates to keep you up to date with the latest version of the tool.

See the [XBee Network Assistant User Guide](#) for more information.

To install the XBee Network Assistant:

1. Navigate to digi.com/xbeenetworkassistant.
2. Click **General Diagnostics, Utilities and MIBs**.
3. Click the **XBee Network Assistant - Windows x86** link.
4. When the file finishes downloading, run the executable file and follow the steps in the XBee Network Assistant Setup Wizard.

XBee Multi Programmer

The XBee Multi Programmer is a combination of hardware and software that enables partners and distributors to program multiple Digi Radio frequency (RF) devices simultaneously. It provides a fast and easy way to prepare devices for distribution or large networks deployment.

The XBee Multi Programmer board is an enclosed hardware component that allows you to program up to six RF modules thanks to its six external XBee sockets. The XBee Multi Programmer application communicates with the boards and allows you to set up and execute programming sessions. Some of the features include:

- Each XBee Multi Programmer board allows you to program up to six devices simultaneously. Connect more boards to increase the programming concurrency.
- Different board variants cover all the XBee form factors to program almost any Digi RF device.

Download the XBee Multi Programmer application from: digi.com/support/productdetail?pid=5641

See the [XBee Multi Programmer User Guide](#) for more information.

Modes

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Transparent operating mode

Devices operate in this mode by default. The device acts as a serial line replacement when it is in Transparent operating mode. The device queues all UART data it receives through the DIN pin for RF transmission. When a device receives RF data, it sends the data out through the DOUT pin. You can set the configuration parameters using Command mode.

API operating mode

API operating mode is an alternative to Transparent operating mode. API mode is a frame-based protocol that allows you to direct data on a packet basis. The device communicates UART or SPI data in packets, also known as API frames. This mode allows for structured communications with computers and microcontrollers.

The advantages of API operating mode include:

- It is easier to send information to multiple destinations
- The host receives the source address for each received data frame
- You can change parameters without entering Command mode

Command mode

Command mode is a state in which the firmware interprets incoming characters as commands. It allows you to modify the device's configuration using parameters you can set using AT commands. When you want to read or set any parameter of the XBee3 DigiMesh RF Module using this mode, you have to send an AT command. Every AT command starts with the letters **AT** followed by the two characters that identify the command and then by some optional configuration values.

The operating modes of the XBee3 DigiMesh RF Module are controlled by the [AP \(API Enable\)](#) setting, but Command mode is always available as a mode the device can enter while configured for any of the operating modes.

Command mode is available on the UART interface for all operating modes. You cannot use the SPI interface to enter Command mode.

Enter Command mode

To get a device to switch into Command mode, you must issue the following sequence: **+++** within one second. There must be at least one second preceding and following the **+++** sequence. Both the command character (**CC**) and the silence before and after the sequence (**GT**) are configurable. When the entrance criteria are met the device responds with **OK\r** on UART signifying that it has entered Command mode successfully and is ready to start processing AT commands.

If configured to operate in [Transparent operating mode](#), when entering Command mode the XBee3 DigiMesh RF Module knows to stop sending data and start accepting commands locally.

Note Do not press **Return** or **Enter** after typing **+++** because it interrupts the guard time silence and prevents you from entering Command mode.

When the device is in Command mode, it listens for user input and is able to receive AT commands on the UART. If **CT** time (default is 10 seconds) passes without any user input, the device drops out of Command mode and returns to the previous operating mode. You can force the device to leave Command mode by sending [CN \(Exit Command mode\)](#).

You can customize the command character, the guard times and the timeout in the device's configuration settings. For more information, see [CC \(Command Character\)](#), [CT \(Command Mode Timeout\)](#) and [GT \(Guard Time\)](#).

Troubleshooting

Failure to enter Command mode is often due to baud rate mismatch. Ensure that the baud rate of the connection matches the baud rate of the device. By default, [BD \(Baud Rate\)](#) = **3** (9600 b/s).

There are two alternative ways to enter Command mode:

- A serial break for six seconds enters Command mode. You can issue the "break" command from a serial console, it is often a button or menu item.
- Asserting DIN (serial break) upon power up or reset enters Command mode. XCTU guides you through a reset and automatically issues the break when needed.

Note You must assert $\overline{\text{RTS}}$ for both of these methods, otherwise the device enters the bootloader.

Both of these methods temporarily set the device's baud rate to 9600 and return an **OK** on the UART to indicate that Command mode is active. When Command mode exits, the device returns to normal operation at the baud rate that **BD** is set to.

Send AT commands

Once the device enters Command mode, use the syntax in the following figure to send AT commands. Every AT command starts with the letters **AT**, which stands for "attention." The AT is followed by two characters that indicate which command is being issued, then by some optional configuration values. To read a parameter value stored in the device's register, omit the parameter field.

“AT” prefix + ASCII command + Space (optional) + Parameter (optional, HEX) + Carriage return



Example: AT NI 2 <CR>

The preceding example changes [NI \(Network Identifier\)](#) to **My XBee**.

Multiple AT commands

You can send multiple AT commands at a time when they are separated by a comma in Command mode; for example, **ATNIMy XBee,AC<cr>**.

The preceding example changes the **NI (Node Identifier)** to **My XBee** and makes the setting active through [AC \(Apply Changes\)](#).

Parameter format

Refer to the list of [AT commands](#) for the format of individual AT command parameters. Valid formats for hexadecimal values include with or without a leading **0x** for example **FFFF** or **0xFFFF**.

Response to AT commands

When using AT commands to set parameters the XBee3 DigiMesh RF Module responds with **OK<cr>** if successful and **ERROR<cr>** if not.

Apply command changes

Any changes you make to the configuration command registers using AT commands do not take effect until you apply the changes. For example, if you send the **BD** command to change the baud rate, the actual baud rate does not change until you apply the changes. To apply changes:

1. Send [AC \(Apply Changes\)](#).
2. Send [WR \(Write\)](#).
or:
3. [Exit Command mode](#).

Make command changes permanent

Send a [WR \(Write\)](#) command to save the changes. **WR** writes parameter values to non-volatile memory so that parameter modifications persist through subsequent resets.

Send as [RE \(Restore Defaults\)](#) to wipe settings saved using **WR** back to their factory defaults, or custom defaults if you have set any.

Note You still have to use **WR** to save the changes enacted with **RE**.

Exit Command mode

1. Send [CN \(Exit Command mode\)](#) followed by a carriage return.
or:
2. If the device does not receive any valid AT commands within the time specified by [CT \(Command Mode Timeout\)](#), it returns to Transparent or API mode. The default Command mode timeout is 10 seconds.

For an example of programming the device using AT Commands and descriptions of each configurable parameter, see [AT commands](#).

Idle mode

When not receiving or transmitting data, the device is in Idle mode. During Idle mode, the device listens for valid data on both the RF and serial ports.

Transmit mode

Transmit mode is the mode in which the device is transmitting data. This typically happens after data is received from the serial port.

Receive mode

This is the default mode for the XBee3 DigiMesh RF Module. The device is in Receive mode when it is not transmitting data. If a destination node receives a valid RF packet, the destination node transfers the data to its serial transmit buffer.

Serial communication

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Serial interface

The XBee3 DigiMesh RF Module interfaces to a host device through a serial port. The device can communicate through its serial port:

- Through logic and voltage compatible universal asynchronous receiver/transmitter (UART).
- Through a level translator to any serial device, for example through an RS-232 or USB interface board.
- Through SPI, as described in [SPI communications](#).

Serial receive buffer

When serial data enters the XBee3 DigiMesh RF Module through the serial port, the device stores the data in the serial receive buffer until it can be processed. Under certain conditions, the device may receive data when the serial receive buffer is already full. In that case, the device discards the data.

The serial receive buffer becomes full when data is streaming into the serial port faster than it can be processed and sent over the air (OTA). While the speed of receiving the data on the serial port can be much faster than the speed of transmitting data for a short period, sustained operation in that mode causes the device to drop data due to running out of places to put the data. Some things that may delay over the air transmissions are address discovery, route discovery, and retransmissions. Processing received RF data can also take away time and resources for processing incoming serial data.

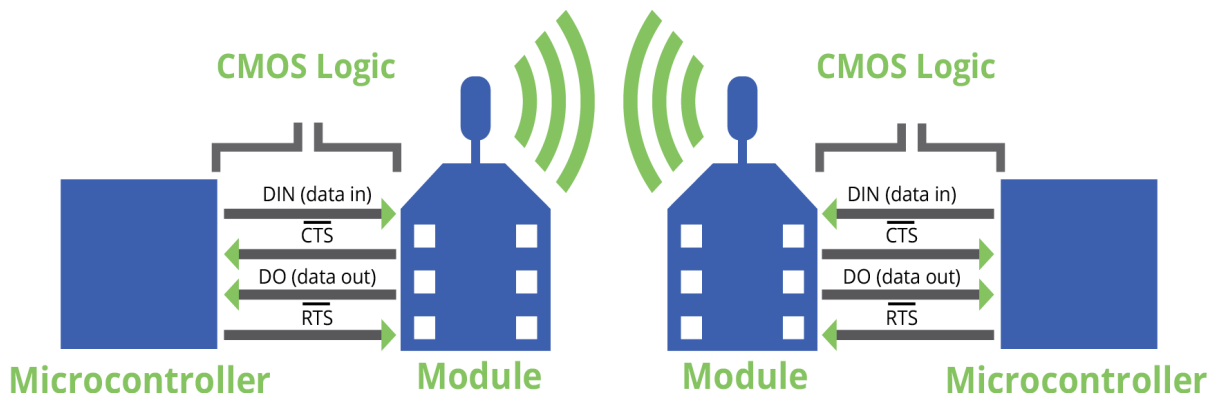
If the UART is the serial port and you enable the CTS flow control, the device alerts the external data source when the receive buffer is almost full. The host delays sending data to the device until the module asserts CTS again, allowing more data to come in.

Serial transmit buffer

When the device receives RF data, it moves the data into the serial transmit buffer and sends it out the UART. If the serial transmit buffer becomes full and the system buffers are also full, then it drops the entire RF data packet. Whenever the device receives data faster than it can process and transmit the data out the serial port, there is a potential of dropping data.

UART data flow

Devices that have a UART interface connect directly to the pins of the XBee3 DigiMesh RF Module as shown in the following figure. The figure shows system data flow in a UART-interfaced environment. Low-asserted signals have a horizontal line over the signal name.



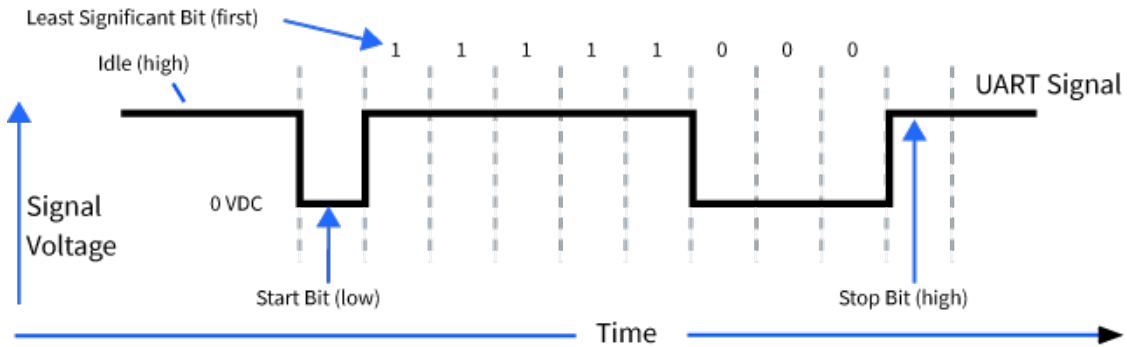
For more information about hardware specifications for the UART, see the [XBee3 Hardware Reference Manual](#).

Serial data

A device sends data to the XBee3 DigiMesh RF Module's UART as an asynchronous serial signal. When the device is not transmitting data, the signals should idle high.

For serial communication to occur, you must configure the UART of both devices (the microcontroller and the XBee3 DigiMesh RF Module) with compatible settings for the baud rate, parity, start bits, stop bits, and data bits.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following diagram illustrates the serial bit pattern of data passing through the device. The diagram shows UART data packet 0x1F (decimal number 31) as transmitted through the device.

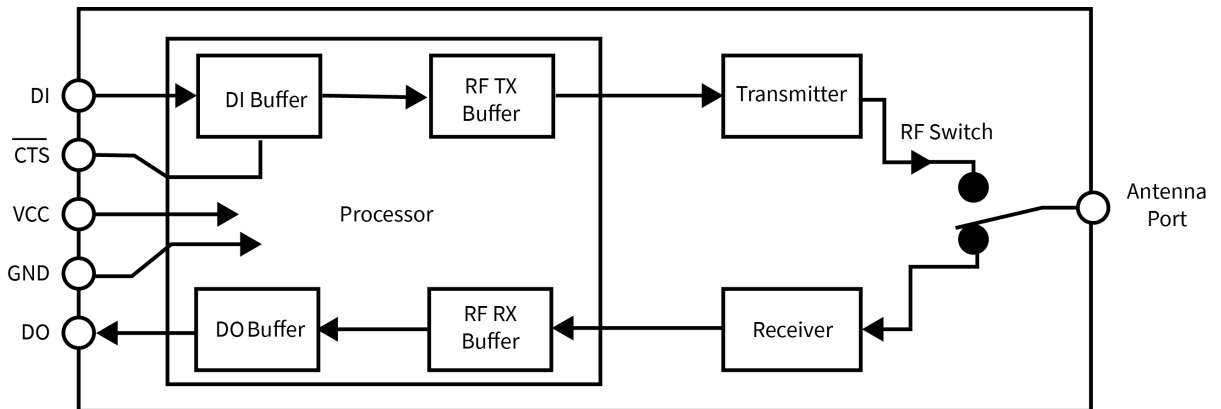


You can configure the UART baud rate, parity, and stop bits settings on the device with the **BD**, **NB**, and **SB** commands respectively. For more information, see [UART interface commands](#).

Flow control

The XBee3 DigiMesh RF Module maintains buffers to collect serial and RF data that it receives. The serial receive buffer collects incoming serial characters and holds them until the device can process them. The serial transmit buffer collects the data it receives via the RF link until it transmits that data out the serial port. The following figure shows the process of device buffers collecting received serial data.

Use [D6 \(DIO6/RTS Configuration\)](#) and [D7 \(DIO7/CTS Configuration\)](#) to set flow control.



Clear-to-send (CTS) flow control

If you enable $\overline{\text{CTS}}$ flow control ([D7 \(DIO7/CTS Configuration\)](#)), when the serial receive buffer is more than **FT** bytes full, the device de-asserts CTS (sets it high) to signal to the host device to stop sending serial data. The device reasserts CTS after the serial receive buffer has less than **FT** bytes in it. See [FT \(Flow Control Threshold\)](#) to configure and read this threshold.

RTS flow control

If you set [D6 \(DIO6/RTS Configuration\)](#) to enable $\overline{\text{RTS}}$ flow control, the device does not send data in the serial transmit buffer out the DOUT pin as long as RTS is de-asserted (set high). Do not de-assert RTS for long periods of time or the serial transmit buffer will fill. If the device receives an RF data packet and the serial transmit buffer does not have enough space for all of the data bytes, it discards the entire RF data packet.

If the device sends data out the UART when $\overline{\text{RTS}}$ is de-asserted (set high) the device could send up to five characters out the UART port after RTS is de-asserted.

Cases in which the DO buffer may become full, resulting in dropped RF packets:

1. If the RF data rate is set higher than the interface data rate of the device, the device may receive data faster than it can send the data to the host. Even occasional transmissions from a large number of devices can quickly accumulate and overflow the transmit buffer.
2. If the host does not allow the device to transmit data out from the serial transmit buffer due to being held off by hardware flow control.

SPI operation

This section specifies how SPI is implemented on the device, what the SPI signals are, and how full duplex operations work.

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SPI communications

The XBee3 DigiMesh RF Module supports SPI communications in slave mode. Slave mode receives the clock signal and data from the master and returns data to the master. The following table shows the signals that the SPI port uses on the device.

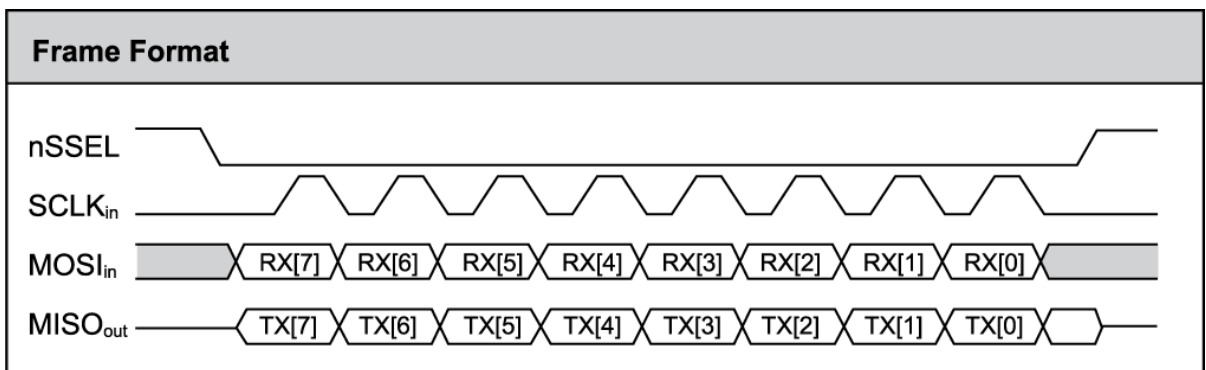
Refer to the [XBee3 Hardware Reference Guide](#) for the pinout of your device.

Signal	Direction	Function
SPI_MOSI (Master Out, Slave In)	Input	Inputs serial data from the master
SPI_MISO (Master In, Slave Out)	Output	Outputs serial data to the master
SPI_SCLK (Serial Clock)	Input	Clocks data transfers on MOSI and MISO
SPI_SSEL (Slave Select)	Input	Enables serial communication with the slave
SPI_ATT $\overline{\text{N}}$ (Attention)	Output	Alerts the master that slave has data queued to send. The XBee3 DigiMesh RF Module asserts this pin as soon as data is available to send to the SPI master and it remains asserted until the SPI master has clocked out all available data.

In this mode:

- SPI clock rates up to 5 MHz (burst) are possible.
- Data is most significant bit (MSB) first; bit 7 is the first bit of a byte sent over the interface.
- Frame Format mode 0 is used. This means CPOL= 0 (idle clock is low) and CPHA = 0 (data is sampled on the clock's leading edge).
- The SPI port only supports API Mode (**AP = 1**).

The following diagram shows the frame format mode 0 for SPI communications.



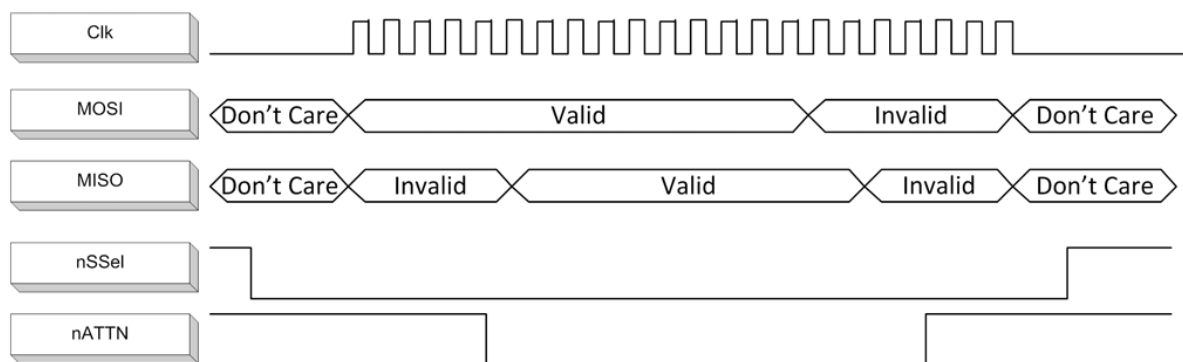
SPI mode is chip to chip communication. We do not supply a SPI communication interface on the XBee development evaluation boards included in the development kit.

Full duplex operation

When using SPI on the XBee3 DigiMesh RF Module the device uses API operation without escaped characters to packetize data. The device ignores the configuration of **AP** because SPI does not operate in any other mode. SPI is a full duplex protocol, even when data is only available in one direction. This means that whenever a device receives data, it also transmits, and that data is normally invalid. Likewise, whenever a device transmits data, invalid data is probably received. To determine whether or not received data is invalid, the firmware places the data in API packets.

SPI allows for valid data from the slave to begin before, at the same time, or after valid data begins from the master. When the master sends data to the slave and the slave has valid data to send in the middle of receiving data from the master, a full duplex operation occurs, where data is valid in both directions for a period of time. Not only must the master and the slave both be able to keep up with the full duplex operation, but both sides must honor the protocol.

The following figure illustrates the SPI interface while valid data is being sent in both directions.



Low power operation

Sleep modes generally work the same on SPI as they do on UART. However, due to the addition of SPI mode, there is an option of another sleep pin, as described below.

By default, Digi configures DIO8 (SLEEP_REQUEST) as a peripheral and during pin sleep it wakes the device and puts it to sleep. This applies to both the UART and SPI serial interfaces.

If SLEEP_REQUEST is not configured as a peripheral and SPI_SSEL is configured as a peripheral, then pin sleep is controlled by SPI_SSEL rather than by SLEEP_REQUEST. Asserting SPI_SSEL by driving it low either wakes the device or keeps it awake. Negating SPI_SSEL by driving it high puts the device to sleep.

Using SPI_SSEL to control sleep and to indicate that the SPI master has selected a particular slave device has the advantage of requiring one less physical pin connection to implement pin sleep on SPI. It has the disadvantage of putting the device to sleep whenever the SPI master negates SPI_SSEL (meaning time is lost waiting for the device to wake), even if that was not the intent.

If the user has full control of SPI_SSEL so that it can control pin sleep, whether or not data needs to be transmitted, then sharing the pin may be a good option in order to make the SLEEP_REQUEST pin available for another purpose.

If the device is one of multiple slaves on the SPI, then the device sleeps while the SPI master talks to the other slave, but this is acceptable in most cases.

If you do not configure either pin as a peripheral, then the device stays awake, being unable to sleep in **SM1** mode.

Select the SPI port

To force SPI mode on through-hole devices, hold DOUT/DIO13 low while resetting the device until SPI_ATT $\overline{\text{N}}$ asserts. This causes the device to disable the UART and go straight into SPI communication mode. Once configuration is complete, the device queues a modem status frame to the SPI port, which causes the SPI_ATT $\overline{\text{N}}$ line to assert. The host can use this to determine that the SPI port is configured properly.

On surface-mount devices, forcing DOUT low at the time of reset has no effect. To use SPI mode on the SMT modules, assert the SPI_SSEL low after reset and before any UART data is input.

Forcing DOUT low on TH devices forces the device to enable SPI support by setting the following configuration values:

Through-hole	Micro and Surface-mount	SPI signal
D1 (DIO1/ADC1/TH_SPI_ATT $\overline{\text{N}}$ Configuration)	P9 (DIO19/SPI_ATT $\overline{\text{N}}$ Configuration)	ATT $\overline{\text{N}}$
D2 (DIO2/ADC2/TH_SPI_CLK Configuration)	P8 (DIO18/SPI_CLK Configuration)	SCLK
D3 (DIO3/ADC3/TH_SPI_SSEL Configuration)	P7 (DIO17/SPI_SSEL Configuration)	SSEL $\overline{\text{}}$
D4 (DIO4/TH_SPI_MOSI Configuration)	P6 (DIO16/SPI_MOSI Configuration)	MOSI
P2 (DIO12/TH_SPI_MISO Configuration)	P5 (DIO15/SPI_MISO Configuration)	MISO

Note The ATT $\overline{\text{N}}$ signal is optional—you can still use SPI mode if you disable the SPI_ATT $\overline{\text{N}}$ pin (**D1** on through-hole or **P9** on surface-mount devices).

As long as the host does not issue a **WR** command, these configuration values revert to previous values after a power-on reset. If the host issues a **WR** command while in SPI mode, these same parameters are written to flash, and after a reset the device continues to operate in SPI mode.

If the UART is disabled and the SPI is enabled in the written configuration, then the device comes up in SPI mode without forcing it by holding DOUT low. If both the UART and the SPI are configured (**P3** (DIO13/UART_DOUT) through **P9** (DIO19/SPI_ATT $\overline{\text{N}}$ Configuration) are set to **1**) at the time of reset, then output goes to the UART until the host sends the first input to the SPI interface. As soon as the first input comes on the SPI port, then all subsequent output goes to the SPI port and the UART is disabled.

Once you select a serial port (UART or SPI), all subsequent output goes to that port, even if you apply a new configuration. Once the SPI interface is made active, the only way to switch the selected serial port back to UART is to reset the device.

When the master asserts the slave select (SPI_SSEL $\overline{\text{}}$) signal, SPI transmit data is driven to the output pin SPI_MISO, and SPI data is received from the input pin SPI_MOSI. The SPI_SSEL pin has to be asserted to enable the transmit serializer to drive data to the output signal SPI_MISO. A rising edge on SPI_SSEL causes the SPI_MISO line to be tri-stated such that another slave device can drive it, if so desired.

If the output buffer is empty, the SPI serializer transmits the last valid bit repeatedly, which may be either high or low. Otherwise, the device formats all output in API mode 1 format, as described in [Operate in API mode](#). The attached host is expected to ignore all data that is not part of a formatted API frame.

Force UART operation

If you configure a device with only the SPI enabled and no SPI master is available to access the SPI slave port, you can recover the device to UART operation by holding DIN / CONFIG low at reset time. DIN/CONFIG forces a default configuration on the UART at 9600 baud and brings up the device in Command mode on the UART port. You can then send the appropriate commands to the device to configure it for UART operation. If you write those parameters, the device comes up with the UART enabled on the next reset.

I/O support

The following topics describe analog and digital I/O line support, line passing and output control.

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Digital I/O support

Digital I/O is available on lines DIO0 through DIO12 ([D0 \(DIO0/ADC0/Commissioning Configuration\)](#) - [D9 \(DIO9/ON_SLEEP Configuration\)](#) and [P0 \(DIO10/RSSI/PWM0 Configuration\)](#) - [P4 \(DIO14/UART_DIN Configuration\)](#)). Digital sampling is enabled on these pins if configured as 3, 4, or 5 with the following meanings:

- 3 is digital input.
 - Use [PR \(Pull-up/Down Resistor Enable\)](#) to enable internal pull up/down resistors for each digital input. Use [PD \(Pull Up/Down Direction\)](#) to determine the direction of the internal pull up/down resistor. All disabled and digital input pins are pulled up by default.
- 4 is digital output low.
- 5 is digital output high.

Function	Micro Pin	SMT Pin	TH Pin	AT Command
DIO0	31	33	20	D0 (DIO0/ADC0/Commissioning Configuration)
DIO1	30	32	19	D1 (DIO1/ADC1/TH_SPI_ATTN Configuration)
DIO2	29	31	18	D2 (DIO2/ADC2/TH_SPI_CLK Configuration)
DIO3	28	30	17	D3 (DIO3/ADC3/TH_SPI_SSEL Configuration)
DIO4	23	24	11	D4 (DIO4/TH_SPI_MOSI Configuration)
DIO5	26	28	15	D5 (DIO5/Associate Configuration)
DIO6	27	29	16	D6 (DIO6/RTS Configuration)
DIO7	24	25	12	D7 (DIO7/CTS Configuration)
DIO8	9	10	9	D8 (DIO8/DTR/SLP_Request Configuration)
DIO9	25	26	13	D9 (DIO9/ON_SLEEP Configuration)
DIO10	7	7	6	P0 (DIO10/RSSI/PWM0 Configuration)
DIO11	8	8	7	P1 (DIO11/PWM1 Configuration)
DIO12	5	5	4	P2 (DIO12/TH_SPI_MISO Configuration)
DIO13	3	3	2	P3 (DIO13/UART_DOUT)
DIO14	4	4	3	P4 (DIO14/UART_DIN Configuration)

I\O sampling is not available for pins P5 through P9. See the [XBee3 Hardware Reference Manual](#) for full pinouts and functionality.

Analog I/O support

Analog input is available on D0 through D3. Configure these pins to **2** (ADC) to enable analog sampling. PWM output is available on P0 and P1, which can be used for [Analog line passing](#). Use [M0 \(PWM0 Duty Cycle\)](#) and [M1 \(PWM1 Duty Cycle\)](#) to set a fixed PWM level.

Function	Micro Pin	SMT Pin	TH Pin	AT Command
ADC0	31	33	20	D0 (DIO0/ADC0/Commissioning Configuration)
ADC1	30	32	19	D1 (DIO1/ADC1/TH_SPI_ATTN Configuration)
ADC2	29	31	18	D2 (DIO2/ADC2/TH_SPI_CLK Configuration)
ADC3	28	30	17	D3 (DIO3/ADC3/TH_SPI_SSEL Configuration)
PWM0	7	7	6	P0 (DIO10/RSSI/PWM0 Configuration)
PWM1	8	8	7	P1 (DIO11/PWM1 Configuration)

[AV \(Analog Voltage Reference\)](#) specifies the analog reference voltage used for the 10-bit ADCs. Analog sample data is represented as a 2-byte value. For a 10-bit ADC, the acceptable range is from **0x0000** to **0x03FF**. To convert this value to a useful voltage level, apply the following formula:

$$\text{ADC} / 1023 (\text{vREF}) = \text{Voltage}$$

Example

An ADC value received is 0x01AE; to convert this into a voltage the hexadecimal value is first converted to decimal (0x01AE = 430). Using the default **AV** reference of 1.25 V, apply the formula as follows:

$$430 / 1023 (1.25 \text{ V}) = 525 \text{ mV}$$

Monitor I/O lines

You can monitor pins you configure as digital input, digital output, or analog input and generate I/O sample data. If you do not define inputs or outputs, no sample data is generated.

Typically, I/O samples are generated by configuring the device to sample I/O pins periodically (based on a timer) or when a change is detected on one or more digital pins. These samples are always sent over the air to the destination address specified with [DH \(Destination Address High\)](#) and [DL \(Destination Address Low\)](#).

You can also gather sample data using on-demand sampling, which allows you to interrogate the state of the device's I/O pins by issuing an AT command. You can do this on either a local or remote device via an AT command request.

The three methods to generate sample data are:

- **Periodic sample ([IR \(Sample Rate\)](#))**
 - Periodic sampling based on a timer
 - Samples are taken immediately upon wake (excluding pin sleep)
 - Sample data is sent to **DH+DL** destination address
 - Can be used with line passing
 - Requires API mode on receiver
- **Change detect ([IC \(DIO Change Detect\)](#))**
 - Samples are generated when the state of specified digital input pin(s) change
 - Sample data is sent to **DH+DL** destination address
 - Can be used with line passing
 - Requires API mode on receiver

- On-demand sample (IS (I/O Sample))
 - Immediately query the device's I/O lines
 - Can be issued locally in Command Mode
 - Can be issued locally or remotely in API mode

These methods are not mutually exclusive and you can use them in combination with each other.

I/O sample data format

Regardless of how I/O data is generated, the format of the sample data is always represented as a series of bytes in the following format:

Bytes	Name	Description
1	Sample sets	Number of sample sets. There is always one sample set per frame.
2	Digital channel mask	Indicates which digital I/O lines have sampling enabled. Each bit corresponds to one digital I/O line on the device. bit 0 = DIO0 bit 1 = DIO1 bit 2 = DIO2 bit 3 = DIO3 bit 4 = DIO4 bit 5 = DIO5 bit 6 = DIO6 bit 7 = DIO7 bit 8 = DIO8 bit 9 = DIO9 bit 10 = DIO10 bit 11 = DIO11 bit 12 = DIO12 bit 13 = DIO13 bit 14 = DIO14 bit 15 = N/A Example: a digital channel mask of 0x002F means DIO0, 1, 2, 3 and 5 are configured as digital inputs or outputs.
1	Analog channel mask	Indicates which lines have analog inputs enabled for sampling. Each bit in the analog channel mask corresponds to one analog input channel. If a bit is set, then a corresponding 2-byte analog data set is included. bit 0 = AD0/DIO0 bit 1 = AD1/DIO1 bit 2 = AD2/DIO2 bit 3 = AD3/DIO3
2	Digital data set	Each bit in the digital data set corresponds to a bit in the digital channel mask and indicates the digital state of the pin, whether high (1) or low (0). If the digital channel mask is 0x0000, then these two bytes are omitted as no digital I/O lines are enabled.

Bytes	Name	Description
2	Analog data set (multiple)	Each enabled ADC line in the analog channel mask will have a separate 2-byte value based on the number of ADC inputs on the originating device. The data starts with AD0 and continues sequentially for each enabled analog input channel up to AD3. If the analog channel mask is 0x00, then no analog sample bytes is included.

API frame support

I/O samples generated using [Periodic I/O sampling \(IR\)](#) and [Digital I/O change detection \(IC\)](#) are transmitted to the destination address specified by **DH** and **DL**. In order to display the sample data, the receiver must be operating in API mode (**AP = 1** or **2**). The sample data is represented as an I/O sample API frame.

See [I/O Data Sample Rx Indicator frame - 0x92](#) for more information on the frame's format and an example.

On-demand sampling

You can use [IS \(I/O Sample\)](#) to query the current state of all digital I/O and ADC lines on the device and return the sample data as an AT command response. If no inputs or outputs are defined, the command returns an ERROR.

On-demand sampling can be useful when performing initial deployment, as you can send **IS** locally to verify that the device and connected sensors are correctly configured. The format of the sample data matches what is periodically sent using other sampling methods. You can also send **IS** remotely using a remote AT command. When sent remotely from a gateway or server to each sensor node on the network, on-demand sampling can improve battery life and network performance as the remote node transmits sample data only when requested instead of continuously.

If you send **IS** using [Command mode](#), then the device returns a carriage return delimited list containing the I/O sample data. If **IS** is sent either locally or remotely via an API frame, the I/O sample data is presented as the parameter value in the AT command response frame ([AT Command Response frame - 0x88](#) or [Remote Command Response frame - 0x97](#)).

Example: Command mode

An **IS** command sent in Command mode returns the following [sample data](#):

Output	Description
01	One sample set
0C0C	Digital channel mask, indicates which digital lines are sampled (0x0C0C = 0000 1100 0000 1100 b = DIO2, 3, 10, 11)
03	Analog channel mask, indicates which analog lines are sampled (0x03 = 0000 00 11 b = AD0, 1)
0408	Digital sample data that corresponds with the digital channel mask 0x0408 = 0000 0100 0000 1000 b = DIO3 and DIO10 are high, DIO2 and DIO11 are low
03D0	Analog sample data for AD0
0124	Analog sample data for AD1

Example: Local AT command in API mode

The **IS** command sent to a local device in API mode would use a [AT Command Frame - 0x08](#) or [AT Command - Queue Parameter Value frame - 0x09](#) frame:

```
7E 00 04 08 53 49 53 08
```

The device responds with a [AT Command Response frame - 0x88](#) that contains the [sample data](#):

```
7E 00 0F 88 53 49 53 00 01 0C 0C 03 04 08 03 D0 01 24 68
```

Output	Field	Description
7E	Start Delimiter	Indicates the beginning of an API frame
00 0F	Length	Length of the packet
88	Frame type	AT Command response frame
53	Frame ID	This ID corresponds to the Frame ID of the 0x08 request
49 53	AT Command	Indicates the AT command that this response corresponds to 0x49 0x53 = IS
00	Status	Indicates success or failure of the AT command 00 = OK if no I/O lines are enabled, this will return 01 (ERROR)
01	I/O sample data	One sample set
0C 0C		Digital channel mask, indicates which digital lines are sampled (0x0C0C = 0000 1100 0000 1100 b = DIO2, 3, 10, 11)
03		Analog channel mask, indicates which analog lines are sampled (0x03 = 0000 00 11 b = AD0, 1)
04 08		Digital sample data that corresponds with the digital channel mask 0x0408 = 0000 0100 0000 1000 b = DIO3 and DIO10 are high, DIO2 and DIO11 are low
03 D0		Analog sample data for AD0
01 24		Analog sample data for AD1
68	Checksum	Can safely be discarded on received frames

Example: Remote AT command in API mode

The **IS** command sent to a remote device with an address of 0013A200 12345678 uses a [Remote AT Command Request frame - 0x17](#):

```
7E 00 0F 17 87 00 13 A2 00 12 34 56 78 FF FE 00 49 53 FF
```

The [sample data](#) from the device is returned in a [Remote Command Response frame - 0x97](#) frame with the sample data as the parameter value:

```
7E 00 19 97 87 00 13 A2 00 12 34 56 78 00 00 49 53 00 01 0C 0C 03 04 08 03 FF 03 FF 50
```

Output	Field	Description
7E	Start Delimiter	Indicates the beginning of an API frame
00 19	Length	Length of the packet
97	Frame type	Remote AT Command response frame
87	Frame ID	This ID corresponds to the Frame ID of the 0x17 request
0013A200 12345678	64-bit source	The 64-bit address of the node that responded to the request
0000	16-bit source	The 16-bit address of the node that responded to the request
49 53	AT Command	Indicates the AT command that this response corresponds to 0x49 0x53 = IS
00	Status	Indicates success or failure of the AT command 00 = OK if no I/O lines are enabled, this will return 01 (ERROR)
01	I/O sample data	One sample set
0C 0C		Digital channel mask, indicates which digital lines are sampled (0x0C0C = 0000 1100 0000 1100b = DIO2, 3, 10, 11)
03		Analog channel mask, indicates which analog lines are sampled (0x03 = 0000 0011b = AD0, 1)
04 08		Digital sample data that corresponds with the digital channel mask 0x0408 = 0000 0100 0000 1000b = DIO3 and DIO10 are high, DIO2 and DIO11 are low
03 D0		Analog sample data for AD0
01 24		Analog sample data for AD1
50		Checksum

Periodic I/O sampling

Periodic sampling allows a device to take an I/O sample and transmit it to a remote device at a periodic rate.

Source

Use [IR \(Sample Rate\)](#) to set the periodic sample rate for enabled I/O lines.

- To disable periodic sampling, set **IR** to **0**.
- For all other **IR** values, the device samples data when **IR** milliseconds elapse and transmits the sampled data to the destination address.

The [DH \(Destination Address High\)](#) and [DL \(Destination Address Low\)](#) commands determine the destination address of the I/O samples. You must configure at least one pin as a [digital I/O](#) or [ADC input](#) on the sending node to generate sample data.

Destination

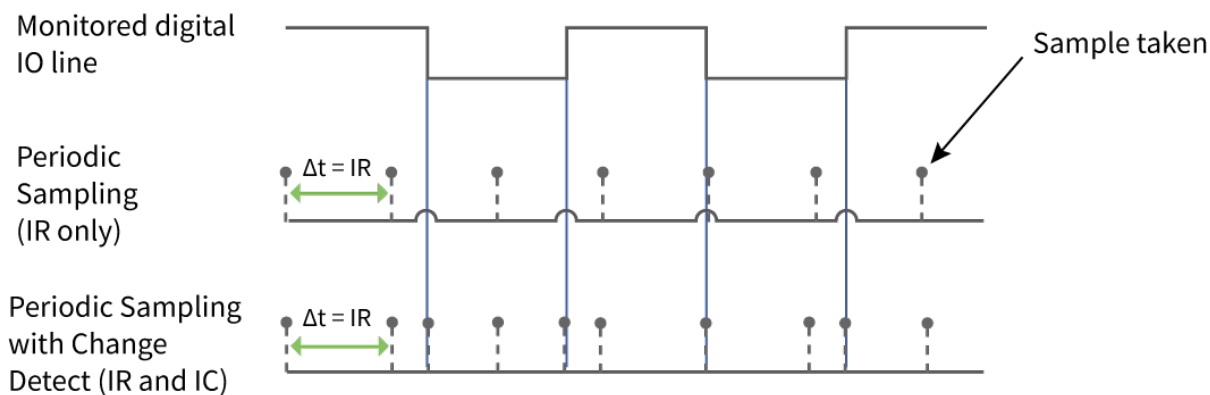
If the receiving device is operating in [API operating mode](#) the [I/O data sample](#) is emitted out of the serial port. Devices that are in [Transparent operating mode](#) discard the I/O data samples they receive unless you enable line passing.

Digital I/O change detection

You can configure devices to transmit a data sample immediately whenever a monitored digital I/O pin changes state. [IC \(DIO Change Detect\)](#) is a bitmask that determines which digital I/O lines to monitor for a state change. If you set one or more bits in **IC**, the device transmits an I/O sample as soon it observes a state change on the monitored digital I/O line(s) using edge detection.

Change detection is only applicable to [digital I/O pins](#) that are configured as digital input (**3**) or digital output (**4** or **5**).

The figure below shows how I/O change detection can work in combination with [Periodic I/O sampling](#) to improve sampling accuracy. In the figure, the gray dashed lines with a dot on top represent samples taken from the monitored DIO line. The top graph shows only [periodic IR samples](#), the bottom graph shows a combination of **IR** periodic samples and **IC** detected changes. In the top graph, the humps indicate that the sample was not taken at that exact moment and needed to wait for the next **IR** sample period.



Note Use caution when combining change detect sampling with [sleep modes](#). **IC** only causes a sample to be generated if a state change occurs during a wake period. If the device is sleeping when the digital transition occurs, then no change is detected and an I/O sample is not generated.

Use periodic sampling with **IR** in conjunction with **IC** in this instance, since **IR** generates an I/O sample upon wakeup and ensures that the change is properly observed.

I/O line passing

Line passing allows you to affect the output pins of one device by sampling the I/O pins of another. To support line passing, you must configure a device to generate I/O sample data using periodic sampling ([IR \(Sample Rate\)](#)) and/or change detection ([IC \(DIO Change Detect\)](#)).

On the device that receives I/O samples, enable line passing setting [IA \(I/O Input Address\)](#) with the address of the device that has the appropriate inputs enabled. This effectively binds the outputs to a particular device's input. This does not affect the ability of the device to receive I/O line data from other devices—only its ability to update enabled outputs. Set **IA** to **0xFFFF** (broadcast address) to affect the output using input data from any device on the network.

Digital line passing

Digital I/O lines are mapped in pairs; pins configured as digital input on the transmitting device affect the corresponding digital output pin on the receiving device. For example, a device that samples D5 as an input (3) only affects D5 on the receiver if D5 is configured as an output (4 or 5).

Each digital pin has an associated timeout value. When an I/O sample is received that affects a digital output pin, the pin returns to its configured state after the timeout period expires. For pins D0 through D9, the associated timeout commands are **T0 (D0 Timeout)** through **T9 (D9 Timeout)**. For pins P0 through P4, the associated timeout commands are **Q0 (P0 Timeout)** through **Q4**.

Digital line passing is only available on pins D0 through P3. You cannot use UART and SPI pins for line passing.

Example: Digital line passing

A sampling XBee3 DigiMesh RF Module is configured with the following settings:

AT command	Parameter value
D2 (DIO2/ADC2/TH_SPI_CLK Configuration)	3 (digital input)
IR (Sample Rate)	0x7D0 (2 seconds)
DH (Destination Address High)	0013A200
DL (Destination Address Low)	12345678

Every two seconds, an I/O sample is generated and sent to the address specified by **DH** and **DL**. The receiver is configured with the following settings:

AT command	Parameter value
D2 (DIO2/ADC2/TH_SPI_CLK Configuration)	5 (digital output low)
T2 (D2 Output Timeout)	0x64 (10 seconds)
IA (I/O Input Address)	0013A20087654321

When this device receives an incoming I/O sample, if the source address matches the one set by **IA**, the device sets the output of **D2** to match the input of **D2** of the receiver. This output level holds for ten seconds before the pin returns to a digital output low state.

Analog line passing

Similar to digital line passing, analog line passing pairs the **Analog I/O support** of one device to a PWM output of another. There are two PWM output pins that can simulate the voltage measured by the ADC inputs. Be aware that ADC inputs are on different pins than the corresponding PWM outputs: **AD0** corresponds to **PWM0**, and **AD1** corresponds to **PWM1**. See **Analog I/O support** for the pinouts.

You can set the analog line passing timeout value with **PT (PWM Output Timeout)**, which affects both **PWM output pins**. You can explicitly set a PWM output level using the **M0 (PWM0 Duty Cycle)** and **M1 (PWM1 Duty Cycle)** commands, when an I/O sample is received that affects a PWM output pin, it returns to its configured state after the **PT** timeout period expires.

Example: Analog line passing

A sampling device is configured with the following settings:

AT command	Parameter value
DO command	2 (ADC input)
IR (Sample Rate)	0x7D0 (2 seconds)
DH (Destination Address High)	0013A200
DL (Destination Address Low)	12345678

Every two seconds, an I/O sample frame is generated and sent to the address specified by **DH** and **DL**. The receiver is configured with the following settings:

AT command	Parameter value
P0	2 (PWM output)
M0	0
PT	0x12C (30 seconds)
IA	0013A20087654321

When this device receives an incoming I/O sample, if the source address matches the one set by **IA**, the device sets the PWM output of **P0** to match the ADC input of **DO** of the receiver. This output level holds for thirty seconds before the pin returns to a digital output low state.

Output sample data

If a device receives an I/O sample whose address matches that set by **IA** (I/O Input Address), it triggers line passing. Line passing operates whether the receiving device is operating in API or Transparent mode.

By default, if the receiver is configured for API mode, it outputs the I/O sample frame in addition to affecting output pins. You can suppress the I/O sample frame output by setting **IU** (Send I/O Sample to Serial Port) to **0**. This only suppresses I/O samples that trigger line passing, a sample generated from a device whose address does not match the **IA** address is sent regardless of **IU**.

Output control

IO (Set Digital I/O Lines) controls the output levels of **D0** (DIO0/ADC0/Commissioning Configuration) through **D7** (DIO7/CTS Configuration) that are configured as output pins (either **4** or **5**). These values override the configured output levels of the pins until they are changed again (the pins do not automatically revert to their configured values after a timeout.)

You can use **IO** to trigger a sample on change detect.

I/O behavior during sleep

When the device sleeps (**SM ! = 0**) the I/O lines are optimized for a minimal sleep current.

Digital I/O lines

Digital I/O lines set as digital output high or low maintain those values during sleep. Disabled or input pins continue to be controlled by the **PR/PD** settings. Peripheral pins (with the exception of CTS) are set low during sleep and SPI pins are set high. Peripheral and SPI pins resume normal operation upon wake.

Digital I/O lines that have been set using I/O line passing hold their values during sleep, however the digital timeout timer (**T0** through **T9**, and **Q0** through **Q2**) are suspended during sleep and resume upon wake.

Analog and PWM I/O Lines

Lines configured as analog inputs or PWM output are not affected during sleep. PWM lines are shut down (set low) during sleep and resume normal operation upon wake.

PWM output pins set by analog line passing are shutdown during sleep and revert to their preset values (**M0** and **M1**) on wake. This happens regardless of whether the timeout has expired or not.

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Network identifiers

You define DigiMesh networks with a unique network identifier. Use the **ID** command to set this identifier. For devices to communicate, you must configure them with the same network identifier and the same operating channel. For devices to communicate, the **CH** and **ID** commands must be equal on all devices in the network.

The **ID** command directs the devices to talk to each other by establishing that they are all part of the same network. The **ID** parameter allows multiple DigiMesh networks to co-exist on the same physical channel.

Operating channels

The XBee3 DigiMesh RF Module operates over the 2.4 GHz band using direct sequence spread spectrum (DSSS) modulation. DSSS modulation allows the device to operate over a channel or frequency that you specify.

The 2.4 GHz frequency band defines 16 operating channels. The XBee3 DigiMesh RF Module supports all 16 channels, but output power on channel 26 on the XBee3 PRO RF Module is limited.

Use the **CH** command to select the operating channel on a device. **CH** tells the device the frequency to use to communicate.

For devices to communicate, the **CH** and **ID** commands must be equal on all devices in the network.

Note these requirements for communication:

- A device can only receive data from other devices within the same network (with the same **ID** value) and using the same channel (with the same **CH** value).
- A device can only transmit data to other devices within the same network (with the same **ID** value) and using the same channel (with the same **CH** value).

Delivery methods

The **TO** ([Transmit Options](#)) command sets the default delivery method that the device uses when in Transparent mode. In API mode, the TxOptions field of the API frame overrides the **TO** command, if non-zero.

The XBee3 DigiMesh RF Module supports three delivery methods:

- Point-to-multipoint (**TO** = 0x40).
- Repeater (directed broadcast) (**TO** = 0x80).
- DigiMesh (**TO** = 0xC0).

Point-to-multipoint

To select point-to-multipoint, set the transmit options to 0x40.

In Transparent mode, use the **TO** (Transmit Options) command to set the transmit options.

In API mode, use the Transmit Request (0x10) and Explicit Addressing Command (0x11) frames to set the transmit options. However, if the transmit options in the API frame are zero, then the transmit options in the **TO** command apply.

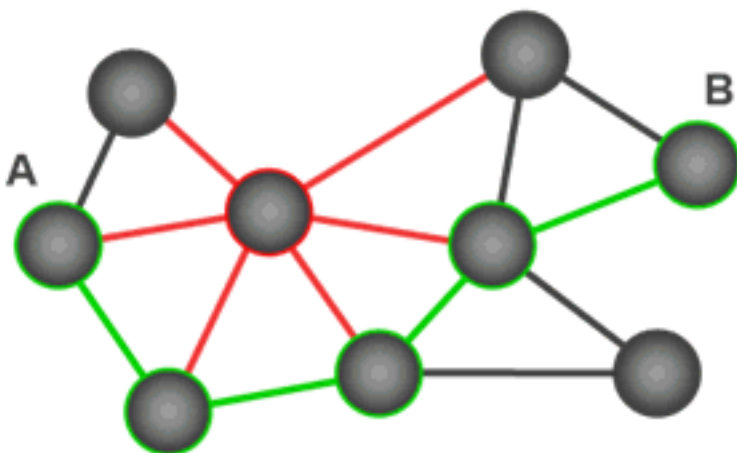
Point-to-multipoint transmissions occur between two adjacent nodes within RF range. No route discovery and no routing occur for these types of transmissions. The networking layer is entirely skipped.

Point-to-multipoint has an advantage over DigiMesh for two adjacent devices due to less overhead. However, it cannot work over multiple hops.

DigiMesh networking

A mesh network is a topology in which each node in the network is connected to other nodes around it. Each node cooperates in transmitting information. Mesh networking provides these important benefits:

- **Routing.** With this technique, the message is propagated along a path by hopping from node to node until it reaches its final destination.
- **Ad-hoc network creation.** This is an automated process that creates an entire network of nodes on the fly, without any human intervention.
- **Self-healing.** This process automatically figures out if one or more nodes on the network is missing and reconfigures the network to repair any broken routes.
- **Peer-to-peer architecture.** No hierarchy and no parent-child relationships are needed.
- **Quiet protocol.** Routing overhead will be reduced by using a reactive protocol similar to AODV.
- **Route discovery.** Rather than maintaining a network map, routes will be discovered and created only when needed.
- **Selective acknowledgments.** Only the destination node will reply to route requests.
- **Reliable delivery.** Reliable delivery of data is accomplished by means of acknowledgments.



With mesh networking, the distance between two nodes does not matter as long as there are enough nodes in between to pass the message along. When one node wants to communicate with another, the network automatically calculates the best path.

A mesh network is also reliable and offers redundancy. For example, If a node can no longer operate because it has been removed from the network or because a barrier blocks its ability to communicate, the rest of the nodes can still communicate with each other, either directly or through intermediate nodes.

Note Mesh networks use more bandwidth for routing than point-to-multipoint networks and therefore have less available for payloads.

Broadcast addressing

All of the routers in a network receive and repeat broadcast transmissions. Broadcast transmissions do not use ACKs, so the sending device sends the broadcast multiple times. By default, the sending device sends a broadcast transmission four times. The transmissions become automatic retries without acknowledgments. This results in all nodes repeating the transmission four times as well.

In order to avoid RF packet collisions, the network inserts a random delay before each router relays the broadcast message. You can change this random delay time with the **NN** parameter.

Sending frequent broadcast transmissions can quickly reduce the available network bandwidth. Use broadcast transmissions sparingly.

The broadcast address is a 64 bit address with the lowest 16 bits set to 1. The upper bits are set to 0. To send a broadcast transmission:

- Set **DH** to 0.
- Set **DL** to 0xFFFF.

In API operating mode, this sets the destination address to 0x000000000000FFFF.

Unicast addressing

When devices transmit using DigiMesh unicast, the network uses retries and acknowledgments (ACKs) for reliable data delivery. In a retry and acknowledgment scheme, for every data packet that a device sends, the receiving device must send an acknowledgment back to the transmitting device to let the sender know that the data packet arrived at the receiver. If the transmitting device does not receive an acknowledgment then it re-sends the packet. It sends the packet a finite number of times before the system times out.

The **MR** (Mesh Network Retries) parameter determines the number of mesh network retries. The sender device transmits RF data packets up to **MR** + 1 times across the network route, and the receiver transmits ACKs when it receives the packet. If the sender does not receive a network ACK within the time it takes for a packet to traverse the network twice, the sender retransmits the packet.

If a device sends a unicast that uses both MAC and NWK retries and acknowledgments:

- Use MAC retries and acknowledgments for transmissions between adjacent devices in the route.
- Use NWK retries and acknowledgments across the entire route.

To send unicast messages while in Transparent operating mode, set the **DH** and **DL** on the transmitting device to match the corresponding **SH** and **SL** parameter values on the receiving device.

Route discovery

Route discovery is a process that occurs when:

1. The source node does not have a route to the requested destination.
2. A route fails. This happens when the source node uses up its network retries without receiving an ACK.

Route discovery begins by the source node broadcasting a route request (RREQ). We call any router that receives the RREQ and is not the ultimate destination, an intermediate node.

Intermediate nodes may either drop or forward a RREQ, depending on whether the new RREQ has a better route back to the source node. If so, the node saves, updates and broadcasts the RREQ.

When the ultimate destination receives the RREQ, it unicasts a route reply (RREP) back to the source node along the path of the RREQ. It does this regardless of route quality and regardless of how many times it has seen an RREQ before.

This allows the source node to receive multiple route replies. The source node selects the route with the best round trip route quality, which it uses for the queued packet and for subsequent packets with the same destination address.

Routing

A device within a mesh network determines reliable routes using a routing algorithm and table. The routing algorithm uses a reactive method derived from Ad-hoc On-demand Distance Vector (AODV). The firmware uses an associative routing table to map a destination node address with its next hop. A device sends a message to the next hop address, and the message either reaches its destination or forwards to an intermediate router that routes the message on to its destination.

If a message has a broadcast address, it is broadcast to all neighbors, then all routers that receive the message rebroadcast the message **MT+1** times. Eventually, the message reaches the entire network.

Packet tracking prevents a node from resending a broadcast message more than **MT+1** times. This means that a node that relays a broadcast will only relay it after it receives it the first time and it will discard repeated instances of the same packet.

Routers

You can use the **CE** command to configure devices in a DigiMesh network to act as routers or end devices. All devices in a DigiMesh network act as routers by default. Any devices that you configure as routers actively relay network unicast and broadcast traffic.

Repeater/directed broadcast

All of the routers in a network receive and repeat directed broadcast transmissions. Because it does not use ACKs, the originating node sends the broadcast multiple times. By default a broadcast transmission is sent four times—the extra transmissions become automatic retries without acknowledgments. This results in all nodes repeating the transmission four times. Sending frequent broadcast transmissions can quickly reduce the available network bandwidth, so use broadcast transmissions sparingly.

MAC layer

The MAC layer is the building block that is used to build repeater capability. To implement Repeater mode, we use a network layer header that comes after the MAC layer header in each packet. In this network layer there is additional packet tracking to eliminate duplicate broadcasts.

In this delivery method, the device sends both unicast and broadcast packets out as broadcasts that are always repeated. All repeated packets are sent to every device. The devices that receive the broadcast send broadcast data out their serial port.

When a device sends a unicast, it specifies a destination address in the network header. Then, only the device that has the matching destination address sends the unicast out its serial port. This is called a directed broadcast.

Any node that has a **CE** parameter set to router rebroadcasts the packet if its **BH** (broadcast hops) or broadcast radius values are not depleted. If a node has already seen a repeated broadcast, it ignores the broadcast.

The **BH** parameter sets the maximum number of hops that a broadcast is repeated, but there are two special cases. If **BH** is **0** or if **BH** is **> NH**, then **NH** specifies the maximum hops for broadcasts instead.

By default the **CE** parameter is set to route all broadcasts. As such, all nodes that receive a repeated packet will repeat it. If you change the **CE** parameter, you can limit which nodes repeat packets, which helps dense networks from becoming overly congested while packets are being repeated.

Transmission timeout calculations for Repeater/directed broadcast mode are the same as for DigiMesh broadcast transmissions.

The MAC layer is the building block that is used to build repeater capability. To implement Repeater mode, we use a network layer header that comes after the MAC layer header in each packet. In this network layer there is additional packet tracking to eliminate duplicate broadcasts.

Encryption

XBee3 DigiMesh provides greater security against replay attacks and attempts to determine the plaintext. The XBee3 DigiMesh RF Module performs Counter (CTR) mode encryption instead of Electronic Codebook (ECB) mode encryption. Since the counter is passed over-the-air (OTA) and changes with each frame, the same text is always encrypted differently and there are no known attacks to determine the plaintext from the ciphertext.

A side effect of this implementation is that the maximum payload is reduced by the size of the counter (8 bytes). Therefore, no frames can exceed 65 bytes with encryption enabled. The maximum payload is still 73 bytes with encryption disabled.

Also effective with XBee3 DigiMesh, the key is 256 bits rather than 128 bits. 256 bits is 32 bytes. Since the key is entered with ASCII HEX characters in Command mode, up to 64 ASCII HEX characters may be entered for the **KY** command.

For compatibility with nodes in the same network that do not support CTR mode encryption, [C8 \(Compatibility Options\)](#) bit 2 was introduced to enable the 128-bit key with ECB mode encryption as supported previously. In this case, only the last 32 ASCII HEX characters of the key are used, even if more characters were previously entered for the key.

Maximum payload

DigiMesh uses the 802.15.4 PHY layer including a 2-byte CRC at the end of the frame. This reduces the size of each frame to 125 bytes. After the MAC header, the NWK header, and the APP header are included at the beginning of the packet, the remaining space is 73 bytes for payload. If CTR mode encryption is enabled, this number is further reduced to 65 bytes. The best way to determine the maximum payload is to read [NP \(Maximum Packet Payload Bytes\)](#).

These maximums only apply in API mode. If you attempt to send an API packet with a larger payload than specified, the device responds with a Transmit Status frame (0x89) with the Status field set to **74** (Data payload too large).

In Transparent mode, the firmware splits the data as necessary to cope with maximum payloads.

Network commissioning and diagnostics

We call the process of discovering and configuring devices in a network for operation, "network commissioning." Devices include several device discovery and configuration features. In addition to configuring devices, you must develop a strategy to place devices to ensure reliable routes. To accommodate these requirements, modules include features to aid in placing devices, configuring devices, and network diagnostics.

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Local configuration

You can configure devices locally using serial commands in Command mode or API mode, or remotely using remote AT commands. Devices that are in API mode can send configuration commands to set or read the configuration settings of any device in the network.

Remote configuration

When you do not have access to the device's serial port, you can use a separate device in API mode to remotely configure it. To remotely configure devices, use the following steps.

Send a remote command

To send a remote command, populate the [Remote AT Command Request frame - 0x17](#) with:

1. The 64-bit address of the remote device.
2. The correct command options value.
3. Optionally, the command and parameter data.
4. If you want a command response, set the Frame ID field to a non-zero value.

XCTU has a Frames Generator tool that can assist you with building and sending a remote AT frame; see [Frames generator tool](#) in the *XCTU User Guide*.

Apply changes on remote devices

When you use remote commands to change the command parameter settings on a remote device, you must apply the parameter changes or they do not take effect. For example, if you change the **BD** parameter, the actual serial interface rate does not change on the remote device until you apply the changes. You can apply the changes using remote commands in one of three ways:

1. Set the apply changes option bit in the API frame.
2. Send an **AC** command to the remote device.
3. Send the **WR** command followed by the **FR** command to the remote device to save the changes and reset the device.

Remote command response

If a local device sends a command request to a remote device, and the API frame ID is non-zero, the remote device sends a remote command response transmission back to the local device.

When the local device receives a remote command response transmission, it sends a remote command response API frame out its UART. The remote command response indicates:

1. The status of the command, which is either success or the reason for failure.
2. In the case of a command query, it includes the register value.

The device that sends a remote command does not receive a remote command response frame if:

1. It could not reach the destination device.
2. You set the frame ID to 0 in the remote command request.

Build aggregate routes

In many applications, many or all of the nodes in the network must transmit data to a central aggregator node. In a new DigiMesh network, the overhead of these nodes discovering routes to the aggregator node can be extensive and taxing on the network. To eliminate this overhead, you can use the **AG** command to automatically build routes to an aggregate node in a DigiMesh network.

To send a unicast, devices configured for Transparent mode (**AP** = 0) must set their **DH/DL** registers to the MAC address of the node that they need to transmit to. In networks of Transparent mode devices that transmit to an aggregator node it is necessary to set every device's **DH/DL** registers to the MAC address of the aggregator node. This can be a tedious process. A simple and effective method is to use the **AG** command to set the **DH/DL** registers of all the nodes in a DigiMesh network to that of the aggregator node.

Upon deploying a DigiMesh network, you can issue the **AG** command on the desired aggregator node to cause all nodes in the network to build routes to the aggregator node. You can optionally use the **AG** command to automatically update the **DH/DL** registers to match the MAC address of the aggregator node.

The **AG** command requires a 64-bit parameter. The parameter indicates the current value of the **DH/DL** registers on a device; typically you should replace this value with the 64-bit address of the node sending the **AG** broadcast. However, if you do not want to update the **DH/DL** of the device receiving the **AG** broadcast you can use the invalid address of 0xFFFFE. The receiving nodes that are configured in API mode output an Aggregator Update API frame (0x8E) if they update their **DH/DL** address; for a description of the frame, see [Aggregate Addressing Update frame - 0x8E](#).

All devices that receive an **AG** broadcast update their routing table information to build a route to the sending device, regardless of whether or not their **DH/DL** address is updated. The devices use this routing information for future DigiMesh unicast transmissions.

DigiMesh routing examples

Example one

In a scenario where you deploy a network, and then you want to update the **DH** and **DL** registers of all the devices in the network so that they use the MAC address of the aggregator node, which has the MAC address 0x0013A200 4052C507, you could use the following technique.

1. Deploy all devices in the network with the default **DH/DL** of 0xFFFF.
2. Serially, send an ATAGFFFF command to the aggregator node so it sends the broadcast transmission to the rest of the nodes.

All the nodes in the network that receive the **AG** broadcast set their **DH** to 0x0013A200 and their **DL** to 0x4052C507. These nodes automatically build a route to the aggregator node.

Example two

If you want all of the nodes in the network to build routes to an aggregator node with a MAC address of 0x0013A200 4052C507 without affecting the **DH** and **DL** registers of any nodes in the network:

1. Send the ATAGFFFE command to the aggregator node. This sends an **AG** broadcast to all of the nodes in the network.
2. All of the nodes internally update only their routing table information to contain a route to the aggregator node.

3. None of the nodes update their **DH** and **DL** registers because none of the registers are set to the 0xFFFE address.

Replace nodes

You can use the **AG** command to update the routing table and **DH/DL** registers in the network after you replace a device. To update only the routing table information without affecting the **DH** and **DL** registers, use the process in example two, above.

To update the **DH** and **DL** registers of the network, use the following example.

Example

This example shows how to cause all devices to update their **DH** and **DL** registers to the MAC address of the sending device. In this case, assume you are using a device with a serial number of 0x0013A200 4052C507 as a network aggregator, and the sending device has a MAC address of 0x0013A200 F5E4D3B2. To update the **DH** and **DL** registers to the sending device's MAC address:

1. Replace the aggregator with 0x0013A200 F5E4D3B2.
2. Send the ATAG0013A200 4052C507 command to the new device.

Test links between adjacent devices

It often helps to test the quality of a link between two adjacent modules in a network. You can use the Test Link Request Cluster ID to send a number of test packets between any two devices in a network. To clarify the example, we refer to "device A" and "device B" in this section.

To request that device B perform a link test against device A:

1. Use device A in API mode (**AP** = 1) to send an Explicit Addressing Command (0x11) frame to device B.
2. Address the frame to the Test Link Request Cluster ID (0x0014) and destination endpoint: 0xE6.
3. Include a 12-byte payload in the Explicit Addressing Command frame with the following format:

Number of bytes	Field name	Description
8	Destination address	The address the device uses to test its link. For this example, use the device A address.
2	Payload size	The size of the test packet. Use the NP command to query the maximum payload size for the device.
2	Iterations	The number of packets to send. This must be a number between 1 and 4000.

4. Device B should transmit test link packets.
5. When device B completes transmitting the test link packets, it sends the following data packet to device A's Test Link Result Cluster (0x0094) on endpoint (0xE6).
6. Device A outputs the following information as an API Explicit RX Indicator (0x91) frame:

Number of bytes	Field name	Description
8	Destination address	The address the device used to test its link.
2	Payload size	The size of the test packet device A sent to test the link.
2	Iterations	The number of packets that device A sent.
2	Success	The number of packets that were successfully acknowledged.
2	Retries	The number of MAC retries used to transfer all the packets.
1	Result	0x00 - the command was successful. 0x03 - invalid parameter used.
1	RR	The maximum number of MAC retries allowed.
1	maxRSSI	The strongest RSSI reading observed during the test.
1	minRSSI	The weakest RSSI reading observed during the test.
1	avgRSSI	The average RSSI reading observed during the test.

Example

Suppose that you want to test the link between device A (**SH/SL** = 0x0013A200 40521234) and device B (**SH/SL**=0x0013A 200 4052ABCD) by transmitting 1000 40-byte packets:

Send the following API packet to the serial interface of device A.

In the following example packet, whitespace marks fields, bold text is the payload portion of the packet:

7E 0020 11 01 0013A20040521234 FFFE E6 E6 0014 C105 00 00 **0013A2004052ABCD 0028 03E8 EB**

When the test is finished, the following API frame may be received:

7E 0027 91 0013A20040521234 FFFE E6 E6 0094 C105 00 **0013A2004052ABCD 0028 03E8 03E7 0064 00 0A 50 53 52 9F**

This means:

- 999 out of 1000 packets were successful.
- The device made 100 retries.
- **RR** = 10.
- maxRSSI = -80 dBm.
- minRSSI = -83 dBm.
- avgRSSI = -82 dBm.

If the Result field does not equal zero, an error has occurred. Ignore the other fields in the packet.

If the Success field equals zero, ignore the RSSI fields.

The device that sends the request for initiating the Test link and outputs the result does not need to be the sender or receiver of the test. It is possible for a third node, "device C", to request device A to perform a test link against device B and send the results back to device C to be output. It is also possible for device B to request device A to perform the previously mentioned test. In other words, the frames can be sent by either device A, device B or device C and in all cases the test is the same: device A sends data to device B and reports the results.

Trace route option

In many networks, it is useful to determine the route that a DigiMesh unicast takes to its destination, particularly when you set up a network or want to diagnose problems within a network.

Note Because of the large number of Route Information Packet frames that a unicast with trace route enabled can generate, we suggest you only use the trace route option for occasional diagnostic purposes and not for normal operations.

The Transmit Request (0x10 and 0x11) frames contain a trace route option, which transmits routing information packets to the originator of the unicast using the intermediate nodes.

When a device sends a unicast with the trace route option enabled, the unicast transmits to its destination devices, which forward the unicast to its eventual destination. The destination device transmits a Route Information Packet (0x8D) frame back along the route to the unicast originator.

The Route Information Packet frame contains:

- Addressing information for the unicast
- Addressing information for the intermediate hop
- Timestamp
- Other link quality information

For a full description of the Route Information Packet frame, see [Route Information Packet frame - 0x8D](#).

Trace route example

Suppose that you successfully unicast a data packet with trace route enabled from device A to device E, through devices B, C, and D. The following sequence would occur:

- After the data packet makes a successful MAC transmission from device A to device B, device A outputs a Route Information Packet frame indicating that the transmission of the data packet from device A to device E was successful in forwarding one hop from device A to device B.
- After the data packet makes a successful MAC transmission from device B to device C, device B transmits a Route Information Packet frame to device A. When device A receives the Route Information packet, it outputs it over its serial interface.
- After the data packet makes a successful MAC transmission from device C to device D, device C transmits a Route Information Packet frame to device A (through device B). When device A receives the Route Information packet, it outputs it over its serial interface.
- After the data packet makes a successful MAC transmission from device D to device E, device D transmits a Route Information Packet frame to device A (through device C and device B). When device A receives the Route Information packet, it outputs it over its serial interface.

There is no guarantee that Route Information Packet frames will arrive in the same order as the route taken by the unicast packet. On a weak route, it is also possible for the transmission of Route Information Packet frames to fail before arriving at the unicast originator.

NACK messages

Transmit Request (0x10 and 0x11) frames contain a negative-acknowledge character (NACK) API option (Bit 2 of the Transmit Options field).

If you use this option when transmitting data, when a MAC acknowledgment failure occurs on one of the hops to the destination device, the device generates a Route Information Packet (0x8D) frame and sends it to the originator of the unicast.

This information is useful because it allows you to identify and repair marginal links.

RSSI indicators

The received signal strength indicator (RSSI) measures the amount of power present in a radio signal. It is an approximate value for signal strength received on an antenna.

You can use the **DB** command to measure the RSSI on a device. **DB** returns the RSSI value measured in -dBm of the last packet the device received. This number can be misleading in multi-hop DigiMesh networks. The **DB** value only indicates the received signal strength of the last hop. If a transmission spans multiple hops, the **DB** value provides no indication of the overall transmission path, or the quality of the worst link, it only indicates the quality of the last link.

To determine the **DB** value in hardware:

1. Set **PO** to 1 to enable the RSSI pulse-width modulation (PWM) functionality.
2. Use the DIO10/RSSI/PWM0 module pin (Micro pin 7/SMT pin 7/TH pin 6). When the device receives data, it sets the RSSI PWM duty cycle to a value based on the RSSI of the packet it receives.

This value only indicates the quality of the last hop of a multi-hop transmission. You could connect this pin to an LED to indicate if the link is stable or not.

Associate LED

The Associate pin (Micro pin 26/SMT pin 28) provides an indication of the device's status. To take advantage of these indications, connect an LED to the Associate pin.

To enable the Associate LED functionality, set the **D5** command to 1; it is enabled by default. If enabled, the Associate pin is configured as an output. This section describes the behavior of the pin.

The pin functions as a power indicator.

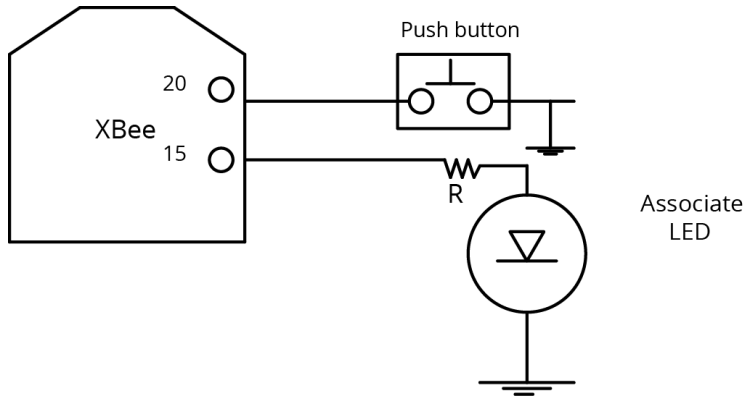
Use the **LT** command to override the blink rate of the Associate pin. If you set **LT** to 0, the device uses the default blink time of 250 ms.

The following table describes the Associate LED functionality.

LED Status	Meaning
On, blinking	The device has power and is operating properly

The Commissioning Pushbutton

The XBee3 DigiMesh RF Module supports a set of commissioning and LED functions to help you deploy and commission devices. These functions include the Commissioning Pushbutton definitions and the associated LED functions. The following diagram shows how the hardware can support these features.



To support the Commissioning Pushbutton and its associated LED functions, connect a pushbutton and an LED to device pins 20 and 15 respectively.

Definitions

To enable the Commissioning Pushbutton functionality on pin 20, set the **DO** command to 1. The functionality is enabled by default.

You must perform the designated number of button presses within two seconds. If any number of commissioning button presses occur while the device is asleep, it will wake up until the sleep cycle is finished or for 30 seconds, whichever occurs first.

The following table provides the pushbutton definitions.

Button presses	Action
1	Sends a Node Identification broadcast transmission. All devices that receive this transmission blink their Associate LED rapidly for one second. Additionally, receiving devices that are operating in API mode also send a Node Identification frame (0x95) out their UART.
2	This function only applies for synchronous sleep networks. Two button presses nominate a node as the sleep coordinator by sending out a sync message. If the sending node has seniority over the current sleep coordinator, the sending node becomes the sleep coordinator. Otherwise, the current sleep coordinator retains that role.
4	Restores the node to default configuration. If custom defaults are in use, they will be applied on top of the factory defaults. Unlike RE (Restore Defaults) , this function not only restores the default configuration, but it also applies those changes.

Use the Commissioning Pushbutton

Use the **CB** command to simulate button presses in software. Send **CB** with a parameter set to the number of button presses to perform. For example, if you send **ATCB1**, the device performs the action (s) associated with a single button press.

[Node Identification Indicator frame - 0x95](#) is similar to [Remote Command Response frame - 0x97](#) – it contains the device’s address, node identifier string (**NI** command), and other relevant data. All devices in API operating mode that receive the Node Identification Indicator frame send it out their UART as a Node Identification Indicator frame.

Node discovery

Node discovery has three variations as shown in the following table:

Commands	Syntax	Description
Node Discovery	ND	Seeks to discover all nodes in the network (on the current Network ID).
Directed Node Discovery	ND <NI String>	Seeks to discover if a particular node named <NI String> is found in the network.
Destination Node	DN <NI String>	Sets DH/DL to point to the MAC address of the node whose <NI String> matches.

The node discovery command (without an NI string designated) sends out a broadcast to every node in the Network ID. Each node in the network sends a response back to the requesting node.

When the node discovery command is issued in Command mode, all other AT commands are inhibited until the node discovery command times out, as determined by the **N?** parameter. After the timeout, an extra CR is output to the terminal window, indicating that new AT commands can be entered. This is the behavior whether or not there were any nodes that responded to the broadcast.

When the node discovery command is issued in API mode, the behavior is the same except that the response is output in API mode. If no nodes respond, there will be no responses at all to the node discover command. The requesting node is not able to process a new AT command until **N?** times out.

Discover all the devices on a network

You can use the **ND** (Network Discovery) command to discover all devices on a network. When you send the **ND** command:

1. The device sends a broadcast **ND** command through the network.
2. All devices that receive the command send a response that includes their addressing information, node identifier string and other relevant information. For more information on the node identifier string, see [NI \(Network Identifier\)](#).

ND is useful for generating a list of all device addresses in a network.

When a device receives the network discovery command, it waits a random time before sending its own response. You can use the **NT** command to set the maximum time delay on the device that you use to send the **ND** command.

- The device that sends the **ND** includes its **NT** setting in the transmission to provide a random delay window for all devices in the network. When devices respond at random intervals during the **NT** window, fewer collisions occur and more responses can be obtained.
- The default **NT** value is 0x82 (13 seconds).

Directed node discovery

The directed node discovery command (**ND** with an **NI** string parameter) sends out a broadcast to find a node in the network with a matching **NI** string. If such a node exists, it sends a response with its information back to the requesting node.

In Transparent mode, the requesting node outputs an extra carriage return following the response from the designated node and the command terminates; it is then ready to accept a new AT

command. In the event that the requested node does not exist or is too slow to respond, the requesting node outputs an ERROR response after **N?** expires.

In API mode, the response from the requesting node will be output in API mode and the command will terminate immediately. If no response comes from the requested node, the requesting node outputs an error response in API mode after **N?** expires. The device's software assumes that each node has a unique **NI** string.

The directed node discovery command terminates after the first node with a matching **NI** string responds. If that **NI** string is duplicated in multiple nodes, the first responding node may not always be the same node or the desired node.

Destination Node

The Destination Node command (**DN** with an **NI** string parameter) sends out a broadcast containing the **NI** string being requested. The responding node with a matching **NI** string sends its information back to the requesting node. The local node then sets **DH/DL** to match the address of the responding node. As soon as this response occurs, the command terminates successfully. If the device is in AT Command mode, an OK string is output and Command mode exits. In API mode, you may enter another AT command.

If an **NI** string parameter is not provided, the **DN** command terminates immediately with an error. If a node with the given **NI** string does not respond, the **DN** command terminates with an error after **N?** times out.

In Transparent mode, unlike **ND** (with or without an **NI** string), **DN** does not cause the information from the responding node to be output; rather it simply sets **DH/DL** to the address of the responding node.

In API mode, the response from the requesting node outputs in API mode and the command terminates immediately. If no response comes from the requested node, the requesting node outputs an error response in API mode after **N?** expires.

The device's software assumes that each node has a unique **NI** string. The directed destination node command terminates after the first node with a matching **NI** string responds. If that **NI** string is duplicated in multiple nodes, **DH/DL** may not be set to the desired value.

Discover devices within RF range

The **FN** (Find Neighbor) command works the same as the **ND** (Node Discovery) except that it is limited to neighboring devices (devices that are only one hop away). See [FN \(Find Neighbors\)](#) for details.

- You can use the **FN** (Find Neighbors) command to discover the devices that are immediate neighbors (within RF range) of a particular device.
- **FN** is useful in determining network topology and determining possible routes.

You can send **FN** locally on a device in Command mode or you can use a local [AT Command Frame - 0x08](#).

To use **FN** remotely, send the target node a [Remote AT Command Request frame - 0x17](#) using **FN** as the name of the AT command.

The device you use to send **FN** transmits a zero-hop broadcast to all of its immediate neighbors. All of the devices that receive this broadcast send an RF packet to the device that transmitted the **FN** command. If you sent **FN** remotely, the target devices respond directly to the device that sent the **FN** command. The device that sends **FN** outputs a response packet in the same format as an [AT Command Response frame - 0x88](#).

Sleep support

Sleep is implemented to support installations where a mains power source is not available and a battery is required. In order to increase battery life, the device sleeps, which means it stops operating. It can be woken by a timer expiration or a pin.

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Sleep modes

A number of low-power modes exist to enable devices to operate for extended periods of time on battery power. Use [SM \(Sleep Mode\)](#) to enable these sleep modes. The sleep modes are characterized as either:

- Asynchronous (**SM = 1, 4, 5, 6**).
- Synchronous (**SM = 7, 8**).

In Synchronous sleep networks, a device functions in one of three roles:

1. A sleep coordinator.
2. A potential coordinator.
3. A non-coordinator.

The difference between a potential coordinator and a non-coordinator is that a non-coordinator node has its [SO \(Sleep Options\)](#) parameter set so that it will not participate in coordinator nomination and election and cannot ever be a sleep coordinator.

Note Synchronous and asynchronous sleep modes are incompatible. Synchronous and asynchronous sleep nodes should not be configured in the same network.

Asynchronous sleep modes

Use the asynchronous sleep modes to control the sleep state on a device by device basis.

Do not use devices operating in asynchronous sleep mode to route data.

We strongly encourage you to set asynchronous sleeping devices as end-devices using [CE \(Routing / Messaging Mode\)](#). This prevents the node from attempting to route data.

Asynchronous Pin Sleep mode (SM = 1)

Pin Sleep mode minimizes quiescent power (power consumed when in a state of rest or inactivity). In order to use Pin Sleep mode, configure [SM \(Sleep Mode\)](#) to **1** and configure [D8 \(DIO8/DTR/SLP_Request Configuration\)](#) (Micro pin 9/SMT pin 10) for DTR/SLEEP_RQ input (**D8 = 1**). This mode is voltage level-activated; when SLEEP_RQ is asserted, the device finishes any transmit or receive activities, enters Idle mode, and then enters a state of sleep. The device does not respond to either serial or RF activity while in pin sleep.

To wake a sleeping device operating in Pin Sleep mode, de-assert $\overline{\text{DTR/SLEEP_RQ}}$. The device wakes when SLEEP_RQ is de-asserted and is ready to transmit or receive when the CTS line is low. When waking the device, the pin must be de-asserted at least two 'byte times' after CTS goes low. This assures that there is time for the data to enter the DI buffer.

Devices with [SPI functionality](#) can use the [SPI_SSEL](#) pin instead of **D8** for pin sleep control. If **D8 = 0** and **P7 = 1**, [SPI_SSEL](#) takes the place of DTR/SLEEP_RQ and functions as described above. In order to use [SPI_SSEL](#) for sleep control while communicating on the UART, the other [SPI pins](#) must be disabled (**P5**, **P6**, and **P8** set to **0**). See [Low power operation](#) for information on using [SPI_SSEL](#) for sleep control while communicating over SPI.

Asynchronous Cyclic Sleep mode (SM = 4)

The Cyclic Sleep modes allow devices to periodically check for RF data. When the **SM** parameter is set to **4**, the XBee3 DigiMesh RF Module is configured to sleep, then wakes once per cycle to check for data from a coordinator. The Cyclic Sleep Remote sends a poll request to the coordinator at a specific

interval set by [SP \(Sleep Time\)](#). The coordinator transmits any queued data addressed to that specific remote upon receiving the poll request.

If no data is queued for the remote, the messaging coordinator does not transmit and the remote returns to sleep for another cycle. If queued data is transmitted back to the remote, it stays awake to allow for back and forth communication until the [ST \(Wake Time\)](#) timer expires. You can also set [SO \(Sleep Options\)](#) bit 8 to force the device to always wake for the full **ST** time.

If configured, $\overline{\text{CTS}}$ goes low each time the remote wakes, allowing for communication initiated by the remote host if desired. If `ON_SLEEP` is configured it goes high (ON) after [SN \(Number of Sleep Periods\)](#) sleep periods. Change **SN** to allow external circuitry to sleep for longer periods if no data is received.

Asynchronous Cyclic Sleep with Pin Wake-up mode (SM = 5)

Use this mode to wake a sleeping remote device through either the RF interface or by asserting (low) `DTR/SLEEP_RQ` for event-driven communications. The cyclic sleep mode works as described previously with the addition of a pin-controlled wake-up at the remote device.

The `DTR/SLEEP_RQ` pin is level-triggered. The device wakes when a low is detected then sets $\overline{\text{CTS}}$ low as soon as it is ready to transmit or receive. The device stays awake as long as `DTR/SLEEP_RQ` is low; once `DTR/SLEEP_RQ` goes high the device returns to cyclic sleep operation. If `DTR/SLEEP_RQ` is momentarily pulsed low, the minimum wake time is [ST \(Wake Time\)](#) even if `DTR/SLEEP_RQ` is low for less time.

Once awake, any activity resets the [ST \(Wake Time\)](#) timer, so the device goes back to sleep only after there is no RF activity for the duration of the timer.

MicroPython sleep with optional pin wake (SM = 6)

The MicroPython sleep option allows a user's MicroPython program to exclusively control the device's sleep operation (with optional pin wake). For full details refer to the [Digi MicroPython Programming Guide](#).

Synchronous sleep modes

Synchronous sleep makes it possible for all nodes in the network to synchronize their sleep and wake times. All synchronized cyclic sleep nodes enter and exit a low power state at the same time. This allows all or most devices in a network to use low power because, unlike Zigbee, low power devices do not need to be adjacent to mains powered devices.

Synchronous sleep forms a cyclic sleeping network with these features:

- A device acting as a sleep coordinator sends a special RF packet called a sync message to synchronize nodes.
- To make a device in the network a coordinator, a node uses several resolution criteria.
- The sleep coordinator sends one sync message at the beginning of each wake period. The coordinator sends the sync message as a broadcast and every routing node in the network repeats it.
- You can change the sleep and wake times for the entire network by locally changing the settings on an individual device. The network uses the most recently set sleep settings.

Synchronous sleep support mode (SM = 7)

Note Sleep support nodes should be mains powered because they do not sleep.

Set **SM** to **7** to enter synchronous sleep support mode.

A device in synchronous sleep support mode synchronizes itself with a sleeping network but will not itself sleep. At any time, the device responds to new devices that are attempting to join the sleeping network with a sync message. A sleep support device only transmits normal data when the other devices in the sleeping network are awake. You can use sleep support devices as sleep coordinator devices and as aids in adding new devices to a sleeping network.

Synchronous cyclic sleep mode (SM = 8)

Set **SM** to 8 to enter synchronous cyclic sleep mode.

A device in synchronous cyclic sleep mode sleeps for a programmed time, wakes in unison with other nodes, exchanges data and sync messages, and then returns to sleep. While asleep, it cannot receive RF messages or receive data (including commands) from the UART port.

Generally, the network's sleep coordinator specifies the sleep and wake times based on its **SP** and **ST** settings. The device only uses these parameters at startup until the device synchronizes with the network.

When a device has synchronized with the network, you can query its sleep and wake times with the **OS** and **OW** commands respectively.

If **D9** = 1 (**ON_SLEEP** enabled) on a cyclic sleep node, the **ON_SLEEP** line goes high when the device is awake and goes low when the device is asleep.

If **D7** = 1, the device de-asserts **CTS** while asleep.

A newly-powered, unsynchronized, sleeping device polls for a synchronized message and then sleeps for the period that the **SP** command specifies, repeating this cycle until it synchronizes by receiving a sync message. Once it receives a sync message, the device synchronizes itself with the network.

Note Configure all nodes in a synchronous sleep network to operate in either synchronous sleep support mode or synchronous cyclic sleep mode. asynchronous sleeping nodes are not compatible with synchronous sleeping nodes.

Sleep parameters

The following AT commands are associated with the sleep modes. See the linked commands for the parameter's description, range and default values.

- [SM \(Sleep Mode\)](#)
- [SN \(Number of Sleep Periods\)](#)
- [SO \(Sleep Options\)](#)
- [ST \(Wake Time\)](#)
- [SP \(Sleep Time\)](#)
- [WH \(Wake Host Delay\)](#)

Sleep pins

The following table describes the three external device pins associated with sleep. See the [XBee3 RF Module Hardware Reference Manual](#) for the pinout of your device.

Pin name	Pin number	Description
$\overline{\text{DTR}}$ / SLEEP_ RQ	Micro pin 9/SMT pin 10	For SM = 1 , high puts the device to sleep and low wakes it up. For SM = 5 , a high to low transition wakes the device up for ST time. The device ignores a low to high transition in SM = 5 .
$\overline{\text{SPI}}$ / SSEL	Micro pin 14/SMT pin 15	This pin operates the same as SLEEP_RQ when D8 is 0 .
$\overline{\text{CTS}}$	Micro pin 24/SMT pin 25	If D7 = 1 , high indicates that the device is asleep and low indicates that it is awake and ready to receive serial data.
$\overline{\text{ON}}$ / SLEEP	Micro pin 25/SMT pin 26	Low indicates that the device is asleep and high indicates that it is awake and ready to receive serial data.

Sleep conditions

Since instructions stop executing while the device is sleeping, it is important to avoid sleeping when the device has work to do. For example, the device will not sleep if any of the following are true:

1. The device is operating in Command mode, or in the process of getting into Command mode with the **+++** sequence.
2. The device is processing AT commands from API mode
3. The device is processing remote AT commands
4. Something is queued to the serial port and that data is not blocked by $\overline{\text{RTS}}$ flow control

If each of the above conditions are false, then sleep may still be blocked in these cases:

1. Enough time has not expired since the device has awakened.
 - a. If the device is operating in pin sleep, the amount of time needed for one character to be received on the UART is enough time.
 - b. If the device is operating in asynchronous cyclic sleep, enough time is defined by a timer. The duration of that timer is:
 - i. defined by **ST** if in **SM** 5 mode and it is awakened by a pin
 - ii. 30 ms to allow enough time for a poll and a poll response
 - c. In addition, if the device is operating in Asynchronous Cyclic Sleep, the wake time is extended by an additional **ST** time when new OTA data or serial data is received.
2. Sleep Request pin is not asserted when operating in pin sleep mode
3. Data is waiting to be sent OTA.

The sleep timer

If the device receives serial or RF data in Asynchronous cyclic sleep mode and Asynchronous cyclic sleep with pin wake up modes (**SM** = 4 or **SM** = 5), it starts a sleep timer (time until sleep).

- If the device receives any data serially or by RF link, the timer resets.
- Use [ST \(Wake Time\)](#) to set the duration of the timer.
- When the sleep timer expires the device returns to sleep.

Sleep coordinator sleep modes in the network

In a synchronized sleeping network, one node acts as the sleep coordinator. During normal operations, at the beginning of a wake cycle the sleep coordinator sends a sync message as a broadcast to all nodes in the network. This message contains synchronization information and the wake and sleep times for the current cycle. All cyclic sleep nodes that receive a sync message remain awake for the wake time and then sleep for the specified sleep period.

The sleep coordinator sends one sync message at the beginning of each cycle with the current wake and sleep times. All router nodes that receive this sync message relay the message to the rest of the network. If the sleep coordinator does not hear a rebroadcast of the sync message by one of its immediate neighbors, then it re-sends the message one additional time.

If you change the **SP** or **ST** parameters, the network does not apply the new settings until the beginning of the next wake time. For more information, see [Change sleep parameters](#).

A sleeping router network is robust enough that an individual node can go several cycles without receiving a sync message, due to RF interference, for example. As a node misses sync messages, the time available for transmitting messages during the wake time reduces to maintain synchronization accuracy. By default, a device reduces its active sleep time progressively as it misses consecutive sync messages.

Synchronization messages

A sleep coordinator regularly sends sync messages to keep the network in sync. Unsynchronized nodes also send messages requesting sync information.

Sleep compatible nodes use Deployment mode when they first power up and the sync message has not been relayed. A sleep coordinator in Deployment mode rapidly sends sync messages until it receives a relay of one of those messages. Deployment mode:

- Allows you to effectively deploy a network.
- Allows a sleep coordinator that resets to rapidly re-synchronize with the rest of the network.

If a node exits deployment mode and then receives a sync message from a sleep coordinator that is in Deployment mode, it rejects the sync message and sends a corrective sync to the sleep coordinator.

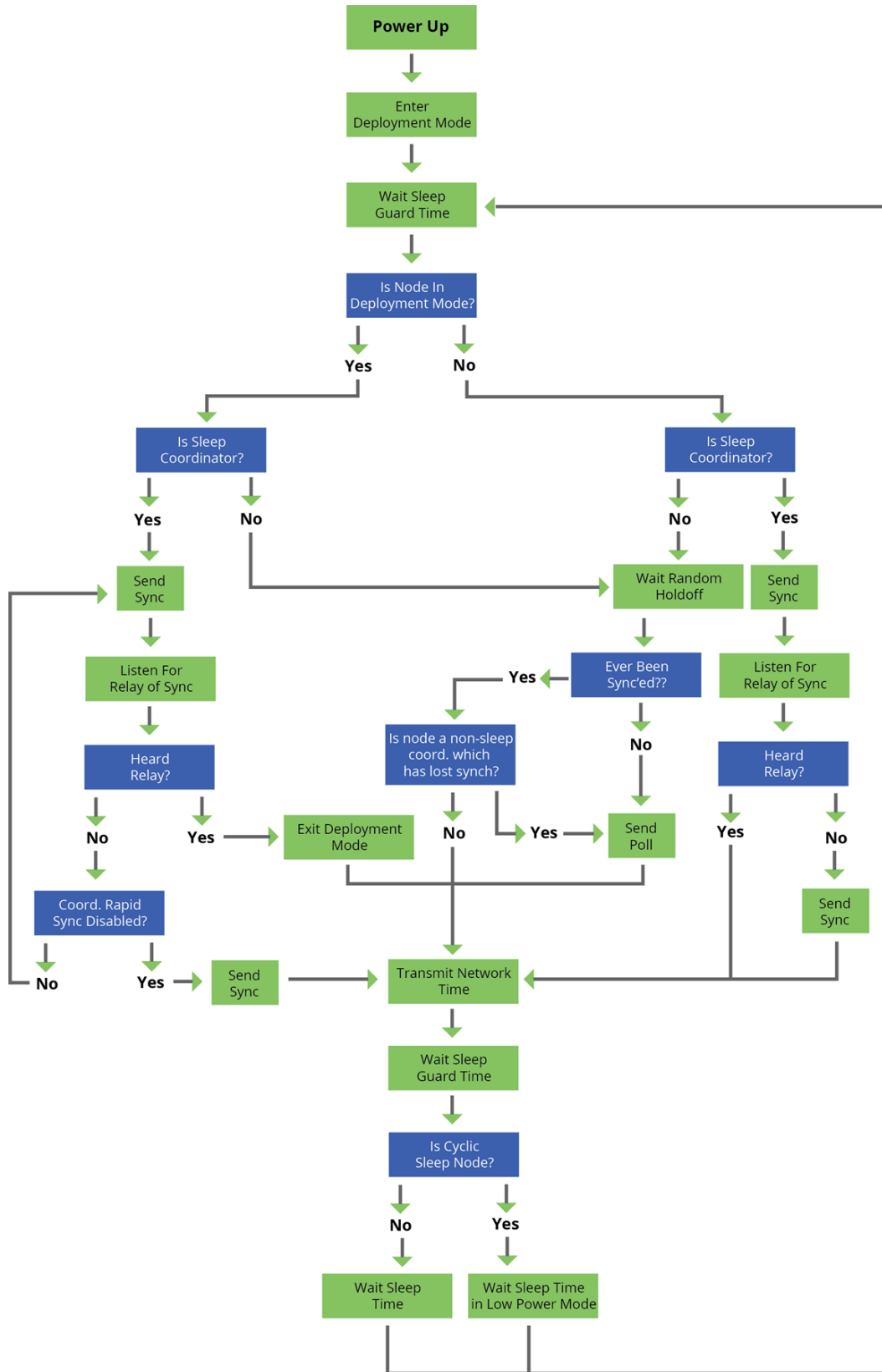
Use the **SO** (sleep options) command to disable deployment mode. This option is enabled by default.

A sleep coordinator that is not in deployment mode sends a sync message at the beginning of the wake cycle. The sleep coordinator listens for a neighboring node to relay the sync. If it does not hear the relay, the sleep coordinator sends the sync one additional time.

A node that is not a sleep coordinator and has never been synchronized sends a message requesting sync information at the beginning of its wake cycle. Synchronized nodes which receive one of these messages respond with a synchronization packet.

If you use the **SO** command to configure nodes as non-coordinators, and if the non-coordinators go six or more sleep cycles without hearing a sync, they send a message requesting sync at the beginning of their wake period.

The following diagram illustrates the synchronization behavior of sleep compatible devices.



Become a sleep coordinator

In DigiMesh networks, a device can become a sleep coordinator in one of four ways:

- Define a sleep coordinator
- A potential sleep coordinator misses three or more sync messages
- Press the Commissioning Pushbutton twice on a potential sleep coordinator
- Change the sleep timing values on a potential sleep coordinator

Set the sleep coordinator option

You can specify that a node always act as a sleep coordinator. To do this, set the sleep coordinator bit (bit 0) in the **SO** command to **1**.

A node with the sleep coordinator bit set always sends a sync message at the beginning of a wake cycle. To avoid network congestion and synchronization conflicts, do not set this bit on more than one node in the network.

A node that is centrally located in the network can serve as a good sleep coordinator, because it minimizes the number of hops a sync message takes to get across the network.

A sleep support node and/or a node that is mains powered is a good candidate to be a sleep coordinator.



CAUTION! Use the sleep coordinator bit with caution. The advantages of using the option become weaknesses if you use it on a node that is not in the proper position or configuration. Also, it is not valid to have the sleep coordinator option bit set on more than one node at a time.

You can also use the sleep coordinator option when you set up a network for the first time. When you start a network, you can configure a node as a sleep coordinator so it will begin sending sleep messages. After you set up the network, we recommend that you disable the sleep coordinator bit.

Resolution criteria and selection option

There is an automatic selection process with resolution criteria that occurs on a node if it loses contact with the network sleep coordinator.

A sleep compatible node may become a sleep coordinator if it:

- Misses three or more sync messages and it:
- Is not configured as a non-coordinator by setting bit 1 of **SO**.

If such a node wins out on the selection process, it becomes the new network sleep coordinator.

It is possible for multiple nodes to declare themselves as the sleep coordinator. If this occurs, the firmware uses the following resolution criteria to identify the sleep coordinator from among the nodes using the selection process:

1. Newer sleep parameters: the network considers a node using newer sleep parameters (**SP** and **ST**) as higher priority than a node using older sleep parameters. See [Commissioning Pushbutton option](#). Note that when **SP** and/or **ST** is changed, it increments the sequence number such that it sends the newest sync message and it has priority to become the sleep coordinator.

2. Sleep coordinator: a node configured as the sleep coordinator is higher priority than other nodes.
3. Sleep support node: sleep support nodes are higher priority than cyclic sleep nodes. You can modify this behavior using the **SO** parameter.
4. Serial number: If the previous factors do not resolve the priority, the network considers the node with the higher serial number to be higher priority.

Commissioning Pushbutton option

Use the Commissioning Pushbutton to select a device to act as the sleep coordinator. The Commissioning Pushbutton is mapped to DIO0 (pin 33) and enabled by default.

Use the Commissioning Pushbutton to select a device to act as the sleep coordinator.

If you enable the Commissioning Pushbutton functionality, you can immediately select a device as a sleep coordinator by pressing the Commissioning Pushbutton twice or by issuing the **CB2** command. The device you select in this manner is still subject to the resolution criteria process.

Only sleep coordinator nodes honor Commissioning Pushbutton nomination requests. A node configured as a non-sleep coordinator ignores commissioning button nomination requests.

Overriding syncs

Any sleep compatible node in the network that does not have the non-coordinator sleep option set can send an overriding sync and become the network sleep coordinator. An overriding sync effectively changes the synchronization of all nodes in the network to the **ST** and **SP** values of the node sending the overriding sync. It also selects the node sending the overriding sync as the network sleep coordinator. While this is a powerful operation, it may be an undesired side effect because the current sleep coordinator may have been carefully selected and it is not desired to change it. Additionally the current wake and sleep cycles may be desired rather than the parameters on the node sending the overriding sync. For this reason, it is important to know what kicks off an overriding sync.

An overriding sync occurs whenever **ST** or **SP** is changed to a value different than **OW** or **OS** respectively. For example no overriding sync will occur if **SP** is changed from 190 to C8 if the network was already operating with **OS** at C8. On the other hand, if **SP** is changed from 190 to 190 (meaning no change), and **OS** is C8, then an overriding sync will occur because the network parameters are being changed.

Even parameters that seem unrelated to sleep can kick off an overriding sync. These are **NH**, **NN**, **RN**, and **MT**. When any of these parameters are changed, they can affect network traversal time. If such changes cause the configured value of **ST** to be smaller than the value needed for network traversal, then **ST** is increased and if that increased value is different than **OW**, then an overriding sync will occur.

For most applications, we recommend configuring the **NH**, **NN**, **RN**, and **MT** network parameters during initial deployment only. The default values of **NH** and **NN** are optimized to work for most deployments. Additionally, it would be best to set **ST** and **SP** the same on all nodes in the network while keeping **ST** sufficiently large so that it won't be affected by an inadvertent change of **NH**, **NN**, **RN**, or **MT**.

Sleep guard times

To compensate for variations in the timekeeping hardware of the various devices in a sleeping router network, the network allocates sleep guard times at the beginning and end of the wake period. The size of the sleep guard time varies based on the sleep and wake times you select and the number of sleep cycles that elapse since receiving the last sync message. The sleep guard time guarantees that

a destination module will be awake when the source device sends a transmission. As a node misses more and more consecutive sync messages, the sleep guard time increases in duration and decreases the available transmission time.

Auto-early wake-up sleep option

If you have nodes that are missing sync messages and could be going out of sync with the rest of the network, enabling an early wake gives the device a better chance to hear the sync messages that are being broadcast.

Similar to the sleep guard time, the auto early wake-up option decreases the sleep period based on the number of sync messages a node misses. This option comes at the expense of battery life.

Use bit 3 of the **SO** command to disable auto-early wake-up sleep. This option is enabled by default.

Select sleep parameters

Choosing proper sleep parameters is vital to creating a robust sleep-enabled network with a desirable battery life. To select sleep parameters that will be good for most applications, follow these steps:

1. Choose **NN** and **NH**.

Based on the placement of the nodes in your network, select the appropriate values for the **NH** (Network Hops) and **NN** (Network Delay Slots) parameters.

We optimize the default values of **NH** and **NN** to work for the majority of deployments. In most cases, we suggest that you do not modify these parameters from their default values. Decreasing these parameters for small networks can improve battery life, but take care to not make the values too small.

2. Calculate the Sync Message Propagation Time (SMPT).

This is the maximum amount of time it takes for a sleep synchronization message to propagate to every node in the network. You can estimate this number with the following formula:

$$\text{SMPT} = \text{NH} * (\text{MT} + 1) * 4 \text{ ms.}$$

Note The 4 msec constant applies to XBee3 DigiMesh, but it is different for every platform on which DigiMesh runs.

3. Select the duty cycle you want.

The ratio of sleep time to wake time is the factor that has the greatest effect on the device's power consumption. Battery life can be estimated based on the following factors:

- sleep period
- wake time
- sleep current
- RX current
- TX current
- battery capacity

4. Choose the sleep period and wake time.

The wake time must be long enough to transmit the desired data as well as the sync message. The **ST** parameter automatically adjusts upwards to its minimum value when you change other AT commands that affect it (**SP**, **NN**, and **NH**).

Use a value larger than this minimum. If a device misses successive sync messages, it reduces its available transmit time to compensate for possible clock drift. Budget a large enough **ST** time to allow for the device to miss a few sync messages and still have time for normal data transmissions.

Start a sleeping synchronous network

By default, all new nodes operate in normal (non-sleep) mode. To start a synchronous sleeping network, follow these steps:

1. Set **SO** to 1 to enable the sleep coordinator option on one of the nodes.
2. Set its **SM** to a synchronous sleep compatible mode (7 or 8) with its **SP** and **ST** set to a quick cycle time. The purpose of a quick cycle time is to allow the network to send commands quickly through the network during commissioning.
3. Power on the new nodes within range of the sleep coordinator. The nodes quickly receive a sync message and synchronize themselves to the short cycle **SP** and **ST** set on the sleep coordinator.
4. Configure the new nodes to the sleep mode you want, either cyclic sleeping modes or sleep support modes.
5. Set the **SP** and **ST** values on the sleep coordinator to the values you want for the network.
6. In order to reduce the possibility of an unintended overriding sync, set **SP** and **ST** to the intended sleep/wake cycle on all nodes in the network. Be sure that **ST** is large enough to prevent it from being inadvertently increased by changing **NN**, **NH**, or **MT**.
7. Wait a sleep cycle for the sleeping nodes to sync themselves to the new **SP** and **ST** values.
8. Disable the sleep coordinator option bit on the sleep coordinator unless you want to force a particular sleep coordinator.
9. Deploy the nodes to their positions.

Alternatively, prior to deploying the network you can use the **WR** command to set up nodes with their sleep settings pre-configured and written to flash. If this is the case, you can use the Commissioning Pushbutton and associate LED to aid in deployment:

1. If you are going to use a sleep coordinator in the network, deploy it first.
2. If more than one node can be the sleep coordinator, select a node for deployment, power it on and press the Commissioning Pushbutton twice. This causes the node to begin emitting sync messages.
3. Verify that the first node is emitting sync messages by watching its associate LED. A slow blink indicates that the node is acting as a sleep coordinator.
4. Power on nodes in range of the sleep coordinator or other nodes that have synchronized with the network. If the synchronized node is asleep, you can wake it by pressing the Commissioning Pushbutton once.
5. Wait a sleep cycle for the new node to sync itself.
6. Verify that the node syncs with the network. The associate LED blinks when the device is awake and synchronized.
7. Continue this process until you deploy all of the nodes.

Add a new node to an existing network

To add a new node to the network, the node must receive a sync message from a node already in the network. On power-up, an unsynchronized, sleep compatible node periodically sends a broadcast requesting a sync message and then sleeps for its **SP** period. Any node in the network that receives this message responds with a sync. Because the network can be asleep for extended periods of time, and cannot respond to requests for sync messages, there are methods you can use to sync a new node while the network is asleep.

1. Power the new node on within range of a sleep support node. Sleep support nodes are always awake and able to respond to sync requests promptly.
2. You can wake a sleeping cyclic sleep node in the network using the Commissioning Pushbutton. Place the new node in range of the existing cyclic sleep node. Wake the existing node by pressing the Commissioning Pushbutton once. The existing node stays awake for 30 seconds and responds to sync requests while it is awake.

If you do not use one of these two methods, you must wait for the network to wake up before adding the new node.

Place the new node in range of the network with a sleep/wake cycle that is shorter than the wake period of the network.

The new node periodically sends sync requests until the network wakes up and it receives a sync message.

Change sleep parameters

To change the sleep and wake cycle of the network, select any sleep coordinator capable node in the network and change the **SP** and/or **ST** of the node to values different than those the network currently uses.

- If you configure a particular sleep coordinator or if you know which node acts as the sleep coordinator, we suggest that you use this node to make changes to network settings.
- If you do not know the network sleep coordinator, you can use any node that does not have the non-sleep coordinator sleep option bit set. For details on the bit, see [SO \(Sleep Options\)](#).

When you make changes to a node's **SP** and/or **ST** parameters and that node does not have the non-sleep coordinator option set then:

- That node broadcasts an overriding sync to the network to advertise the new sleep cycle.
- That node nominates itself to become the sleep coordinator.
- That node will remain the sleep coordinator unless another node in the network designates itself as the sleep coordinator.
- The network will apply the new sleep parameters at the beginning of the next wake cycle.

Changing sleep parameters increases the chances that nodes will lose sync. If a node does not receive the sync message with the new sleep settings, it continues to operate on its old settings. To minimize the risk of a node losing sync and to facilitate the re-syncing of a node that does lose sync, take the following precautions:

1. Whenever possible, avoid changing sleep parameters.
2. Enable the missed sync early wake up sleep option in the **SO** command. This option is enabled by default. This command tells a node to wake up progressively earlier based on the number of cycles it goes without receiving a sync. This increases the probability that the un-synced node will be awake when the network wakes up and sends the sync message.

Note Using this sleep option increases reliability but may decrease battery life. Nodes using this sleep option that miss sync messages increase their wake time and decrease their sleep time during cycles where they miss the sync message. This increases power consumption.

When you are changing between two sets of sleep settings, choose settings so that the wake periods of the two sleep settings occur at the same time. In other words, try to satisfy the following equation:

$$(SP_1 + ST_1) = N * (SP_2 + ST_2)$$

where SP_1/ST_1 and SP_2/ST_2 are the desired sleep settings and N is an integer.

Rejoin nodes that lose sync

DigiMesh networks get their robustness from routing redundancies which may be available. We recommend architecting the network with redundant mesh nodes to increase robustness.

If a scenario exists where the only route connecting a subnet to the rest of the network depends on a single node, and that node fails or the wireless link fails due to changing environmental conditions (a catastrophic failure condition), then multiple subnets may arise using the same wake and sleep intervals. When this occurs the first task is to repair, replace, and strengthen the weak link with new and/or redundant devices to fix the problem and prevent it from occurring in the future.

If a network has multiple subnets that drift out of phase with each other, get the subnets back in phase with the following steps:

1. Place a sleep support node in range of both subnets.
2. Select a node in the subnet that you want the other subnet to sync with.
3. Use this node to slightly change the sleep cycle settings of the network, for example, increment **ST**.
4. Wait for the subnet's next wake cycle. During this cycle, the node you select to change the sleep cycle parameters sends the new settings to the entire subnet it is in range of, including the sleep support node that is in range of the other subnet.
5. Wait for the out of sync subnet to wake up and send a sync. When the sleep support node receives this sync, it rejects it and sends a sync to the subnet with the new sleep settings.
6. The subnets will now be in sync. You can remove the sleep support node.
7. You can also change the sleep cycle settings back to the previous settings.

If you only need to replace a few nodes, you can use this method:

1. Reset the out of sync node and set its sleep mode to Synchronous Cyclic Sleep mode (**SM = 8**).
2. Set up a short sleep cycle.
3. Place the node in range of a sleep support node or wake a sleeping node with the Commissioning Pushbutton.
4. The out of sync node receives a sync from the node that is synchronized to the network. It then syncs to the network sleep settings.

Diagnostics

The following diagnostics are useful in applications that manage a sleeping router network:

Query sleep cycle

Use the **OS** and **OW** commands to query the current operational sleep and wake times that a device uses.

Sleep status

Use the **SS** command to query useful information regarding the sleep status of the device. Use this command to query if the node is currently acting as a network sleep coordinator.

Missed sync messages command

Use the **MS** command to query the number of cycles that elapsed since the device received a sync message.

Sleep status API messages

When you use the **SO** command to enable this option, a device that is in API operating mode outputs modem status frames immediately after it wakes up and prior to going to sleep.

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Networking commands

The following commands affect the DigiMesh network.

CH (Operating Channel)

Set or read the operating channel devices used to transmit and receive data.

In order for devices to communicate with each other, they must share the same channel number. A network can use different channels to prevent devices in one network from listening to the transmissions of another and to reduce interference.

The command uses IEEE 802.15.4 channel numbers.

Parameter range

0xB - 0x1A

Default

0xC (channel 12)

ID (Network ID)

Set or read the user network identifier.

Devices must have the same network identifier to communicate with each other.

Parameter range

0 - 0xFFFF

Default

0x7FFF

CE (Routing / Messaging Mode)

The routing mode of the XBee3 DigiMesh RF Module.

A routing device forwards broadcasts and route discoveries for unicasts. A non-routing device does neither.

Indirect Messaging Coordinator

Device will not transmit point to multi-point unicasts until an end device requests them. Indirect messaging is only applicable for point-to-multipoint messages ([TO \(Transmit Options\)](#) = **0x40**).

Indirect Messaging Poller

Device will periodically poll a coordinator for messages.

Parameter range

0 - 6

Parameter	Description	Routes packets
0	Standard router	Yes

Parameter	Description	Routes packets
1	Indirect message coordinator	Yes
2	Non-routing device	No
3	Non-routing coordinator	No
4	Indirect message poller	Yes
5	N/A	N/A
6	Non-routing poller	No

Default

0

C8 (Compatibility Options)

Sets or displays the operational compatibility with a legacy DigiMesh 2.4 device (S1 or S2C hardware). This parameter should only be set when operating in a mixed network that contains XBee Series 1 or XBee S2C devices.

Parameter range

0, 4

Bit field:

Bit	Meaning	Setting	Description
2	TX compatibility	0	When encryption is enabled, AES Counter mode is used with a 256-bit key.
		1	When encryption is enabled AES ECB mode is used with a 128-bit key. This is compatible with legacy versions of DigiMesh 2.4.
3	Use XBee S1 compatible synchronous sleep messages	0	Use native XBee3 synchronous sleep messages. This mode involves the least processing to keep the nodes synchronized.
		1	Convert synchronous sleep messages to be compatible with XBee S1. This mode must be used on all the nodes in the network if there are any XBee S1 nodes in the network. This mode may always be used, even if there are no S1 nodes in the network. But doing so reduces performance and accuracy and is not recommended unless XBee S1 nodes exist in the same network.

Default

0

NI (Network Identifier)

Stores the node identifier string for a device, which is a user-defined name or description of the device. This can be up to 20 ASCII characters.

XCTU prevents you from exceeding the string limit of 20 characters for this command. If you are using another software application to send the string, you can enter longer strings, but the software on the device returns an error.

Use the **ND** (Network Discovery) command with this string as an argument to easily identify devices on the network.

The **DN** command also uses this identifier.

Parameter range

A string of case-sensitive ASCII printable characters from 1 to 20 bytes in length. A carriage return or a comma automatically ends the command.

Default

0x20 (an ASCII space character)

ND (Network Discover)

Discovers and reports all of the devices it finds on a network. If you send **ND** through a local or remote API frame, each network node returns a separate AT Command Response (0x88) or Remote Command Response (0x97) frame, respectively.

The command reports the following information after a jittered time delay.

SH<CR> (4 bytes)

SL<CR> (4 bytes)

DB<CR> (Contains the detected signal strength of the response in negative dBm units)

NI <CR> (variable, 0-20 bytes plus 0x00 character)

DEVICE_TYPE<CR> (1 byte: **0** = Coordinator, **1** = Router, **2** = End Device)

STATUS<CR> (1 byte: reserved)

PROFILE_ID<CR> (2 bytes)

MANUFACTURER_ID<CR> (2 bytes)

DIGI DEVICE TYPE<CR> (4 bytes. Optionally included based on **NO** settings.)

RSSI OF LAST HOP<CR> (1 byte. Optionally included based on **NO** settings.)

If you send the **FN** command in Command mode, after (**NT***100) ms + overhead time, the command ends by returning a carriage return, represented by <CR>.

The **ND** command accepts an **NI** (Node Identifier) as an argument. For more details, see [Directed node discovery](#).

Broadcast an **ND** command to the network. If the command includes an optional node identifier string parameter, only those devices with a matching **NI** string respond without a random offset delay. If the command does not include a node identifier string parameter, all devices respond with a random offset delay.

The **NT** setting determines the range of the random offset delay. The **NO** setting sets options for the Node Discovery.

For more information about options that affect the behavior of the **ND** command Refer to [NO \(Network Discovery Options\)](#) for options which affect the behavior of the **ND** command.



WARNING! If the **NT** setting is small relative to the number of devices on the network, responses may be lost due to channel congestion. Regardless of the **NT** setting, because the random offset only mitigates transmission collisions, getting responses from all devices in the network is not guaranteed.

Parameter range

20-byte printable ASCII string

Default

N/A

DN (Discover Node)

Resolves an **NI** (Node identifier) string to a physical address (case sensitive).

The following events occur after **DN** discovers the destination node:

When **DN** is sent in Command mode:

1. The requesting node sets **DL** and **DH** to the address of the device with the matching **NI** string.
2. The requesting node returns **OK** (or ERROR).
3. If the requesting node returns **OK** (node found), it exits Command mode immediately with **DH/DL** set to the node that is found so that the next serial input is sent to the node designated by the **DN** parameter.
4. If the requesting node returns **ERROR**, (node not found), it remains in Command mode, allowing you to enter further commands.

When **DN** is sent as a local [AT Command Frame - 0x08](#):

1. The requesting node returns 0xFFFE followed by its 64-bit extended addresses in an [AT Command Response frame - 0x88](#).
2. If there is no response from a module within (**N?*** 100) milliseconds or you do not specify a parameter (by leaving it blank), the requesting node returns an ERROR message.

Parameter range

20-byte ASCII string

Default

N/A

FN (Find Neighbors)

Discovers and reports all devices found within immediate (1 hop) RF range. **FN** reports the following information for each device it discovers:

```

MY<CR> (always 0xFFFE)
SH<CR>
SL<CR>
NI<CR> (Variable length)
PARENT_NETWORK ADDRESS<CR> (2 Bytes) (always 0xFFFE)
DEVICE_TYPE<CR> (1 Byte: 0 = Coordinator, 1 = Router, 2 = End Device)
STATUS<CR> (1 Byte: Reserved)
PROFILE_ID<CR> (2 Bytes)
MANUFACTURER_ID<CR> (2 Bytes)
DIGI_DEVICE_TYPE<CR> (4 Bytes. Optionally included based on NO settings.)
RSSI OF LAST HOP<CR> (1 Byte. Optionally included based on NO settings.)
<CR>

```

If you send the **FN** command in Command mode, after (**NT***100) ms + overhead time, the command ends by returning a carriage return, represented by <CR>.

If you send the **FN** command through a local AT Command (0x08) or remote AT command (0x17) API frame, each response returns as a separate AT Command Response (0x88) or Remote Command Response (0x97) frame, respectively. The data consists of the bytes in the previous list without the carriage return delimiters. The **NI** string ends in a 0x00 null character.

FN accepts a **NI** (Node Identifier) as an argument.

See [Find specific neighbor](#) for more details.

Parameter range

0 to 20 ASCII characters

Default

N/A

NT (Network Discovery Back-off)

The **ND** and **FN** commands use **NT**. The read-only **N?** command increases and decreases with **NT**.

Parameter range

0x20 - 0x2EE0 (x 100 ms)

Default

0x82 (13 seconds)

NO (Network Discovery Options)

Set or read the network discovery options value for **ND (Network Discover)** on a particular device. The options bit field value changes the behavior of the **ND** command and what optional values the local device returns when it receives an **ND** command or API Node Identification Indicator (0x95) frame.

Use **NO** to suppress or include a self-response to **ND** (Node Discover) commands. When **NO** bit 1 = 1, a device performing a Node Discover includes a response entry for itself.

Parameter range

0x0 - 0x7 (bit field)

Option	Description
0x01	Append the DD (Digi Device Identifier) value to ND responses or API node identification frames.
0x02	Local device sends ND response frame out the serial interface when ND is issued.
0x04	Append the RSSI of the last hop to ND , FN , and responses or API node identification frames.

Default

0x0

NP (Maximum Packet Payload Bytes)

Reads the maximum number of RF payload bytes that you can send in a transmission.

The XBee3 DigiMesh RF Module firmware returns a fixed number of bytes: 0x49 = 73 bytes without encryption, 65 bytes with encryption.

Note **NP** returns a hexadecimal value. For example, if **NP** returns 0x41, this is equivalent to 65 bytes.

Parameter range

[read-only]

Default

N/A

DigiMesh Addressing commands

The following commands affect the source and destination addressing for the device.

SH (Serial Number High)

Displays the upper 32 bits of the unique IEEE 64-bit address assigned to the XBee in the factory. The 64-bit source address is always enabled. This value is read-only and it never changes.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

SL (Serial Number Low)

Displays the lower 32 bits of the unique IEEE 64-bit RF address assigned to the XBee in the factory. The 64-bit source address is always enabled. This value is read-only and it never changes.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

DH (Destination Address High)

Set or read the upper 32 bits of the 64-bit destination address. When you combine **DH** with **DL**, it defines the destination address that the device uses for transmissions in Transparent mode.

This destination address is also used for outgoing I/O samples in both Transparent and API modes.

0x000000000000FFFF is the broadcast address. It is also used as the polling address when the device functions as end device.

Parameter range

0 - 0xFFFFFFFF

Default

0

DL (Destination Address Low)

Set or display the lower 32 bits of the 64-bit destination address. When you combine **DH** with **DL**, it defines the destination address that the device uses for transmissions in Transparent mode. This destination address is also used for outgoing I/O samples in both Transparent and API modes.

0x000000000000FFFF is the broadcast address. It is also used as the polling address when the device functions as end device.

Parameter range

0 - 0xFFFFFFFF

Default

0xFFFF (broadcast)

RR (Unicast Mac Retries)

Set or read the maximum number of MAC level packet delivery attempts for unicasts. If **RR** is non-zero, the sent unicast packets request an acknowledgment from the recipient. Unicast packets can be retransmitted up to **RR** times if the transmitting device does not receive a successful acknowledgment.

Parameter range

0 - 0xF

Default

0xA (10 retries)

MT (Broadcast Multi-Transmits)

Set or read the number of additional MAC-level broadcast transmissions. All broadcast packets are transmitted **MT+1** times to increase chances that they are received.

Parameter range

0 - 0xF

Default

3

TO (Transmit Options)

The device's transmit options. The device uses these options for all transmissions. API transmissions can override this using the TxOptions field in the API frame.

Parameter range

0x40-0xDF

Bit field:

Bit	Meaning	Description
0	Disable ACK	Disable acknowledgments on all unicasts
1	Disable RD	Disable Route Discovery on all DigiMesh unicasts
2	NACK	Enable a NACK messages on all DigiMesh API packets
3	Trace Route	Enable a Trace Route on all DigiMesh API packets
4	Reserved	<set this bit to 0>

Bit	Meaning	Description
5	Reserved	<set this bit to 0>
6,7	Delivery method	b'00 = <invalid option> b'01 = Point-multipoint (0x40) b'10 = Directed Broadcast (0x80) b'11 = DigiMesh (0xC0)

Default

0xC0

CI (Cluster ID)

The application layer cluster ID value. The device uses this value as the cluster ID for all data transmissions in Transparent mode and for all transmissions performed with the [Transmit Request frame - 0x10](#) in API mode. In API mode, transmissions performed with the [Explicit Addressing Command frame - 0x11](#) ignore this parameter.

If you set this value to **0x12** (loopback Cluster ID), the destination node echoes any transmitted packet back to the source device.

Parameter range

0 - 0xFFFF

Default

0x11 (Transparent data cluster ID)

DigiMesh configuration commands

The following commands affect outgoing transmissions in a DigiMesh network.

MR (Mesh Unicast Retries)

Set or read the maximum number of network packet delivery attempts. If **MR** is non-zero, the packets a device sends request a network acknowledgment, and can be resent up to **MR+1** times if the device does not receive an acknowledgment.

Changing this value dramatically changes how long a route request takes.

We recommend that you set this value to **1**.

If you set this parameter to **0**, it disables network ACKs. Initially, the device can find routes, but a route will never be repaired if it fails.

Parameter range

0 - 7 mesh unicast retries

Default

1

BH (Broadcast Hops)

The maximum transmission hops for broadcast data transmissions.

If you set **BH** greater than **NH (Network Hops)**, the device uses the value of **NH**.

If you set **BH** to **0**, the device uses **NH** as a limit to the maximum number of hops.

When working in API mode, the **Broadcast Radius** field in the API frame is used instead of this configuration.

Parameter range

0 - 0x20

Default

0

NH (Network Hops)

Sets or displays the maximum number of hops across the network. This parameter limits the number of hops for both unicasts and broadcasts. For example a RREQ is discarded after **NH** hops occur, preventing the route to a node more than **NH** hops away from being created. Without a route, unicasts will not work to that node. You can use this parameter to calculate the maximum network traversal time.

You must set this parameter to the same value on all nodes in the network.

If **BH (Broadcast Hops) = 0**, **NH** is used to set the maximum number of hops across the network when sending a broadcast transmission. **NH** is also used to set the maximum number of hops for broadcast if **BH > NH**.

Parameter range

1 - 0x20 (1 - 32 hops)

Default

7

NN (Network Delay Slots)

Set or read the maximum random number of network delay slots before rebroadcasting a network packet.

One network delay slot is approximately 13 ms.

Parameter range

1 - 0xA network delay slots

Default

3

DM (DigiMesh Options)

A bit field mask that you can use to enable or disable DigiMesh features. We highly recommend that you set the same **DM** value on every node on the network, otherwise you may encounter unexpected behavior when attempting to use the DigiMesh diagnostic features.

Bit:

0: Disable aggregator updates. When set to 1, the device does not issue or respond to **AG** requests.

1: Disable Trace Route and NACK responses. When set to 1, the device does not generate or respond to Trace Route or NACK requests.

Parameter range

0 - 0x03 (bit field)

Default

0

AG (Aggregator Support)

The **AG** command sends a broadcast through the network that has the following effects on nodes that receive the broadcast:

- The receiving node establishes a DigiMesh route back to the originating node, if there is space in the routing table.
- The **DH** and **DL** of the receiving node update to the address of the originating node if the **AG** parameter matches the current **DH/DL** of the receiving node.
- API-enabled devices with updated **DH** and **DL** send an Aggregate Addressing Update frame (0x8E) out the serial port.

Parameter range

Any 64-bit address

Default

N/A

Diagnostic commands - addressing timeouts

The following AT commands provide the transmission and discovery timeout values.

%H (MAC Unicast One Hop Time)

The MAC unicast one hop time timeout in milliseconds. If you change the MAC parameters it can change this value.

The time to send a unicast between two nodes in the network should not exceed the product of the unicast one hop time (**%H**) and the number of hops between those two nodes.

Parameter range

[read-only]

Default

N/A

%8 (MAC Broadcast One Hop Time)

The MAC broadcast one hop time timeout in milliseconds. If you change MAC parameters, it can change this value.

The time to send a broadcast between two nodes in the network should not exceed the product of the broadcast one hop time (**%8**) and the number of hops between those two nodes.

Parameter range

[read-only]

Default

N/A

N? (Network Discovery Timeout)

The maximum response time, in milliseconds, for **ND** (Network Discovery) responses and **DN** (Discover Node) responses. The timeout is the sum of **NT** (Network Discovery Back-off Time) and the network propagation time.

Parameter range

This is a read-only parameter, however, its value increases or decreases as **NT** increases or decreases and you can modify **NT**.

Default

N/A

Security commands

The following commands enable and control the encryption used for RF transmissions.

EE (Encryption Enable)

Enables or disables Advanced Encryption Standard (AES) encryption. See bit 2 of [C8 \(Compatibility Options\)](#), which controls the encryption mode.

Set this command parameter the same on all devices in a network.

Parameter range

0 - 1

Parameter	Description
0	Encryption Disabled
1	Encryption Enabled

Default

0

KY (AES Encryption Key)

The Link Key used for encryption and decryption. If [C8 \(Compatibility Options\)](#) bit 2 is cleared, encryption/decryption uses the 256 bits of the **KY** value (all 64 ASCII characters of the **KY** value). **C8** bit 2 sets encryption/decryption, and uses the last 32 ASCII characters of the 256-bit **KY** value entered.

This command is write-only and cannot be read. If you attempt to read **KY**, the device returns an **OK** status.

Set this command parameter the same on all devices in a network.

Parameter range

256-bit value (up to 32 hex bytes/64 ASCII bytes)

Default

0

RF interfacing commands

The following AT commands affect the RF interface of the device.

PL (TX Power Level)

Sets or displays the power level at which the device transmits conducted power.

Note If operating on channel 26 (**CH** = 0x1A), output power will be capped and cannot exceed 8 dBm regardless of the **PL** setting.

Parameter range

0 - 4

PL setting	XBee3 TX power	XBee3-PRO TX power
4	8 dBm	19 dBm
3	5 dBm	15 dBm
2	2 dBm	8 dBm
1	-1 dBm	3 dBm
0	-5 dBm	-5 dBm

Default

4

PP (Output Power in dBm)

Display the operating output power based on the current configuration (channel and **PL** setting). The values returned are in dBm, with negative values represented in two's complement; for example:

-5 dBm = 0xFB.

Parameter range

0 - 0xFF [read-only]

Default

N/A

CA (CCA Threshold)

Defines the Clear Channel Assessment (CCA) threshold. Prior to transmitting a packet, the device performs a CCA to detect energy on the channel. If the device detects energy above the CCA threshold, it will not transmit the packet.

The **CA** parameter is measured in units of -dBm.

Parameter range

0 (disabled), 0x28 - 0x64 (-dBm)

Default

0x0 (CCA disabled)

DB (Last Packet RSSI)

Reports the RSSI in -dBm of the last received RF data packet. **DB** returns a hexadecimal value for the -dBm measurement.

For example, if **DB** returns 0x60, then the RSSI of the last packet received was -96 dBm.

DB only indicates the signal strength of the last hop. It does not provide an accurate quality measurement for a multihop link.

If the XBee3 DigiMesh RF Module has been reset and has not yet received a packet, **DB** reports **0**.

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFF [read-only]

Default

0

MAC diagnostics commands

The following commands provide Media Access Control diagnostic information.

EA (MAC ACK Failure Count)

The number of unicast transmissions that time out awaiting a MAC ACK. This can be up to **RR + 1** timeouts per unicast when **RR > 0**.

This count increments whenever a MAC ACK timeout occurs on a MAC-level unicast. When the number reaches **0xFFFF**, the firmware does not count further events.

To reset the counter to any 16-bit unsigned value, append a hexadecimal parameter to the command.

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

0x0

EC (CCA Failures)

Sets or displays the number of frames that were blocked and not sent due to CCA failures or receptions in progress. If CCA is disabled (**CA** is **0**), then this count only increments for frames that are blocked due to receive in progress. When this count reaches its maximum value of **0xFFFF**, it stops counting.

You can reset **EC** to **0** (or any other value) at any time to make it easier to track errors. This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

0x0

BC (Bytes Transmitted)

The number of RF bytes transmitted. The firmware counts every byte of every packet, including MAC/PHY headers and trailers.

You can reset the counter to any 32-bit value by appending a hexadecimal parameter to the command. This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFFFFFF

Default

N/A (0 after reset)

GD (Good Packets Received)

This count increments when a device receives a good frame with a valid MAC header on the RF interface. Received MAC ACK packets do not increment this counter. Once the number reaches 0xFFFF, it does not count further events.

To reset the counter to any 16-bit unsigned value, append a hexadecimal parameter to the command. This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

N/A (0 after reset)

TR (Transmission Failure Count)

This count increments whenever a MAC transmission attempt exhausts all MAC retries without ever receiving a MAC acknowledgment message from the destination node. Once the number reaches 0xFFFF, it does not count further events.

To reset the counter to any 16-bit value, append a hexadecimal parameter to the command.

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

N/A (0 after reset)

UA (Unicasts Attempted Count)

The number of unicast transmissions expecting an acknowledgment (when **RR** > 0). To reset the counter to any 16-bit value, append a hexadecimal parameter to the command. **UA** is a volatile value—that is, the value does not persist across device resets.

Parameter range

0 - 0xFFFF

Default

0

ED (Energy Detect)

Starts an energy detect scan. This command accepts an argument to specify the time in milliseconds to scan all channels. The device loops through all the available channels until the time elapses. It returns the maximal energy on each channel, a comma follows each value, and the list ends with a carriage return. The values returned reflect the energy level that ED detects in -dBm units.

Parameter range

0 - 0x80

Default

0xA (10 ms)

Sleep settings commands

The following commands enable and configure the low power sleep modes of the device.

SM (Sleep Mode)

Sets or displays the sleep mode of the device.

Normal mode is always awake. Pin sleep modes allow you to wake the device with the SLEEP_REQUEST line. Asynchronous cyclic mode sleeps for **SP** time and briefly wakes, checking for activity. Sleep support mode is always awake, but can effectively communicate with synchronized cyclic sleep nodes. Synchronized Cyclic Sleep nodes keep the same wake and sleep cycles for all nodes in the network.

Parameter range

0 - 5

Parameter	Description
0	No sleep (always awake)
1	Pin sleep
2	Unused
3	Unused

Parameter	Description
4	Asynchronous cyclic sleep
5	Asynchronous cyclic sleep with pin wakeup
6	MicroPython sleep (with optional pin wake). For complete details see the Digi MicroPython Programming Guide .
7	Synchronous sleep support mode
8	Synchronous cyclic sleep

Default

0

SP (Sleep Time)

Sets or displays the device's sleep time. This command defines the amount of time the device sleeps per cycle.

For a node operating as an Indirect Messaging Coordinator, this command defines the amount of time that it will hold an indirect message for an end device. The coordinator will hold the message for (2.5 * **SP**).

Parameter range

0x1 - 0x15F900 (x 10 ms) (4 hours)

Default

0xC8

ST (Wake Time)

Sets or displays the wake time of the device.

For devices in asynchronous cyclic sleep, **ST** defines the amount of time that a device stays awake after it receives RF or serial data.

For devices in synchronous sleep, the minimum wake time is a function of **MT**, **RN**, **NH**, and **NN**. If you increase these values such that **ST** is no longer big enough to get a message through the network during a wake cycle, then **ST** will be increased appropriately.

Parameter range

0x1 - 0x36EE80 (x 1 ms)

Default

0x7D0 (2 seconds)

SN (Number of Sleep Periods)

Set or read the number of sleep periods value. This command controls the number of sleep periods that must elapse between assertions of the ON_SLEEP line during the wake time of Asynchronous or Synchronous Cyclic Sleep. This allows external circuitry to sleep longer than the **SP** time.

Parameter range

1 - 0xFFFF

Default

1

WH (Wake Host Delay)

Sets or displays the wake host timer value. You can use **WH to give** a sleeping host processor sufficient time to power up after the device asserts the ON_SLEEP line.

If you set **WH** to a non-zero value, this timer specifies a time in milliseconds that the device delays after waking from sleep before sending data out the UART or transmitting an I/O sample. If the device receives serial characters, the **WH** timer stops immediately.

Parameter range

0 - 0xFFFF (x 1 ms)

Default

0

SO (Sleep Options)

You can set or clear any of the available sleep option bits.

You cannot set bit 0 and bit 1 at the same time.

Parameter range

0 - 0x13E

Bit	Option
0	Sleep coordinator; setting this bit causes a sleep compatible device to always act as sleep coordinator.
1	Non-sleep coordinator; setting this bit causes a device to never act as a sleep coordinator.
2	Enable API sleep status messages.
3	Disable early wake-up for missed syncs.
4	Enable node type equality (disables seniority based on device type).
5	Disable coordinator rapid sync deployment mode.

For asynchronous sleep devices, the following sleep bit field options are defined:

Bit	Option
8	Always wake for ST time.

Default

0

Diagnostic - sleep status/timing commands

The following AT commands are Diagnostic sleep status/timing commands.

SS (Sleep Status)

Queries a number of Boolean values that describe the device's status.

Bit	Description
0	This bit is true when the network is awake and able to receive transmissions.
1	This bit is true if the node currently acts as a network sleep coordinator.
2	This bit is true if the node ever receives a valid sync message after it powers on.
3	This bit is true if the node receives a sync message in the current wake cycle.
4	This bit is true if you alter the sleep settings on the device so that the node nominates itself and sends a sync message with the new settings at the beginning of the next wake cycle.
5	This bit is true if you request that the node nominate itself as the sleep coordinator using the Commissioning Pushbutton or the CB2 command.
6	This bit is true if the node is currently in deployment mode.
All other bits	Reserved. Ignore all non-documented bits.

Parameter range

N/A

Default

N/A

OS (Operating Sleep Time)

Reads the current network sleep time that the device is synchronized to, in units of 10 milliseconds. If the device has not been synchronized, then **OS** returns the value of **SP**.

If the device synchronizes with a sleeping router network, **OS** may differ from **SP**.

Parameter range

N/A

Default

N/A

OW (Operating Wake Time)

Reads the current network wake time that a device is synchronized to, in 1 ms units.

If the device has not been synchronized, then **OW** returns the value of **ST**.

If the device synchronizes with a sleeping router network, **OW** may differ from **ST**.

Parameter range

N/A

Default

N/A

MS (Missed Sync Messages)

Reads the number of sleep or wake cycles since the device received a sync message.

Parameter range

N/A

Default

N/A

SQ (Missed Sleep Sync Count)

Counts the number of sleep cycles in which the device does not receive a sleep sync.

Set the value to 0 to reset this value.

When the value reaches 0xFFFF it does not increment anymore.

Parameter range

0 - 0xFFFF

Default

N/A

UART interface commands

The following AT commands are serial interfacing commands.

BD (Baud Rate)

To request non-standard baud rates with values above 0x80, you can use the Serial Console toolbar in XCTU to configure the serial connection (if the console is connected), or click the **Connect** button (if the console is not yet connected).

When you send non-standard baud rates to a device, it stores the closest interface data rate represented by the number in the **BD** register. Read the **BD** command by sending **ATBD** without a parameter value, and the device returns the value stored in the **BD** register.

Parameter range

Standard baud rates: 0x0 - 0x0A

Non-standard baud rates: 0x12C - 0x0EC400

Parameter	Description
0x0	1200 b/s

Parameter	Description
0x1	2400 b/s
0x2	4800 b/s
0x3	9600 b/s
0x4	19200 b/s
0x5	38400 b/s
0x6	57600 b/s
0x7	115200 b/s
0x8	230400 b/s
0x9	460,800 b/s
0xA	921,600 b/s
0x4B0 (1200 b/s) to 0xEC400 (967680 b/s) (non standard baud rates)	

Default

0x03 (9600 baud)

NB (Parity)

Set or read the serial parity settings for UART communications.

Parameter range

0x00 - 0x02

Parameter	Description
0x00	No parity
0x01	Even parity
0x02	Odd parity

Default

0

SB (Stop Bits)

Sets or displays the number of stop bits for UART communications.

Parameter range

0 - 1

Parameter	Configuration
0	One stop bit
1	Two stop bits

Default

0

FT (Flow Control Threshold)

Set or display the flow control threshold.

The device de-asserts $\overline{\text{CTS}}$ when **FT** bytes are in the UART receive buffer. It re-asserts $\overline{\text{CTS}}$ when less than **FT** bytes are in the UART receive buffer.

Parameter range

0x14 - 0x110 bytes

Default

0xD9

RO (Packetization Timeout)

Set or read the number of character times of inter-character silence required before transmission begins when operating in Transparent mode.

A “character time” is the amount of time it takes to send a single ASCII character at the operating baud rate (**BD**).

Set **RO** to 0 to transmit characters as they arrive instead of buffering them into one RF packet.

The **RO** command only applies to Transparent mode, it does not apply to API mode.

Parameter range

0 - 0xFF (x character times)

Default

3

AP (API Enable)

Set or read the API mode setting. The device can format the RF packets it receives into API frames and sends them out the serial port.

When you enable API, you must format the serial data as API frames because Transparent operating mode is disabled.

Parameter range

0 - 2

Parameter	Description
0	API disabled (operate in Transparent mode)
1	API enabled
2	API enabled (with escaped control characters)

Default

0

AO (API Options)

The API data frame output format for RF packets received.

Use **AO** to enable different API output frames.

Parameter range

0 - 1

Parameter	Description
0	API Rx Indicator - 0x90, this is for standard data frames.
1	API Explicit Rx Indicator - 0x91, this is for Explicit Addressing data frames.

Default

0

AZ (Extended API Options)

Optionally output additional ZCL messages that would normally be masked by the XBee application.

Use this when debugging OTA firmware updates by enabling client-side messages to be sent out of the serial port.

Parameter range

0 - 2

Parameter	Description
0	Suppress ZCL output
1	Reserved
2	Output supported ZCL packets

Default

0

Command mode options

The following commands affect how [Command mode](#) operates.

CC (Command Character)

The character value the device uses to enter Command mode.

The default value (**0x2B**) is the ASCII code for the plus (+) character. You must enter it three times within the guard time to enter Command mode. To enter Command mode, there is also a required period of silence before and after the command sequence characters of the Command mode sequence (**GT + CC + GT**). The period of silence prevents inadvertently entering Command mode. For more information, see [Enter Command mode](#).

Parameter range

0 - 0xFF

Recommended: 0x20 - 0x7F (ASCII)

Default

0x2B (the ASCII plus character: +)

CT (Command Mode Timeout)

Sets or displays the Command mode timeout parameter. If a device does not receive any valid commands within this time period, it returns to Transparent mode or API mode.

Parameter range

2 - 0x1770 (x 100 ms)

Default

0x64 (10 seconds)

GT (Guard Time)

Set the required period of silence before and after the command sequence characters of the Command mode sequence, **GT + CC + GT** (including spaces). The period of silence prevents inadvertently entering Command mode. For more information, see [Enter Command mode](#).

Parameter range

0x2 - 0x6D3 (x 1 ms)

Default

0x3E8 (one second)

CN (Exit Command mode)

Executable command. **CN** immediately exits Command mode and applies pending changes.

Parameter range

N/A

Default

N/A

MicroPython commands

The following commands relate to using MicroPython on the XBee3 DigiMesh RF Module.

PS (Python Startup)

Sets whether or not the XBee3 DigiMesh RF Module runs the stored Python code at startup.

Range

0 - 1

Parameter	Description
0	Do not run stored Python code at startup.
1	Run stored Python code at startup.

Default

0

PY (MicroPython Command)

Interact with the XBee3 DigiMesh RF Module using MicroPython. **PY** is a command with sub-commands. These sub-commands are arguments to **PY**.

PYB (Bundled Code Report)

You can store compiled code in flash using the **os.bundle()** function in the MicroPython REPL; refer to the [Digi MicroPython Programming Guide](#). The **PYB** sub-command reports details of the bundled code. In Command mode, it returns two lines of text, for example:

```
bytecode: 619 bytes (hash=0x0900DBCE)
compiled: 2017-05-09T15:49:44
```

The messages are:

- **bytecode**: the size of bytecode stored in flash and its 32-bit hash. A size of **0** indicates that there is no stored code.
- **compiled**: a compilation timestamp. A timestamp of **2000-01-01T00:00:00** indicates that the clock was not set during compilation.

In API mode, **PYB** returns three 32-bit big-endian values:

- bytecode size
- bytecode hash
- timestamp as seconds since 2000-01-01T00:00:00

PYE (Erase Bundled Code)

PYE interrupts any running code, erases any bundled code and then does a soft-reboot on the MicroPython subsystem.

PYV (Version Report)

Report the MicroPython version.

PY^ (Interrupt Program)

Sends **KeyboardInterrupt** to MicroPython. This is useful if there is a runaway MicroPython program and you have filled the stdin buffer. You can enter Command mode (**+++**) and send **ATPY^** to interrupt the program.

Default

N/A

File system commands

To access the file system, enter Command mode and use the following commands. All commands block the AT command processor until completed and only work from Command mode; they are not valid for API mode or MicroPython's **xbee.atcmd()** method. Commands are case-insensitive as are file and directory names. Optional parameters are shown in square brackets ([]).

FS (File System)

FS is a command with sub-commands. These sub-commands are arguments to **FS**.

Error responses

If a command succeeds it returns information such as the name of the current working directory or a list of files, or **OK** if there is no information to report. If it fails, you see a detailed error message instead of the typical **ERROR** response for a failing AT command. The response is a named error code and a textual description of the error.

Note The exact content of error messages may change in the future. All errors start with a upper case **E**, followed by one or more uppercase letters and digits, a space, and an description of the error. If writing your own AT command parsing code, you can determine if an **FS** command response is an error by checking if the first letter of the response is upper case **E**.

FS (File System)

When sent without any parameters, **FS** prints a list of supported commands.

FS PWD

Prints the current working directory, which always starts with **/** and defaults to **/flash** at startup.

FS CD *directory*

Changes the current working directory to **directory**. Prints the current working directory or an error if unable to change to **directory**.

FS MD *directory*

Creates the directory **directory**. Prints **OK** if successful or an error if unable to create the requested directory.

FS LS [*directory*]

Lists files and directories in the specified directory. The **directory** parameter is optional and defaults to a period (**.**), which represents the current directory. The list ends with a blank line.

Entries start with zero or more spaces, followed by file size or the string **<DIR>** for directories, then a single space character and the name of the entry. Directory names end with a forward slash (**/**) to differentiate them from files.

```

<DIR> ./
<DIR> ../
<DIR> lib/
      32 test.txt

```

FS PUT filename

Starts a YMODEM receive on the XBee Smart Modem, storing the received file to **filename** and ignoring the filename that appears in block 0 of the YMODEM transfer. The XBee Smart Modem sends a prompt (**Receiving file with YMODEM...**) when it is ready to receive, at which point you should initiate a YMODEM send in your terminal emulator.

If the command is incorrect, the reply will be an error as described in [Error responses](#).

FS HASH filename

Print a SHA-256 hash of a file to allow for verification against a local copy of the file. On Windows, you can generate a SHA-256 hash of a file with the command **certutil -hashfile test.txt SHA256**. On Mac and Linux use **shasum -b -a 256 test.txt**.

FS GET filename

Starts a YMODEM send of filename on the XBee device. When it is ready to send, the XBee Smart Modem sends a prompt: (**Sending file with YMODEM...**). When the prompt is sent, you should initiate a YMODEM receive in your terminal emulator.

If the command is incorrect, the reply will be an error as described in [Error responses](#).

FS RM file_or_directory

Removes the file or empty directory specified by **file_or_directory**. This command fails with an error if **file_or_directory** does not exist, is not empty, refers to the current working directory or one of its parents.

Note Removing a file does not reclaim the space used by that file. Use the **ATFS INFO** command to see how much space is used up by removed files.

FS INFO

Report on the size of the filesystem, showing bytes in use, available, marked bad and total. The report ends with a blank line, as with most multi-line AT command output. Example output:

```

204800 used
695296 free
   0 bad
900096 total

```

FS FORMAT confirm

Formats the file system, leaving it with a default directory structure. Pass the word **confirm** as the first parameter to confirm the format. The XBee Smart Modem responds with **Formatting...** when the format starts, and will print **OK** followed by a carriage return when it finishes.

FK (File System Public Key)

Configures the device's File System Public Key.

The 65-byte public key is required to verify that the file system that is downloaded over-the-air is a valid XBee3 file system compatible with the DigiMesh firmware.

For further information, refer to [Set the public key on the XBee3 device](#).

Parameter range

- A valid 65-byte ECDSA public key.
- Other accepted parameters:
- 0 = Clear the public key
- 1 = Returns the upper 48 bytes of the public key
- 2 = Returns the lower 17 bytes of the public key

Default

0

Note The Default value of **0** indicates that no public key has been set and hence, all file system updates will be rejected.

UART pin configuration commands

The following commands are related to pin configuration for the UART interface.

D6 (DIO6/RTS Configuration)

Sets or displays the DIO6/ $\overline{\text{RTS}}$ configuration (Micro pin 27/SMT pin 29/TH pin 16).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	$\overline{\text{RTS}}$ flow control
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D7 (DIO7/CTS Configuration)

Sets or displays the DIO7/ $\overline{\text{CTS}}$ configuration (Micro pin 24/SMT pin 25/TH pin 12).

Parameter range

0, 1, 3 - 7

Parameter	Description
0	Disabled
1	$\overline{\text{CTS}}$ flow control
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high
6	RS-485 enable, low
7	RS-485 enable, high

Default

1

P3 (DIO13/UART_DOUT)

Sets or displays the DIO13/UART_DOUT configuration (Micro pin 3/SMT pin 3/TH pin 2).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	UART DOUT
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

P4 (DIO14/UART_DIN Configuration)

Sets or displays the DIO14/UART_DIN configuration (Micro pin 4/SMT pin 4/TH pin 3).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	UART DIN
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

SPI interface commands

The following commands affect the SPI serial interface on SMT and MMT variants. These commands are not applicable to the through-hole variant of the XBee3; see **D1** through **D4** and **P2** for through-hole SPI support.

P5 (DIO15/SPI_MISO Configuration)

Sets or displays the DIO15/SPI_MISO configuration (Micro pin 16/SMT pin 17). This only applies to surface-mount and micro devices.

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_MISO
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

P6 (DIO16/SPI_MOSI Configuration)

Sets or displays the DIO16/SPI_MOSI configuration (Micro pin 15/SMT pin 16). This only applies to surface-mount and micro devices.

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_MOSI
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

P7 (DIO17/SPI_SSEL Configuration)

Sets or displays the DIO17/SPI_SSEL configuration (Micro pin 14/SMT pin 15). This only applies to surface-mount and micro devices.

Parameter range

0 - 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_SSEL
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

P8 (DIO18/SPI_CLK Configuration)

Sets or displays the DIO18/SPI_CLK configuration (Micro pin 13/SMT pin 14). This only applies to surface-mount and micro devices.

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_CLK
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

P9 (DIO19/SPI_ATTN Configuration)

Sets or displays the DIO19/SPI_ATTN configuration (Micro pin 11/SMT pin 12). This only applies to surface-mount and micro devices.

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_ATTN
2	N/A
3	N/A
4	Digital output, low
5	Digital output, high

Default

1

I/O settings commands

The following commands configure the various I/O lines available on the XBee3 DigiMesh RF Module.

D0 (DIO0/ADC0/Commissioning Configuration)

Sets or displays the DIO0/ADC0/CB configuration (Micro pin 31/SMT pin 33/TH pin 20).

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	Commissioning Pushbutton
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

D1 (DIO1/ADC1/TH_SPI_ATTN Configuration)

Sets or displays the DIO1/ADC1/TH_SPI_ATTN configuration (Micro pin 30/SMT pin 32/TH pin 19).

Parameter range

SMT/MMT: 0, 2 - 5

TH: 0 - 5

Parameter	Description
0	Disabled
1	SPI_ATTN for the through-hole device N/A for the surface-mount device
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D2 (DIO2/ADC2/TH_SPI_CLK Configuration)

Sets or displays the DIO2/ADC2/TH_SPI_CLK configuration (Micro pin 29/SMT pin 31/TH pin 18).

Parameter range

SMT/MMT: 0, 2 - 5

TH: 0 - 5

Parameter	Description
0	Disabled
1	SPI_CLK for through-hole devices N/A for surface-mount devices
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D3 (DIO3/ADC3/TH_SPI_SSEL Configuration)

Sets or displays the DIO3/ADC3/TH_SPI_SSEL configuration (Micro pin 28/SMT pin 30/TH pin 17).

Parameter range

SMT/MMT: 0, 2 - 5

TH: 0 - 5

Parameter	Description
0	Disabled
1	SPI_SSEL for the through-hole device N/A for surface-mount device
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D4 (DIO4/TH_SPI_MOSI Configuration)

Sets or displays the DIO4/TH_SPI_MOSI configuration (Micro pin 23/SMT pin 24/TH pin 11).

Parameter range

SMT/MMT: 0, 3 - 5

TH: 0, 1, 3 - 5

Parameter	Description
0	Disabled
1	SPI_MOSI for the through-hole device N/A for the surface-mount and micro device
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D5 (DIO5/Associate Configuration)

Sets or displays the DIO5/ASSOCIATED_INDICATOR configuration (Micro pin 26/SMT pin 28/TH pin 15).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	Associate LED indicator - blinks when associated
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

D8 (DIO8/DTR/SLP_Request Configuration)

Sets or displays the DIO8/DTR/SLP_RQ configuration (Micro pin 9/SMT pin 10/TH pin 9).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled

Parameter	Description
1	DTR/Sleep_Request (used with pin sleep and cyclic sleep with pin wake)
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

D9 (DIO9/ON_SLEEP Configuration)

Sets or displays the DIO9/ON_SLEEP configuration (Micro pin 25/SMT pin 26/TH pin 13).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	ON/SLEEP indicator
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

P0 (DIO10/RSSI/PWM0 Configuration)

Sets or displays the DIO10/RSSI/PWM0 configuration (Micro pin 7/SMT pin 7/TH pin 6).

When configured as RSSI PWM output, the device outputs a PWM signal with a duty cycle equivalent to the dBm of the received packet.

Use [RP command](#) to configure the timeout.

When configured as PWM output (2): you can use **M0** to explicitly control the PWM0 output. When used with [Analog line passing](#), PWM0 corresponds with ADC0.

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	RSSI PWM output
2	PWM0 output. M0 (PWM0 Duty Cycle) or I/O line passing control the value.
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

P1 (DIO11/PWM1 Configuration)

Sets or displays the DIO11 configuration (Micro pin 8/SMT pin 8/TH pin 7).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A
2	PWM1 output. M1 (PWM1 Duty Cycle) or I/O line passing control the value.
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

P2 (DIO12/TH_SPI_MISO Configuration)

Sets or displays the DIO12/TH_SPI_MISO configuration (Micro pin 5/SMT pin 5/TH pin 4).

Parameter range

SMT/MMT: 0, 3 - 5

TH: 0, 1, 3 - 5

Parameter	Description
0	Disabled

Parameter	Description
1	SPI_MISO for the through-hole device N/A for the surface-mount and micro device
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

PR (Pull-up/Down Resistor Enable)

The bit field that configures the internal pull-up resistor status for the I/O lines.

- If you set a **PR** bit to 1, it enables the pull-up/down resistor
- If you set a **PR** bit to 0, it specifies no internal pull-up/down resistor.

PR and **PD** only affect lines that are configured as digital inputs (**3**) or disabled (**0**).

The following table defines the bit-field map for **PR** and **PD** commands.

Bit	I/O line	Micro pin	Surface-mount pin	Through-hole pin
0	DIO4	23	24	11
1	DIO3	28	30	17
2	DIO2	29	31	18
3	DIO1	30	32	19
4	DIO0	31	33	20
5	DIO6	27	29	16
6	DIO8	9	10	9
7	DIO14	4	4	3
8	DIO5	26	28	15
9	DIO9	25	26	13
10	DIO12	5	5	4
11	DIO10	7	7	6
12	DIO11	8	8	7
13	DIO7	24	25	12
14	DIO13	3	3	2

Bit	I/O line	Micro pin	Surface-mount pin	Through-hole pin
15	DIO15	16	17	N/A
16	DIO16	15	16	N/A
17	DIO17	14	15	N/A
18	DIO18	13	14	N/A
19	DIO19	11	12	N/A

Parameter range

Through-hole: 0 - 0xFFFF

SMT/MMT: 0 - 0xFFFFF

Default

0xFFFF

PD (Pull Up/Down Direction)

The resistor pull direction bit field (1 = pull-up, 0 = pull-down) for corresponding I/O lines that are set by the **PR** command.

See [PR \(Pull-up/Down Resistor Enable\)](#) for the bit mappings.

Parameter range

Through-hole: 0 - 0xFFFF

SMT/MMT: 0 - 0xFFFFF

Default

0xFFFF

IO (Set Digital I/O Lines)

Sets digital output levels. This allows DIO lines setup as outputs to be changed through Command mode.

Parameter range

8-bit bit map; each bit represents the level of an I/O line set up as an output

Default

N/A

M0 (PWM0 Duty Cycle)

The duty cycle of the PWM0 line (Micro pin 7/SMT pin 7).

If [IA \(I/O Input Address\)](#) is set correctly and [P0 \(DIO10/RSSI/PWM0 Configuration\)](#) is configured as PWM0 output, incoming AD0 samples automatically modify the PWM0 value. See [PT \(PWM Output Timeout\)](#).

To configure the duty cycle of PWM0:

1. Enable PWM0 output (**P0 = 2**).
2. Change **M0** to the desired value.
3. Apply settings (use **CN** or **AC**).

The PWM period is 64 μ s and there are 0x03FF (1023 decimal) steps within this period. When **M0 = 0** (0% PWM), 0x01FF (50% PWM), 0x03FF (100% PWM), and so forth.

Parameter range

0 - 0x3FF

Default

0

M1 (PWM1 Duty Cycle)

If [IA \(I/O Input Address\)](#) is set correctly and [P1 \(DIO11/PWM1 Configuration\)](#) is configured as PWM1 output, incoming AD0 samples automatically modify the PWM1 value. See [PT \(PWM Output Timeout\)](#).

To configure the duty cycle of PWM1:

1. Enable PWM1 output (**P1 = 2**).
2. Change **M1** to the desired value.
3. Apply settings (use **CN** or **AC**).

The PWM period is 64 μ s and there are 0x03FF (1023 decimal) steps within this period. When **M1 = 0** (0% PWM), 0x01FF (50% PWM), 0x03FF (100% PWM), and so forth.

Parameter range

0 - 0x3FF

Default

0

RP command

The PWM timer expiration is 0.1 seconds. **RP** sets the duration of pulse width modulation (PWM) signal output on the RSSI pin. The signal duty cycle updates with each received packet and shuts off when the timer expires.

When **RP = 0xFF**, the output is always on.

Parameter range

0 - 0xFF (x 100 ms), 0xFF

Default

0x28 (four seconds)

LT command

Set or read the Associate LED blink time. If you use [D5 \(DIO5/Associate Configuration\)](#) to enable the Associate LED functionality (DIO5/Associate pin), this value determines the on and off blink times for the LED when the device has joined the network.

If **LT = 0**, the device uses the default blink rate of 250 ms.

For all other **LT** values, the firmware measures **LT** in 10 ms increments.

Parameter range

0, 0x14 - 0xFF (x 10 ms)

Default

0

CB (Commissioning Button)

Use **CB** to simulate Commissioning Pushbutton presses in software.

You can enable a physical commissioning pushbutton with [D0 \(DIO0/ADC0/Commissioning Configuration\)](#).

Set the parameter value to the number of button presses that you want to simulate. For example, send **CB1** to perform the action of pressing the Commissioning Pushbutton once.

Parameter range

1, 2, 4

Parameter	Description
1	Keeps device awake for 30 seconds.
2	Nominate the node as the sleep coordinator for synchronous sleep networks.
4	Restore defaults (equivalent to sending an RE (Restore Defaults)).

Default

N/A

I/O sampling commands

The following commands configure I/O sampling on an originating device. Any I/O sample generated by this device is sent to the address specified by **DH** and **DL**. You must configure at least one I/O line as an input or output for a sample to be generated.

IS (I/O Sample)

Immediately forces an I/O sample to be generated. If you issue the command to the local device, the sample data is sent out the local serial interface. If sent remotely, the sample data is returned as a [AT Command Response frame - 0x88](#).

If the device receives ERROR as a response to an **IS** query, there are no valid I/O lines to sample.

Parameter range

N/A

Default

N/A

IR (Sample Rate)

Determines the I/O sample rate used to generate outgoing I/O sample data. When the IR value is greater than 0, the device samples and transmits all enabled digital I/O and ADCs every **IR** milliseconds. I/O Samples transmit to the address specified by **DH + DL**.

At least one I/O line must be configured as an input or explicit output for samples to be generated.

Parameter range

0, 0x32 - 0xFFFF (ms)

Default

0

IC (DIO Change Detect)

Set or read the digital I/O pins to monitor for changes in the I/O state.

IC works with the individual pin configuration commands (**D0 - D9, P0 - P4**). If the device detects a change on an enabled digital I/O pin, it immediately transmits a digital I/O sample to the address specified by **DH + DL**. If sleep is enabled, the edge transition must occur during a wake period to trigger a change detect.

The data transmission contains only DIO data.

IC is a bitmask you can use to enable or disable edge detection on individual digital I/O lines. Only DIO0 through DIO14 can be sampled using a Change Detect.

Set unused bits to **0**.

Bit field

Bit	I/O line	Micro pin	Surface-mount pin	Through-hole pin
0	DIO0	31	33	20
1	DIO1	30	32	19
2	DIO2	29	31	18
3	DIO3	28	30	17
4	DIO4	23	24	11
5	DIO5	26	28	15
6	DIO6	27	29	16
7	DIO7	24	25	12
8	DIO8	9	10	9
9	DIO9	25	26	13
10	DIO10	7	7	6
11	DIO11	8	8	7
12	DIO12	5	5	4

Bit	I/O line	Micro pin	Surface-mount pin	Through-hole pin
13	DIO13	3	3	2
14	DIO14	4	4	3
15	N/A	N/A	N/A	N/A

Parameter range

0 - 0x7FFF

Default

0

AV (Analog Voltage Reference)

The analog voltage reference used for A/D sampling.

ADC lines are 10-bit analog inputs.

Parameter range

0 - 2

Parameter	Description
0	1.25 V reference
1	2.5 V reference
2	VDD reference

Default

0

IF (Sleep Sample Rate)

Set or read the number of sleep cycles that must elapse between periodic I/O samples. This allows the firmware to take I/O samples only during some wake cycles. During those cycles, the firmware takes I/O samples at the rate specified by [IR \(Sample Rate\)](#).

To enable periodic sampling, set **IR** to a non-zero value, and enable the analog or digital I/O functionality of at least one device pin. The sample rate is measured in milliseconds.

For more information, see the following commands:

- [D0 \(DIO0/ADC0/Commissioning Configuration\)](#) through [D9 \(DIO9/ON_SLEEP Configuration\)](#)
- [P0 \(DIO10/RSSI/PWM0 Configuration\)](#) through [P2 \(DIO12/TH_SPI_MISO Configuration\)](#)

Parameter range

1 - 0xFFFF (x 1 ms)

Default

1

I/O line passing commands

Configure the device for I/O line passing. When enabled, incoming I/O sample data will affect the state of analog and digital lines that are configured as output.

IA (I/O Input Address)

The source address of the device to which outputs are bound.

To disable I/O line passing, set all bytes to **0xFF**.

To allow any I/O packet addressed to this device (including broadcasts) to change the outputs, set **IA** to **0xFFFF**.

Parameter range

0 - 0xFFFF FFFF FFFF FFFF

Default

0xFFFFFFFFFFFFFFFF (I/O line passing disabled)

IU (Send I/O Sample to Serial Port)

Indicates whether or not I/O samples should be sent to the serial port. 0 suppresses output; 1 allows output (only if the device is in API mode).

Parameter range

0 - 1

Parameter	Description
0	Disabled
1	Enabled

Default

1

T0 (D0 Timeout)

Specifies how long pin [D0 \(DIO0/ADC0/Commissioning Configuration\)](#) holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T1 (D1 Output Timeout)

Specifies how long pin [D1 \(DIO1/ADC1/TH_SPI_ATTn Configuration\)](#) holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T2 (D2 Output Timeout)

Specifies how long pin [D2 \(DIO2/ADC2/TH_SPI_CLK Configuration\)](#) holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T3 (D3 Output Timeout)

Specifies how long pin [D3 \(DIO3/ADC3/TH_SPI_SSEL Configuration\)](#) holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T4 (D4 Output Timeout)

Specifies how long pin [D4 \(DIO4/TH_SPI_MOSI Configuration\)](#) holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T5 (D5 Output Timeout)

Specifies how long pin [D5 \(DIO5/Associate Configuration\)](#) holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T6 (D6 Output Timeout)

Specifies how long pin **D6 (DIO6/RTS Configuration)** holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T7 (D7 Output Timeout)

Specifies how long pin **D7 (DIO7/CTS Configuration)** holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T8 (D8 Timeout)

Specifies how long pin **D8 (DIO8/DTR/SLP_Request Configuration)** holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T9 (D9 Timeout)

Specifies how long pin **D9 (DIO9/ON_SLEEP Configuration)** holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q0 (P0 Timeout)

Specifies how long pin **P0** holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q1 (P1 Timeout)

Specifies how long pin P1 holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q2 (P2 Timeout)

Specifies how long pin P2 holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

PT (PWM Output Timeout)

Specifies how long both PWM outputs (**P0, P1**) output a given PWM signal before it reverts to the configured value (**M0/M1**). If set to **0**, there is no timeout. This timeout only affects these pins when they are configured as PWM output.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0xFF

Diagnostics – Firmware/Hardware Information

The following AT commands provide information about the XBee3 DigiMesh RF Module hardware and firmware.

VR (Firmware Version)

Reads the firmware version on a device.

Parameter range

0x3000 - 0x30FF [read-only]

Default

Set in the firmware

VL (Version Long)

Shows detailed version information including the application build date and time.

Parameter range

N/A

Default

N/A

VH (Bootloader Version)

Reads the bootloader version of the device.

Parameter range

N/A

Default

N/A

HV (Hardware Version)

Display the hardware version number of the device.

Parameter range

0 - 0xFFFF [read-only]

Default

Set in firmware

%C (Hardware/Software Compatibility)

Specifies what firmware is compatible with this device's hardware. %C is compared to the to the "compatibility_number" field of the firmware configuration xml file. Firmware with a compatibility number lower than the value returned by %C cannot be loaded onto the board. If an invalid firmware is loaded, the device will not boot until a valid firmware is reloaded.

Parameter range

[read-only]

Default

N/A

%V (Supply Voltage)

Reads the voltage on the Vcc pin in mV.

Parameter range

0 - 0xFFFF (in mV) [read only]

Default

N/A

TP (Temperature)

The current module temperature in degrees Celsius. The temperature is represented in two's complement, as shown in the following example:

1 °C = 0x0001 and -1°C = 0xFFFF

Parameter range

0 - 0xFFFF (Celsius) [read-only]

Default

N/A

DD (Device Type Identifier)

Stores the Digi device type identifier value. Use this value to differentiate between multiple types of devices.

Parameter range

0 - 0xFFFFFFFF

Default

0x50000

CK (Configuration CRC)

Reads the cyclic redundancy check (CRC) of the current AT command configuration settings to determine if the configuration has changed.

After a firmware update this command may return a different value.

Parameter range

0 - 0xFFFF [read-only]

Default

N/A

FR (Software Reset)

Resets the device. The device responds immediately with an **OK** and performs a reset 100 ms later.

If you issue **FR** while the device is in Command mode, the reset effectively exits Command mode.

Parameter range

N/A

Default

N/A

Memory access commands

This section details the executable commands that provide memory access to the device.

AC (Apply Changes)

Immediately applies new settings without exiting Command mode.

Parameter range

N/A

Default

N/A

WR (Write)

Immediately writes parameter values to non-volatile flash memory so they persist through a power cycle. Operating network parameters are persistent and do not require a **WR** command for the device to reattach to the network.

Writing parameters to non-volatile memory does not apply the changes immediately. However, since the device uses non-volatile memory to determine initial configuration following reset, the written parameters are applied following a reset.

Note Once you issue a **WR** command, do not send any additional characters to the device until after you receive the **OK** response. Use the **WR** command sparingly; the device's flash supports a limited number of write cycles.

Parameter range

N/A

Default

N/A

RE (Restore Defaults)

Restore device parameters to factory defaults.

Parameter range

N/A

Default

N/A

Custom default commands

The following commands are used to assign custom defaults to the device. Send [RE \(Restore Defaults\)](#) to restore custom defaults. You must send these commands as local AT commands, they cannot be set using [Remote AT Command Request frame - 0x17](#).

%F (Set Custom Default)

When **%F** is received, the XBee3 DigiMesh RF Module takes the next command received and applies it to both the current configuration and the custom defaults, so that when defaults are restored with [RE \(Restore Defaults\)](#) the custom value is used.

Parameter range

N/A

Default

N/A

!C (Clear Custom Defaults)

Clears all custom defaults. This command does not change the current settings, but only changes the defaults so that [RE \(Restore Defaults\)](#) restores settings to the factory values.

Parameter range

N/A

Default

N/A

R1 (Restore Factory Defaults)

Restores factory defaults, ignoring any custom defaults set using [%F \(Set Custom Default\)](#).

Parameter range

N/A

Default

N/A

Operate in API mode

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API mode overview

As an alternative to Transparent operating mode, you can use API operating mode. API mode provides a structured interface where data is communicated through the serial interface in organized packets and in a determined order. This enables you to establish complex communication between devices without having to define your own protocol. The API specifies how commands, command responses and device status messages are sent and received from the device using the serial interface or the SPI interface.

We may add new frame types to future versions of the firmware, so we recommend building the ability to filter out additional API frames with unknown frame types into your software interface.

Use the AP command to set the operation mode

Use [AP \(API Enable\)](#) to specify the operation mode:

AP command setting	Description
AP = 0	Transparent operating mode, UART serial line replacement with API modes disabled. This is the default option.
AP = 1	API operation.
AP = 2	API operation with escaped characters (only possible on UART).

The API data frame structure differs depending on what mode you choose.

API frame format

An API frame consists of the following:

- Start delimiter
- Length
- Frame data
- Checksum

API operation (AP parameter = 1)

This is the recommended API mode for most applications. The following table shows the data frame structure when you enable this mode:

Frame fields	Byte	Description
Start delimiter	1	0x7E
Length	2 - 3	Most Significant Byte, Least Significant Byte
Frame data	4 - number (n)	API-specific structure
Checksum	n + 1	1 byte

Any data received prior to the start delimiter is silently discarded. If the frame is not received correctly or if the checksum fails, the XBee replies with a radio status frame indicating the nature of the failure.

API operation with escaped characters (AP parameter = 2)

Setting API to 2 allows escaped control characters in the API frame. Due to its increased complexity, we only recommend this API mode in specific circumstances. API 2 may help improve reliability if the serial interface to the device is unstable or malformed frames are frequently being generated.

When operating in API 2, if an unescaped 0x7E byte is observed, it is treated as the start of a new API frame and all data received prior to this delimiter is silently discarded. For more information on using this API mode, see the [Escaped Characters and API Mode 2](#) in the Digi Knowledge base.

API escaped operating mode works similarly to API mode. The only difference is that when working in API escaped mode, the software must escape any payload bytes that match API frame specific data, such as the start-of-frame byte (0x7E). The following table shows the structure of an API frame with escaped characters:

Frame fields	Byte	Description	
Start delimiter	1	0x7E	
Length	2 - 3	Most Significant Byte, Least Significant Byte	Characters escaped if needed
Frame data	4 - n	API-specific structure	
Checksum	n + 1	1 byte	

Start delimiter field

This field indicates the beginning of a frame. It is always 0x7E. This allows the device to easily detect a new incoming frame.

Escaped characters in API frames

If operating in API mode with escaped characters (**AP** parameter = 2), when sending or receiving a serial data frame, specific data values must be escaped (flagged) so they do not interfere with the data frame sequencing. To escape an interfering data byte, insert 0x7D and follow it with the byte to be escaped (XORed with 0x20).

The following data bytes need to be escaped:

- 0x7E: start delimiter
- 0x7D: escape character
- 0x11: XON
- 0x13: XOFF

To escape a character:

1. Insert 0x7D (escape character).
2. Append it with the byte you want to escape, XORed with 0x20.

In API mode with escaped characters, the length field does not include any escape characters in the frame and the firmware calculates the checksum with non-escaped data.

Example: escape an API frame

To express the following API non-escaped frame in API operating mode with escaped characters:

Start delimiter	Length	Frame type	Frame Data								Checksum						
			Data														
7E	00 0F	17	01	00	13	A2	00	40	AD	14	2E	FF	FE	02	4E	49	6D

You must escape the 0x13 byte:

1. Insert a 0x7D.
2. XOR byte 0x13 with 0x20: $13 \oplus 20 = 33$

The following figure shows the resulting frame. Note that the length and checksum are the same as the non-escaped frame.

Start delimiter	Length	Frame type	Frame Data											Checksum				
			Data															
7E	00 0F	17	01	00	7D	33	A2	00	40	AD	14	2E	FF	FE	02	4E	49	6D

The length field has a two-byte value that specifies the number of bytes in the frame data field. It does not include the checksum field.

Length field

The length field is a two-byte value that specifies the number of bytes contained in the frame data field. It does not include the checksum field.

Frame data

This field contains the information that a device receives or will transmit. The structure of frame data depends on the purpose of the API frame:

Start delimiter	Length		Frame data								Checksum
			Frame type	Data							
1	2	3	4	5	6	7	8	9	...	n	n+1
0x7E	MSB	LSB	API frame type	Data							Single byte

- **Frame type** is the API frame type identifier. It determines the type of API frame and indicates how the Data field organizes the information.
- **Data** contains the data itself. This information and its order depend on the what type of frame that the Frame type field defines.

Multi-byte values are sent big-endian.

Calculate and verify checksums

To calculate the checksum of an API frame:

1. Add all bytes of the packet, except the start delimiter 0x7E and the length (the second and third bytes).
2. Keep only the lowest 8 bits from the result.
3. Subtract this quantity from 0xFF.

To verify the checksum of an API frame:

1. Add all bytes including the checksum; do not include the delimiter and length.
2. If the checksum is correct, the last two digits on the far right of the sum equal 0xFF.

Example

Consider the following sample data packet: **7E 00 0A 01 01 50 01 00 48 65 6C 6C 6F B8+**

Byte(s)	Description
7E	Start delimiter
00 0A	Length bytes
01	API identifier
01	API frame ID
50 01	Destination address low
00	Option byte
48 65 6C 6C 6F	Data packet
B8	Checksum

To calculate the check sum you add all bytes of the packet, excluding the frame delimiter **7E** and the length (the second and third bytes):

7E 00 0A 01 01 50 01 00 48 65 6C 6C 6F B8

Add these hex bytes:

$$01 + 01 + 50 + 01 + 00 + 48 + 65 + 6C + 6C + 6F = 247$$

Now take the result of 0x247 and keep only the lowest 8 bits which in this example is 0xC4 (the two far right digits). Subtract 0x47 from 0xFF and you get 0x3B (0xFF - 0xC4 = 0x3B). 0x3B is the checksum for this data packet.

If an API data packet is composed with an incorrect checksum, the XBee3 DigiMesh RF Module will consider the packet invalid and will ignore the data.

To verify the check sum of an API packet add all bytes including the checksum (do not include the delimiter and length) and if correct, the last two far right digits of the sum will equal FF.

$$01 + 01 + 50 + 01 + 00 + 48 + 65 + 6C + 6C + 6F + B8 = 2FF$$

Frame descriptions

The following sections describe the API frames.

AT Command Frame - 0x08	169
AT Command - Queue Parameter Value frame - 0x09	171
Transmit Request frame - 0x10	173
Explicit Addressing Command frame - 0x11	176
Remote AT Command Request frame - 0x17	179
AT Command Response frame - 0x88	181
Modem Status frame - 0x8A	183
Transmit Status frame - 0x8B	184
Route Information Packet frame - 0x8D	186
Aggregate Addressing Update frame - 0x8E	189
Receive Packet frame - 0x90	191
Explicit Rx Indicator frame - 0x91	193
I/O Data Sample Rx Indicator frame - 0x92	196
Node Identification Indicator frame - 0x95	198
Remote Command Response frame - 0x97	202

AT Command Frame - 0x08

Description

Use this frame to query or set command parameters on the local device. This API command applies changes after running the command. You can query parameter values by sending the [AT Command Frame - 0x08](#) with no parameter value field (the two-byte AT command is immediately followed by the frame checksum). Any parameter that is set with this frame type will apply the change immediately. If you wish to queue multiple parameter changes and apply them later, use the [AT Command - Queue Parameter Value frame - 0x09](#) instead.

A [Transmit Status frame - 0x8B](#) response frame is populated with the parameter value that is currently set on the device.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x08
AT command	5-6	Command name: two ASCII characters that identify the AT command.
Parameter value	7-n	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the register.

Example

The following example illustrates an AT Command frame when you modify the device's **NH** parameter value.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x04
Frame type	3	0x08
Frame ID	4	0x52
AT command	5	0x4E (N)
	6	0x48 (H)

Frame data fields	Offset	Example
Parameter value (NH2 = two network hops)	7	0x02
Checksum	8	0x0D

AT Command - Queue Parameter Value frame - 0x09

Description

This frame allows you to query or set device parameters. In contrast to the AT Command (0x08) frame, this frame sets new parameter values and does not apply them until you issue either:

- The **AT** Command (0x08) frame
- The **AC** command

When querying parameter values, the 0x09 frame behaves identically to the 0x08 frame; the response for this command is also an **AT** Command Response frame (0x88).

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x09
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK. If set to 0 , the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the AT command.
Parameter value	7-n	If present, indicates the requested parameter value to set the given register. If no characters are present, queries the register.

Example

The following example sends a command to change the baud rate (**BD**) to 115200 baud, but does not apply the changes immediately. The device continues to operate at the previous baud rate until you apply the changes.

Note In this example, you could send the parameter as a zero-padded 2-byte or 4-byte value.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x05
Frame type	3	0x09

Frame data fields	Offset	Example
Frame ID	4	0x01
AT command	5	0x42 (B)
	6	0x44 (D)
Parameter value (BD7 = 115200 baud)	7	0x07
Checksum	8	0x68

Transmit Request frame - 0x10

Description

This frame causes the device to send payload data as an RF packet to a specific destination.

- For broadcast transmissions, set the 64-bit destination address to **0x000000000000FFFF**.
- For unicast transmissions, set the 64 bit address field to the address of the desired destination node.
- Set the reserved field to **0xFFFE**.
- Query the **NP** command to read the maximum number of payload bytes.

You can set the broadcast radius from **0** up to **NH**. If set to **0**, the value of **NH** specifies the broadcast radius (recommended). This parameter is only used for broadcast transmissions.

You can read the maximum number of payload bytes with the **NP** command.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x10
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK. If set to 0 , the device does not send a response.
64-bit destination address	5-12	MSB first, LSB last. Set to the 64-bit address of the destination device. Broadcast = 0x000000000000FFFF
Reserved	13-14	Set to 0xFFFE.
Broadcast radius	15	Sets the maximum number of hops a broadcast transmission can occur. If set to 0, the broadcast radius is set to the maximum hops value.
Transmit options	16	See the Transmit Options table below. Set all other bits to 0.
RF data	17-n	Up to NP bytes per packet. Sent to the destination device.

Transmit Options bit field

Bit field

Bit	Meaning	Description
0	Disable ACK	Disable acknowledgments on all unicasts
1	Disable RD	Disable Route Discovery on all DigiMesh unicasts
2	NACK	Enable unicast NACK messages on all DigiMesh API packets
3	Trace route	Enable a unicast Trace Route on all DigiMesh API packets
4	Reserved	<set this bit to 0>
5	Reserved	<set this bit to 0>
6,7	Delivery method	b'00 = <invalid option> b'01 = Point-multipoint (0x40) b'10 = Directed Broadcast (0x80) b'11 = DigiMesh (0xC0)

Example

The example shows how to send a transmission to a device if you disable escaping (**AP** = 1), with destination address 0x0013A200 400A0127, and payload "TxData0A".

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x16
Frame type	3	0x10
Frame ID	4	0x01
64-bit destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x0A
	11	0x01
	LSB 12	0x27
16-bit destination network address	MSB 13	0xFF
	LSB 14	0xFE
Broadcast radius	15	0x00

Frame data fields	Offset	Example
Options	16	0x00
RF data	17	0x54
	18	0x78
	19	0x44
	20	0x61
	21	0x74
	22	0x61
	23	0x30
	24	0x41
Checksum	25	0x13

If you enable escaping (**AP** = 2), the frame should look like:

0x7E 0x00 0x16 0x10 0x01 0x00 0x7D 0x33 0xA2 0x00 0x40 0x0A 0x01 0x27 0xFF 0xFE 0x00
 0x00 0x54 0x78 0x44 0x61 0x74 0x61 0x30 0x41 0x7D 0x33

The device calculates the checksum (on all non-escaped bytes) as [0xFF - (sum of all bytes from API frame type through data payload)].

Explicit Addressing Command frame - 0x11

Description

This frame is similar to Transmit Request (0x10), but it also requires you to specify the application-layer addressing fields: endpoints, cluster ID, and profile ID.

This frame causes the device to send payload data as an RF packet to a specific destination, using specific source and destination endpoints, cluster ID, and profile ID. These fields ignore the ones specified by **DE,SE** and **CI**.

- For broadcast transmissions, set the 64-bit destination address to **0x000000000000FFFF**.
- For unicast transmissions, set the 64 bit address field to the address of the desired destination node, otherwise set the 16-bit address field to the desired 16-bit destination.
- Set the reserved field to **0xFFFE**.

Query the **NP** command to read the maximum number of payload bytes. For more information, see [Diagnostics – Firmware/Hardware Information](#).

You can read the maximum number of payload bytes with the **NP** command.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x11
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK. If set to 0 , the device does not send a response.
64-bit destination Address	5-12	MSB first, LSB last. Set to the 64-bit address of the destination device. Broadcast = 0x000000000000FFFF
Reserved	13-14	Set to 0xFFFE .
Source Endpoint	15	Source Endpoint for the transmission.
Destination Endpoint	16	Destination Endpoint for the transmission.
Cluster ID	17-18	The Cluster ID that the host uses in the transmission.
Profile ID	19-20	The Profile ID that the host uses in the transmission.

Frame data fields	Offset	Description
Broadcast Radius	21	Sets the maximum number of hops a broadcast transmission can traverse. If set to 0, the transmission radius set to the network maximum hops value. If the broadcast radius exceeds the value of NH then the devices use the value of NH as the radius. Only broadcast transmissions use this parameter.
Transmission Options	22	See the Transmit Options table below. Set all other bits to 0.
Data Payload	23-n	Data that is sent to the destination device.

Transmit Options bit field

See [Bit field](#).

Example

The following example sends a data transmission to a device with:

- 64-bit address: 0x0013A200 01238400
- Source endpoint: 0xE8
- Destination endpoint: 0xE8
- Cluster ID: 0x11
- Profile ID: 0xC105
- Payload: TxData

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x1A
Frame type	3	0x11
Frame ID	4	0x01

Frame data fields	Offset	Example
64-bit destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x01
	10	0x23
	11	0x84
	LSB12	0x00
Reserved	13	0xFF
	14	0xFE
Source endpoint	15	0xE8
Destination endpoint	16	0xE8
Cluster ID	17	0x00
	18	0x11
Profile ID	19	0xC1
	20	0x05
Broadcast radius	21	0x00
Transmit options	22	0x00
Data payload	23	0x54
	24	0x78
	25	0x44
	26	0x61
	27	0x74
	28	0x61
Checksum	29	0xA6

Remote AT Command Request frame - 0x17

Description

Used to query or set device parameters on a remote device. For parameter changes on the remote device to take effect, you must apply changes, either by setting the Apply Changes options bit, or by sending an **AC** command to the remote.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x17
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK. If set to 0 , the device does not send a response.
64-bit destination address	5-12	MSB first, LSB last. Set to the 64-bit address of the destination device.
Reserved	13-14	Set to 0xFFFE.
Remote command options	15	0x02 = Apply changes on remote. If you do not set this, you must send the AC command for changes to take effect. Set all other bits to 0.
AT command	16-17	Command name: two ASCII characters that identify the command.
Command parameter	18-n	If present, indicates the parameter value you request for a given register. If no characters are present, it queries the register. Numeric parameter values are given in binary format.

Example

The following example sends a remote command:

- Change the broadcast hops register on a remote device to 1 (broadcasts go to 1-hop neighbors only).
- Apply changes so the new configuration value takes effect immediately.

In this example, the 64-bit address of the remote device is 0x0013A200 40401122.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x10
Frame type	3	0x17
Frame ID	4	0x01
64-bit destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x40
	11	0x11
	LSB 12	0x22
Reserved	13	0xFF
	14	0xFE
Remote command options	15	0x02 (apply changes)
AT command	16	0x42 (B)
	17	0x48 (H)
Command parameter	18	0x01
Checksum	19	0xF5

AT Command Response frame - 0x88

Description

A device sends this frame in response to an AT Command (0x08 or 0x09) frame. Some commands send back multiple frames; for example, the **ND** command.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x88
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK. If set to 0 , the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the command.
Command status	7	0 = OK 1 = ERROR 2 = Invalid command 3 = Invalid parameter 4 = Tx failure
Command data		The register data in binary format. If the host sets the register, the device does not return this field.

Example

If you change the **BD** parameter on a local device with a frame ID of 0x01, and the parameter is valid, the user receives the following response.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x05
Frame type	3	0x88
Frame ID	4	0x01

Frame data fields	Offset	Example
AT command	5	0x42 (B)
	6	0x44 (D)
Command status	7	0x00
Command data		(No command data implies the parameter was set rather than queried)
Checksum	8	0xF0

Modem Status frame - 0x8A

Description

Devices send the status messages in this frame in response to specific conditions.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x8A
Status	4	0x00 = Hardware reset 0x01 = Watchdog timer reset 0x02 = End device successfully associated with a coordinator 0x03 = End device disassociated from coordinator or coordinator failed to form a new network 0x06 = End device successfully associated with a coordinator 0x0B = Network woke up 0x0C = Network went to sleep 0x0D Input voltage is too high

Example

When a device powers up, it returns the following API frame.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
LSB 2	LSB 2	0x02
Frame type	3	0x8A
Status	4	0x00
Checksum	5	0x75

Transmit Status frame - 0x8B

Description

When a Transmit Request (0x10, 0x11) completes, the device sends an 0x8B Transmit Status message out of the serial interface. This message indicates if the Transmit Request was successful or if it failed.

Note Broadcast transmissions are not acknowledged and always return a status of 0x00, even if the delivery failed.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x8B
Frame ID	4	The Frame ID of the response will be the same value that was used in the originating Tx request.
16-bit destination address	5	The 16-bit Network Address where the packet was delivered (if successful). If not successful, this address is 0xFFFF (destination address unknown).
	6	
Transmit retry count	7	The number of application transmission retries that occur.
Delivery status	8	0x00 = Success 0x01 = MAC ACK Failure 0x02 = Collision avoidance failure 0x21 = Network ACK Failure 0x25 = Route not found 0x31 = Internal resource error 0x32 = Internal error 0x74 = Data payload too large 0x75 = Indirect message unrequested
Discovery status	9	0x00 = No discovery overhead 0x02 = Route discovery

Example

In the following example, the destination device reports a successful unicast data transmission successful and a route discovery occurred. The outgoing Transmit Request that this response frame came from uses Frame ID of 0x47.

Frame Fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x07
Frame type	3	0x8B
Frame ID	4	0x47
Reserved	5	0xFF
	6	0xFE
Transmit retry count	7	0x00
Delivery status	8	0x00
Discovery status	9	0x02
Checksum	10	0x2E

Route Information Packet frame - 0x8D

Description

If you enable NACK or the Trace Route option on a DigiMesh unicast transmission, a device can output this frame for the transmission.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x8D
Source event	4	0x11 = NACK 0x12 = Trace route
Length	5	The number of bytes that follow, excluding the checksum. If the length increases, new items have been added to the end of the list for future revisions.
Timestamp	6-9	System timer value on the node generating the Route Information Packet. The timestamp is in microseconds. Only use this value for relative time measurements because the time stamp count restarts approximately every hour.
ACK timeout count	10	The number of MAC ACK timeouts that occur.
TX blocked count	11	The number of times the transmission was blocked due to reception in progress.
Reserved	12	Reserved, set to 0s.
Destination address	13-20	The address of the final destination node of this network-level transmission.
Source address	21-28	Address of the source node of this network-level transmission.
Responder address	29-36	Address of the node that generates this Route Information packet after it sends (or attempts to send) the packet to the next hop (the Receiver node).
Successor address	37-44	Address of the next node after the responder in the route towards the destination, whether or not the packet arrived successfully at the successor node.

Example

The following example represents a possible Route Information Packet. A device receives the packet when it performs a trace route on a transmission from one device (serial number 0x0013A200 4052AAAA) to another (serial number 0x0013A200 4052DDDD).

This particular frame indicates that the network successfully forwards the transmission from one device (serial number 0x0013A200 4052BBBB) to another device (serial number 0x0013A200 4052CCCC).

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x2A
Frame type	3	0x8D
Source event	4	0x12
Length	5	0x27 0x2B
Timestamp	MSB 6	0x9C
	7	0x93
	8	0x81
	LSB 9	0x7F
ACK timeout count	10	0x00
TX blocked count	11	0x00
Reserved	12	0x00
Destination address	MSB 13	0x00
	14	0x13
	15	0xA2
	16	0x00
	17	0x40
	18	0x52
	19	0xAA
	LSB 20	0xAA

Frame data fields	Offset	Example
Source address	MSB 21	0x00
	22	0x13
	23	0xA2
	24	0x00
	25	0x40
	26	0x52
	27	0xDD
	LSB 28	0xDD
Responder address	MSB 29	0x00
	30	0x13
	31	0xA2
	32	0x00
	33	0x40
	34	0x52
	35	0xBB
	LSB 36	0xBB
Successor address	MSB 37	0x00
	38	0x13
	39	0xA2
	40	0x00
	41	0x40
	42	0x52
	43	0xCC
	LSB 44	0xCC
Checksum	45	0xD2

Aggregate Addressing Update frame - 0x8E

Description

The device sends out an Aggregate Addressing Update frame on the serial interface of an API-enabled node when an address update frame (generated by the **AG** command being issued on a node in the network) causes the node to update its **DH** and **DL** registers.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x8E
Format ID	4	Byte reserved to indicate the format of additional packet information which may be added in future firmware revisions. In the current firmware revision, this field returns 0x00.
New address	5-12	Address to which DH and DL are being set.
Old address	13-20	Address to which DH and DL were previously set.

Example

In the following example, a device with destination address (**DH/DL**) of 0x0013A200 4052AAAA updates its destination address to 0x0013A200 4052BBBB.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x12
Frame type	3	0x8E
Format ID	4	0x00

Frame data fields	Offset	Example
New address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x52
	11	0xBB
	LSB 12	0xBB
Old address	13	0x00
	14	0x13
	15	0xA2
	16	0x00
	17	0x40
	18	0x52
	19	0xAA
	20	0xAA
Checksum	21	0x19

Receive Packet frame - 0x90

Description

When a device configured with a standard API Rx Indicator (**AO (API Options) = 0**) receives an RF data packet, it sends it out the serial interface using this message type.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description	
Frame type	3	0x90	
64-bit source address	4-11	The sender's 64-bit address. MSB first, LSB last.	
Reserved	12-13	16-bit source address.	
Receive options	14	Bit	Interpretation
		0	Packet acknowledged
		1	Broadcast packet
		2 - 5	Reserved
		6 - 7	Delivery mode:
			b 00 Invalid
b 01 Point-to-multipoint			
b 10 Repeater mode			
		b 11 DigiMesh	
Received data	15 - n	The RF data the device receives.	

Example

In the following example, a device with a 64-bit address of 0x0013A200 40522BAA sends a unicast data transmission to a remote device with payload RxData. If **AO = 0** on the receiving device, it sends the following frame out its serial interface.

Frame data fields	Offset	Example
Start delimiter	0	0x7E

Frame data fields	Offset	Example
Length	MSB 1	0x00
	LSB 2	0x12
Frame type	3	0x90
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x52
	10	0x2B
	LSB 11	0xAA
Reserved	12	0xFF
	13	0xFE
Receive options	14	0x01
Received data	15	0x52
	16	0x78
	17	0x44
	18	0x61
	19	0x74
	20	0x61
Checksum	21	0x11

Explicit Rx Indicator frame - 0x91

Description

When a device configured with explicit API Rx Indicator ([AO \(API Options\)](#) = 1) receives an RF packet, it sends it out the serial interface using this message type.

Note The values of the fields in the 0x91 frame (for example, endpoints and cluster ID) depend on the values sent by the initiator. If the initiator sends a [Transmit Request frame - 0x10](#) (which does not specify endpoints and cluster IDs), then the initiator sends the values configured in [DE command](#), [SE command](#), and [CI \(Cluster ID\)](#) instead.

The Cluster ID and endpoints must be used to identify the type of transaction that occurred.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x91
64-bit source address	4-11	MSB first, LSB last. The sender's 64-bit address.
Reserved	12-13	16-bit source address.
Source endpoint	14	Endpoint of the source that initiates transmission.
Destination endpoint	15	Endpoint of the destination where the message is addressed.
Cluster ID	16-17	The Cluster ID where the frame is addressed.
Profile ID	18-19	The Profile ID where the fame is addressed.
Receive options	20	Bit field: 0x00 = Packet acknowledged 0x01 = Packet was a broadcast packet 0x06, 0x07: b'01 = Point-Multipoint b'10 = Repeater mode (directed broadcast) b'11 = DigiMesh Ignore all other bits.
Received data	21-n	Received RF data.

Example

In the following example, a device with a 64-bit address of 0x0013A200 40522BAA sends a broadcast data transmission to a remote device with payload RxData.

If a device sends the transmission:

- With source and destination endpoints of 0xE0
- Cluster ID = 0x2211
- Profile ID = 0xC105

If **AO = 1** on the receiving device, it sends the following frame out its serial interface.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x18
Frame type	3	0x91
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x52
	10	0x2B
	LSB 11	0xAA
Reserved	12	0xFF
	13	0xFE
Source endpoint	14	0xE0
Destination endpoint	15	0xE0
Cluster ID	16	0x22
	17	0x11
Profile ID	18	0xC1
	19	0x05
Receive options	20	0x02

Frame data fields	Offset	Example
Received data	21	0x52
	22	0x78
	23	0x44
	24	0x61
	25	0x74
	26	0x61
Checksum	27	0x68

I/O Data Sample Rx Indicator frame - 0x92

Description

When you enable periodic I/O sampling or digital I/O change detection on a remote device, the UART of the device that receives the sample data sends this frame out.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x92
64-bit source address	4-11	The sender's 64-bit address.
Reserved	12-13	Reserved.
Receive options	14	Bit field: 0x01 = Packet acknowledged 0x02 = Packet is a broadcast packet Ignore all other bits
Number of samples	15	The number of sample sets included in the payload. Always set to 1.
Digital channel mask	16-17	Bitmask field that indicates which digital I/O lines on the remote have sampling enabled, if any.
Analog channel mask	18	Bitmask field that indicates which analog I/O lines on the remote have sampling enabled, if any.
Digital samples (if included)	19-20	If the sample set includes any digital I/O lines (Digital channel mask > 0), these two bytes contain samples for all enabled digital I/O lines. DIO lines that do not have sampling enabled return 0. Bits in these two bytes map the same as they do in the Digital channel mask field.
Analog sample	21-n	If the sample set includes any analog I/O lines (Analog channel mask > 0), each enabled analog input returns a 2-byte value indicating the A/D measurement of that input. Analog samples are ordered sequentially from ADO/DIO0 to AD3/DIO3.

Example

In the following example, the device receives an I/O sample from a device with a 64-bit serial number of 0x0013A20040522BAA.

The configuration of the transmitting device takes a digital sample of a number of digital I/O lines and an analog sample of AD1. It reads the digital lines to be 0x0014 and the analog sample value is 0x0225.

The complete example frame is:

```
7E00 1492 0013 A200 4052 2BAA FFFE 0101 001C 0200 1402 25F9
```

Frame fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x14
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x52
	10	0x2B
	LSB 11	0xAA
Reserved	MSB 12	0xFF
	LSB 13	0xFE
Receive options	14	0x01
Number of samples	15	0x01
Digital channel mask	16	0x00
	17	0x1C
Analog channel mask	18	0x02
Digital samples (if included)	19	0x00
	20	0x14
Analog sample	21	0x02
	22	0x25
Checksum	23	0xF5

Node Identification Indicator frame - 0x95

Description

A device receives this frame when:

- it transmits a node identification message to identify itself
- **AO = 0**. If **AO = 1**, then the node identification indicator is produced as a [Explicit Rx Indicator frame - 0x91](#).

The data portion of this frame is similar to a network discovery response. For more information, see [ND \(Network Discover\)](#).

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description	
Frame type	3	0x95	
64-bit source address	4-11	MSB first, LSB last. The sender's 64-bit address.	
Reserved	12-13	Reserved	
Receive options	14	Bit	Interpretation
		0	Packet acknowledged
		1	Broadcast packet
		2 - 5	Reserved
		6 - 7	Delivery mode:
			b 00 Invalid
			b 01 Point-to-multipoint
b 10 Repeater mode			
	b 11 DigiMesh		
Reserved	15-16	Reserved	
64-bit remote address	17-24	Indicates the 64-bit address of the remote device that transmitted the Node Identification Indicator frame.	

Frame data fields	Offset	Description
NI string	25-26	Node identifier string on the remote device. The NI string is terminated with a NULL byte (0x00).
Reserved	27-28	Reserved
Device type	29	0 = Coordinator 1 = Normal Mode 2 = End Device For more options, see NO (Network Discovery Options)
Source event	30	1 = Frame sent by node identification pushbutton event - see D0 (DIO0/ADC0/Commissioning Configuration)
Digi Profile ID	31-32	Set to the Digi application profile ID
Digi Manufacturer ID	33-34	Set to the Digi Manufacturer ID
Digi DD value (optional)	35-38	Reports the DD value of the responding device. Use the NO command to enable this field.
RSSI (optional)	39	Received signal strength indicator. Use the NO command to enable this field.

Example

If you press the commissioning pushbutton on a remote device with 64-bit address 0x0013A200407402AC and a default **NI** string sends a Node Identification, all devices on the network receive the following node identification indicator:

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x25
Frame type	3	0x95

Frame data fields	Offset	Example
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x74
	10	0x02
	LSB 11	0xAC
Reserved	12	0xFF
	13	0xFE
Receive options	14	0xC2
Reserved	15	0xFF
	16	0xFE
64-bit remote address	MSB 17	0x00
	18	0x13
	19	0xA2
	20	0x00
	21	0x40
	22	0x74
	23	0x02
	LSB 24	0xAC
NI string	25	0x20
	26	0x00
Reserved	27	0xFF
	28	0xFE
Device type	29	0x01
Source event	30	0x01
Digi Profile ID	31	0xC1
	32	0x05

Frame data fields	Offset	Example
Digi Manufacturer ID	33	0x10
	34	0x1E
Digi DD value (optional)	35	0x00
	36	0x0C
	37	0x00
	38	0x00
RSSI (optional)	39	0x2E
Checksum	40	0x33

Remote Command Response frame - 0x97

Description

If a device receives this frame in response to a Remote Command Request (0x17) frame, the device sends an AT Command Response (0x97) frame out the serial interface.

Some commands, such as the **ND** command, may send back multiple frames.

Format

The following table provides the contents of the frame. For details on frame structure, see [API frame format](#).

Frame data fields	Offset	Description
Frame type	3	0x97
Frame ID	4	This is the same value that is passed into the request.
64-bit source (remote) address	5-12	The address of the remote device returning this response.
Reserved	13-14	Reserved.
AT commands	15-16	The name of the command.
Command status	17	0 = OK 1 = ERROR 2 = Invalid Command 3 = Invalid Parameter
Command data	18-n	The value of the requested register.

Example

If a device sends a remote command to a remote device with 64-bit address 0x0013A200 40522BAA to query the **SL** command, and if the frame ID = 0x55, the response would look like the following example.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x13
Frame type	3	0x97
Frame ID	4	0x55

Frame data fields	Offset	Example
64-bit source (remote) address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x52
	11	0x2B
	LSB 12	0xAA
Reserved	13	0xFF
	14	0xFE
AT commands	15	0x53 (S)
	16	0x4C (L)
Command status	17	0x00
Command data	18	0x40
	19	0x52
	20	0x2B
	21	0xAA
Checksum	22	0xF4

Over-the-air firmware/file system upgrade process for DigiMesh 2.4

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OTA upgrade image file formats

OTA/OTB file

The .ota file extension represents a file which contains an OTA firmware upgrade image. The .otb file extension represents a file which contains an OTA combined upgrade image containing both the bootloader and the firmware. However, the way the XBee3 DigiMesh RF Module processes both the files remain the same.

fs.ota file

The .fs.ota file extension represents an over-the-air MicroPython file system upgrade image. The XBee3 DigiMesh RF Module processes these files differently as compared to OTA/OTB files.

The over-the-air file system upgrade process is explained in detail in [OTA file system upgrades](#).

The OTA header

The OTA firmware uses a specific firmware file with a .ota extension. We recommend parsing the OTA header from the OTA file first to obtain the firmware version, manufacturer code, image type and the size of the GBL file. These parameters are required to generate the rest of the OTA firmware upgrade messages.

Note All fields in the OTA header with the exception of the OTA Header String are in little-endian format.

The format of the OTA header is:

Bytes	Field name	Description
4	OTA upgrade file identifier	Has to match 0x0BEEF11E in little endian. If it is not, then the OTA file is not a valid upgrade file.
2	OTA Header version	0x0001
2	OTA Header length	Length of the OTA Header including any optional fields used.
2	OTA Header Field control	Bit mask that indicates if additional information is included in the image. See the last three fields in this table.
2	Manufacturer Code	0x101E
2	Image Type	0x0000 for a firmware upgrade, or 0x0100 for a file system update.
4	File Version	For firmware upgrades, the version of the upgrade. For file system upgrades, the firmware version used to create the image.
2	Stack Version	This is set to 2 by default.
32	OTA Header String	An ascii string that can contain a human-readable description of the file.

Bytes	Field name	Description
4	Image Size	The number of bytes that will be transferred over the air. This is usually the size of the image contained in the file.
0/1	Security Credential version	Included if bit 0 of OTA Header Field Control is set. This indicates the security credential version type that the client is required to have, before it will install the image (set to 2).
0/8	Upgrade File Destination	Included if bit 1 of OTA Header Field Control is set. This indicates that this OTA file contains security credential/certificate 577 data or other type of information that is specific to a particular device. Currently, we do not use this feature.
0/2	Minimum Hardware Version	Included if bit 2 of OTA Header Field Control is set. This is the minimum hardware version that can use this file.
0/2	Maximum Hardware Version	Included if bit 2 of OTA Header Field Control is set. This is the maximum hardware version that can use this file. Currently, we do not use this feature.

For OTA firmware update images, the file version field contains additional hardware/software compatibility information. We recommend that if you intend to perform an OTA update, you use the OTA header extracted from the file so that you can avoid undesired behavior.

Hardware/software compatibility

The Hardware Software Compatibility number ensures that an incompatible firmware is not flashed on to the XBee3 DigiMesh RF Module. To obtain this value, query [%C \(Hardware/Software Compatibility\)](#) on the target device. You can successfully update the device to a firmware if, and only if, the value in the Minimum Hardware Version field of the OTA header is equal to or less than the value obtained by querying [%C](#) on the device.

Sub-elements and tags

All data after the OTA header is organized into sub-elements. Most OTA files will contain a single sub-element: the upgrade image. Sub-elements are arranged as tag-length-value sets, as shown in the table below.

Bytes	Field name	Description
2	Sub-element Tag	The tag for the sub-element, in little-endian format. This is usually 0x0000 for 'upgrade image' (this is the case for both firmware upgrades and file system updates).
4	Sub-element length	The length of the sub-element data (n) in little-endian format.
n	Sub-element data	The data to be transferred.

Parse the image blocks

To parse the image blocks:

1. Divide the contents of the OTA payload into 48 byte blocks for encrypted networks and 56 byte blocks for unencrypted networks
2. Create Image Block Requests around the image blocks; see [Image Block request](#).

Note The payload data starts after the OTA header and the first sub-element tag/length. The offset of the payload data can be found by taking the OTA header length from the OTA header and adding 6 for the sub-element tag and length.

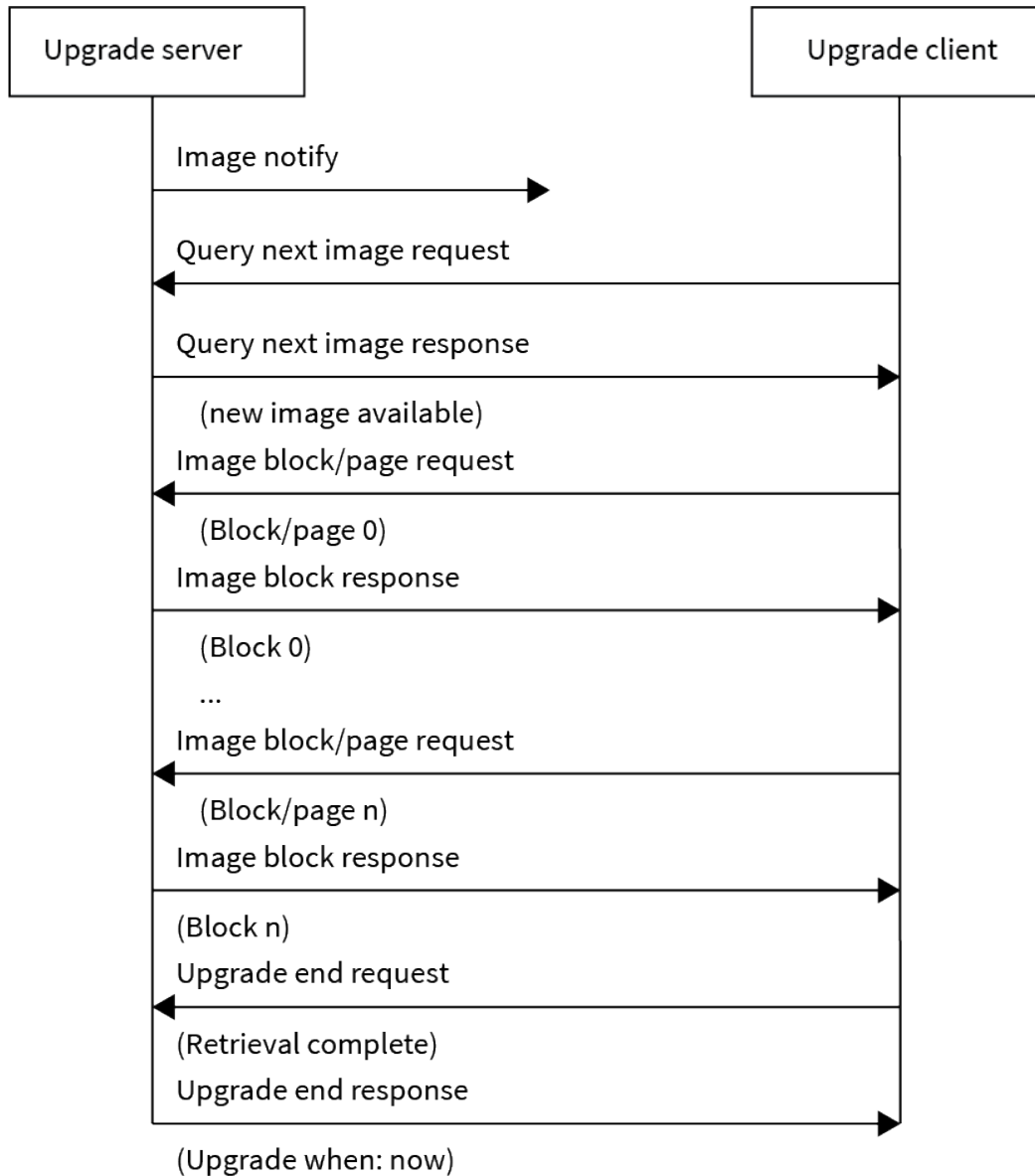
Storage

The OTA firmware image blocks are received and stored in a separate internal flash slot that is allotted exclusively for this purpose. Once all the image bytes are written to the slot, the new image must be validated by the current application before it can be used.

If the new image is deemed invalid, the running DigiMesh firmware rejects the image and continues operating with the current, valid application.

ZCL OTA messaging

The following figure provides the messaging sequence between the Server (updater node) and the Client (target node).



ZCL message output

By default ZCL messages are not printed to the UART on the client. To see these messages, set [AZ \(Extended API Options\)](#) to 2. ZCL messages received by the server are always printed to the UART.

Image Notify

The server sends the Image Notify message to the client informing the device of the presence of an update image. The Image Notify message is sent when the upgrade process is initiated from the server.

Create the Image Notify request

The Image Notify Request is an explicit transmit frame (0x11 type) passed into the server with the following information:

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x21	
Frame Type	3	0x11	
Frame ID	4	0x01	
64-bit destination address	MSB 5	0x00	
	6	0x13	
	7	0xA2	
	8	0xFE	
	9	0x00	
	10	0x00	
	11	0x00	
	LSB 12	0x03	
16-bit destination address	MSB 13	0x28	
	LSB 14	0x2F	
Source Endpoint	15	0xE8	
Destination Endpoint	16	0xE8	
Cluster ID	MSB 17	0x00	
	LSB 18	0x19	
Profile ID	MSB 19	0xC1	
	LSB 20	0x05	
Broadcast radius	21	0x00	
Transmit options	22	0x00	

Frame data fields			Offset	Example	Comments
Data payload	ZCL frame header	Frame control	23	0x09	
		Transaction sequence number	24	0x01	
	ZCL payload	Command ID	25	0x00	Image Notify Command ID
		Payload type	26	0x03	Contains Jitter, Image Type, Firmware Version
		Query jitter	27	0x00	
		Manufacturer ID	LSB 28	0x1E	Digi's Manufacturer ID in little-endian
			MSB 29	0x10	
		Image type	LSB 30	0x00	0x0000 - OTA/OTB file 0x0100 - OTA file system image
			MSB 31	0x00	
		Firmware version	LSB 32	0x01	Firmware version of the update file. This should be the version parsed out of the OTA header, in little-endian format.
			33	0x10	
			34	0x00	
MSB 35	0x00				
Checksum			36	0xE5	

Query Next Image request

The client device sends the Query Next Image request message to the server to indicate it is ready to receive a firmware image and is sent as a response to an Image Notify message. The client sends information about the existing firmware version as a part of this message. The server emits the following frame after receiving the request from the client:

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x1E	
Frame Type	3	0x91	
64-bit source address	MSB 4	0x00	
	5	0x13	
	6	0xA2	
	7	0xFE	
	8	0x00	
	9	0x00	
	10	0x00	
	LSB 11	0x03	
16-bit source address	MSB 12	0x28	
	LSB 13	0x2F	
Source Endpoint	14	0xE8	
Destination Endpoint	15	0xE8	
Cluster ID	MSB 16	0x00	
	LSB 17	0x19	
Profile ID	MSB 18	0xC1	
	LSB 19	0x05	
Receive options	20	0x01	

Frame data fields			Offset	Example	Comments
Data payload	ZCL frame header	Frame control	21	0x01	
		Transaction sequence number	22	0x00	
	ZCL payload	Command ID	23	0x01	Query Next Image request
		Field control	24	0x00	
		Manufacturer ID	LSB 25	0x1E	
			MSB 26	0x10	
		Image type	LSB 27	0x00	
			MSB 28	0x00	
		Firmware version	LSB 29	0x00	
			30	0x10	
			31	0x00	
			MSB 32	0x00	
		Checksum			33

Query Next Image response

The server obtains the information sent by the Client in the Query Next Image request and determines if it has a suitable image for the client. It then sends a Query Next Image response with one of the following status messages as appropriate:

- 0x00 - SUCCESS: The server is authorized to upgrade the client with the image.
- 0x98 - NO_IMAGE_AVAILABLE: The server is authorized to update the client but does not have a new OTA update image available.
- 0x7E - NOT_AUTHORIZED: The server is not authorized to update the client.

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x24	
Frame Type	3	0x11	
Frame ID	4	0x01	
64-bit destination address	MSB 5	0x00	
	6	0x13	
	7	0xA2	
	8	0xFE	
	9	0x00	
	10	0x00	
	11	0x00	
	LSB 12	0x03	
16-bit destination address	MSB 13	0x28	
	LSB 14	0x2F	
Source Endpoint	15	0xE8	
Destination Endpoint	16	0xE8	
Cluster ID	MSB 17	0x00	
	LSB 18	0x19	

Frame data fields			Offset	Example	Comments
Profile ID			MSB 19	0xC1	
			LSB 20	0x05	
Broadcast radius			21	0x00	
Transmit options			22	0x00	
Data payload	ZCL frame header	Frame control	23	0x09	
		Transaction sequence number	24	0x01	
	ZCL payload	Command ID	25	0x02	Query Next Image Response
		Status	26	0x00	Success = 0x00 No Image Available = 0x98 Not Authorized = 0x7E
		Manufacturer ID	LSB 27	0x1E	
			MSB 28	0x10	
		Image type	LSB 29	0x00	0x0000 - OTA/OTB file 0x0100 - OTA file system image
			MSB 30	0x00	
		Firmware version	LSB 31	0x01	
			32	0x10	
			33	0x00	
			MSB 34	0x00	
		Image Size	LSB 35	0x2E	This is the total number of bytes that will be transferred - it is usually the size of the image.
			36	0xF3	
			37	0x02	
MSB 38	0x00				
Checksum			39	0xE5	

Image Block request

The Client generates Image Block requests to request the server for bytes of the OTA firmware image. Each image block is 64 byte long. The client also sends the file offset as a way to keep the synchronization of every block intact.

The Image Block requests are repeated by the client until all the blocks of the image are successfully obtained. The size of the OTA upgrade image is usually obtained by the client in the Query Next Image response message and hence it knows the exact number of Image Block requests it needs to send.

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x1E	
Frame Type	3	0x91	
64-bit source address	MSB 4	0x00	
	5	0x13	
	6	0xA2	
	7	0xFE	
	8	0x00	
	9	0x00	
	10	0x00	
	LSB 11	0x03	
16-bit source address	MSB 12	0x28	
	LSB 13	0x2F	
Source Endpoint	14	0xE8	
Destination Endpoint	15	0xE8	
Cluster ID	MSB 16	0x00	
	LSB 17	0x19	

Frame data fields			Offset	Example	Comments
Profile ID			MSB 18	0xC1	
			LSB 19	0x05	
Receive options			20	0x01	
Data payload	ZCL frame header	Frame control	21	0x01	
		Transaction sequence number	22	0x01	
Data payload	ZCL payload	Command ID	23	0x03	Image Block Request
		Field control	24	0x00	
		Manufacturer ID	LSB 25	0x1E	
			MSB 26	0x10	
		Image type	LSB 27	0x00	0x0000 - OTA/OTB file 0x0100 - OTA file system image
			MSB 28	0x00	
		Firmware version	LSB 29	0x01	
			30	0x10	
			31	0x00	
			MSB 32	0x00	
		File Offset	LSB 33	0x00	0x0 for the first request. Offset by multiples of Image Block size. For example, 0x00000000 for the first request, 0x00000040, 0x00000080 and so on.
			34	0x00	
			35	0x00	
LSB 36	0x00				
Image Block Size		37	0x40	0x30 for encrypted networks 0x38 for unencrypted networks	
Checksum			38	0x2D	

Image Block response

The server generates an Image Block response upon receiving an Image Block request command. It responds with a SUCCESS status on being able to retrieve the data for the client. The server uses the file offset sent by the client to determine the location of the requested data within the OTA upgrade image.

If you wish to cancel the update process, send an ABORT (0x95) status.

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x65	
Frame Type	3	0x11	
Frame ID	4	0x01	
64-bit destination address	MSB 5	0x00	
	6	0x13	
	7	0xA2	
	8	0xFE	
	9	0x00	
	10	0x00	
	11	0x00	
	LSB 12	0x03	
16-bit destination address	MSB 13	0x28	
	LSB 14	0x2F	
Source Endpoint	15	0xE8	
Destination Endpoint	16	0xE8	
Cluster ID	MSB 17	0x00	
	LSB 18	0x19	

Frame data fields			Offset	Example	Comments
Profile ID			MSB 19	0xC1	
			LSB 20	0x05	
Broadcast radius			21	0x00	
Transmit options			22	0x00	
Data payload	ZCL frame header	Frame control	23	0x09	
Data payload		Transaction sequence number	24	0x02	
Data payload	ZCL payload	Command ID	25	0x05	Image Block Response
Data payload	ZCL payload	Status	26	0x00	Success = 0x00 Abort = 0x95
Data payload	ZCL payload	Manufacturer ID	LSB 27	0x1E	
Data payload			MSB 28	0x10	
Data payload	ZCL payload	Image type	LSB 29	0x00	0x0000 - OTA/OTB file 0x0100 - OTA file system image
Data payload			MSB 30	0x00	
Data payload	ZCL payload	Firmware version	LSB 31	0x01	
Data payload			32	0x10	
Data payload			33	0x00	
Data payload			MSB 34	0x00	

Frame data fields			Offset	Example	Comments
Data payload	ZCL payload	File Offset	LSB 35	0x00	
Data payload	ZCL payload		36	0x00	
Data payload	ZCL payload		37	0x00	
Data payload	ZCL payload		MSB 38	0x00	
Data payload	ZCL payload	Image Block Size	39	0x40	64 byte blocks 48 byte blocks for encrypted networks 56 byte blocks for unencrypted networks
Data payload	ZCL payload	Image Block Data	40- 104	0xEB- 0x00	An image block of the size mentioned in Image Block Size
Checksum			106	0x4E	

Upgrade End request

The Upgrade End request is generated by the client after it verifies the received firmware image to ensure its integrity and validity. If the image fails any integrity checks, the client sends an Upgrade End request command to the upgrade server with INVALID_IMAGE as the status. If the image passes all integrity checks, the client sends an Upgrade End request command to the upgrade server with SUCCESS as the status.

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x1E	
Frame Type	3	0x91	
64-bit source address	MSB 4	0x00	
	5	0x13	
	6	0xA2	
	7	0xFE	
	8	0x00	
	9	0x00	
	10	0x00	
	LSB 11	0x03	
16-bit source address	MSB 12	0x28	
	LSB 13	0x2F	
Source Endpoint	14	0xE8	
Destination Endpoint	15	0xE8	
Cluster ID	MSB 16	0x00	
	LSB 17	0x19	
Profile ID	MSB 18	0xC1	
	LSB 19	0x05	

Frame data fields			Offset	Example	Comments
Receive options			20	0x01	
Data payload	ZCL frame header	Frame control	21	0x01	
		Transaction sequence number	22	0x30	
	ZCL payload	Command ID	23	0x06	Upgrade End Request
		Status	24	0x00	Success = 0x00 Invalid Image = 0x96 Abort = 0x95 Require More Image = 0x99
		Manufacturer ID	LSB 25	0x1E	
			MSB 26	0x10	
		Image type	LSB 27	0x00	0x0000 - OTA/OTB file 0x0100 - OTA file system image
			MSB 28	0x00	
		Firmware version	LSB 29	0x01	
			30	0x10	
	31		0x00		
	MSB 32		0x00		
Checksum			38	0x3B	

Upgrade End response

If the server receives an Upgrade End request with a SUCCESS status, it generates an Upgrade End response along with the time at which the device should upgrade to the new image.

Frame data fields	Offset	Example	Comments
Start delimiter	0	0x7E	
Length	MSB 1	0x00	
	LSB 2	0x24	
Frame Type	3	0x11	
Frame ID	4	0x01	
64-bit destination address	MSB 5	0x00	
	6	0x13	
	7	0xA2	
	8	0xFE	
	9	0x00	
	10	0x00	
	11	0x00	
	LSB 12	0x03	
16-bit destination address	MSB 13	0x28	
	LSB 14	0x2F	
Source Endpoint	15	0xE8	
Destination Endpoint	16	0xE8	
Cluster ID	MSB 17	0x00	
	LSB 18	0x19	
Profile ID	MSB 19	0xC1	
	LSB 20	0x05	
Broadcast radius	21	0x00	

Frame data fields			Offset	Example	Comments
Transmit options			22	0x00	
Data payload	ZCL frame header	Frame control	23	0x09	
		Transaction sequence number	24	0x01	
	ZCL payload	Command ID	25	0x07	Upgrade End response
		Manufacturer ID	LSB 26	0x1E	
			MSB 27	0x10	
		Image type	LSB 28	0x00	0x0000 - OTA/OTB file 0x0100 - OTA file system image
			MSB 29	0x00	
		Firmware version	LSB 30	0x01	
			31	0x10	
			32	0x00	
			MSB 33	0x00	
		Current Time	LSB 34	0xF0	32 bit unsigned integer Seconds since Epoch (currently unused)
			35	0x1A	
			36	0x53	
			MSB 37	0x21	
		Upgrade Time	LSB38	0x00	This field is not currently supported—it will be ignored by the device and the device will upgrade immediately.
39	0x1B				
40	0x53				
MSB 41	0x21				
Checksum			38	0xE5	

OTA error handling

ZCL OTA status code	Value	Description
SUCCESS	0x00	Successful operation
ABORT	0x95	Failed when client or server decides to abort the upgrade process
NOT_AUTHORIZED	0x7E	Server is not authorized to upgrade the client
INVALID_IMAGE	0x96	Invalid OTA upgrade image. For example, the image failed signature validation or CRC.
WAIT_FOR_DATA	0x97	Server does not have data block available yet
NO_IMAGE_AVAILABLE	0x98	No OTA upgrade image available for a particular client
MALFORMED_COMMAND	0x80	The command received is badly formatted or has incorrect parameters
UNSUP_CLUSTER_COMMAND	0x81	Such command is not supported on the device
REQUIRE_MORE_IMAGE	0x99	The client still requires more OTA upgrade image files in order to successfully upgrade

Default response commands

The OTA framework has a command ID **0xB** reserved for error messages that are sent by the target device. Default response commands are transmitted by the target device by wrapping the ZCL payload in a [Explicit Addressing Command frame - 0x11](#). The table below shows the ZCL Payload contents.

Note This is an example for a default response that has been received by an OTA source device. You can see that it is an [Explicit Rx Indicator frame - 0x91](#).

Start Delimiter	8	7E
Length	16	00 17
Frame Type	8	91
Source Address	64	FF FF FF FF FF FF FF FF
Source Address	16	FF FF
Source Endpoint	8	E8
Destination Endpoint	8	E8
Cluster ID	16	00 19
Profile ID	16	C1 05

Receive Options	8	C1
RF Data (ZCL payload. Hex In Little Endian)	Frame Control	00
	Sequence Number	00
	Command ID	0B
	Erring Command	02
	Status	8A
Checksum	F2	

The example above reports an error on the **Query Next Image Response(Erring Command: 0x02)** command informing the server that there is an attempt to update to the same firmware version as the one that is running on the target radio (Status : **0x8A**).

The following table explains the different error statuses which occur at different stages in the OTA upgrade process.

Command ID	ZCL OTA command	Status	XCTU message
0x0B Default Response	0x02 Query Next Image Response	0x80	Incorrect Query Next Image Response Format
		0x85	Attempting to upgrade to invalid firmware (Bad Image Type, Wrong Mfg ID, Wrong HW/SW compatibility(%C))
		0x89	Image size is too big
		0x8A	Please ensure that the image you are attempting to upgrade has a different version than the current version
		0x01	ZCL OTA Message Out of Sequence
0x05 Image Block Response	0x05 Image Block Response	0x80	Incorrect Image Block Response Format
		0x01	ZCL OTA Message Out of Sequence
		0x87	Upgrade File Mismatch
0x08 Upgrade End Response	0x08 Upgrade End Response	0x87	Wrong Upgrade File

When the source device or the server receives a default response frame with a command ID of **0x0B** and the erring command is **0x02** that is, the **Query Next Image Response**, it means there is something wrong with the **Query Next Image Response** sent by the server. Similarly, if the erring command is **0x05** that is, the **Image Block Response**, it means there is something wrong with the **Image Block Response** sent by the server, and the same applies to **Upgrade End Response** where there is an error on the **Upgrade End response** message sent by the server.

Upgrade End Request error statuses

The status field in the [Upgrade End request](#) informs the server of any errors during the download or verification of the OTA firmware update image on the client. The error codes that could be reported

are:

ZCL OTA Command	Status	Error Message
0x06 Upgrade End Request	0x94	Client Timed Out
	0x96	Invalid OTA Image
	0x95	Client Aborted Upgrade
	0x05	Storage Erase Failed
	0x87	Contact Tech Support (Highly unlikely to occur)

OTA file system upgrades

After an OTA firmware update, all file system data and bundled MicroPython code is erased. To continue running code, a new file system needs to be sent to the device after the firmware update is complete. This section contains information on how to update the file system of remote devices over the air.

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OTA file system update process

Since OTA file system updates are signed, remote devices must be configured so that they can validate incoming updates. To set up a network for OTA file system updates:

1. Generate a public/private Elliptic Curve Digital Signature Algorithm (ECDSA) signing key pair.
2. Using the generated public key, set [FK \(File System Public Key\)](#) on all devices that will receive OTA file system updates.

Note You cannot set **FK** remotely. You must either set **FK** before the XBee3 DigiMesh RF Module is deployed, or else serial access to the device is needed to set it.

To perform an OTA file system update:

1. On a local device, create a copy of the file system that you want to send over the air.
2. Create an OTA file system image, signed using the private key generated previously.
3. Perform an OTA update using the created OTA file.

Note The local device used to create the file system image must have the same firmware version installed as the target device or the file system will be rejected. Use [VR \(Firmware Version\)](#) to check the version number on both the staging and target devices.

You can perform all of these steps automatically through XCTU or manually using other tools.

OTA file system updates using XCTU

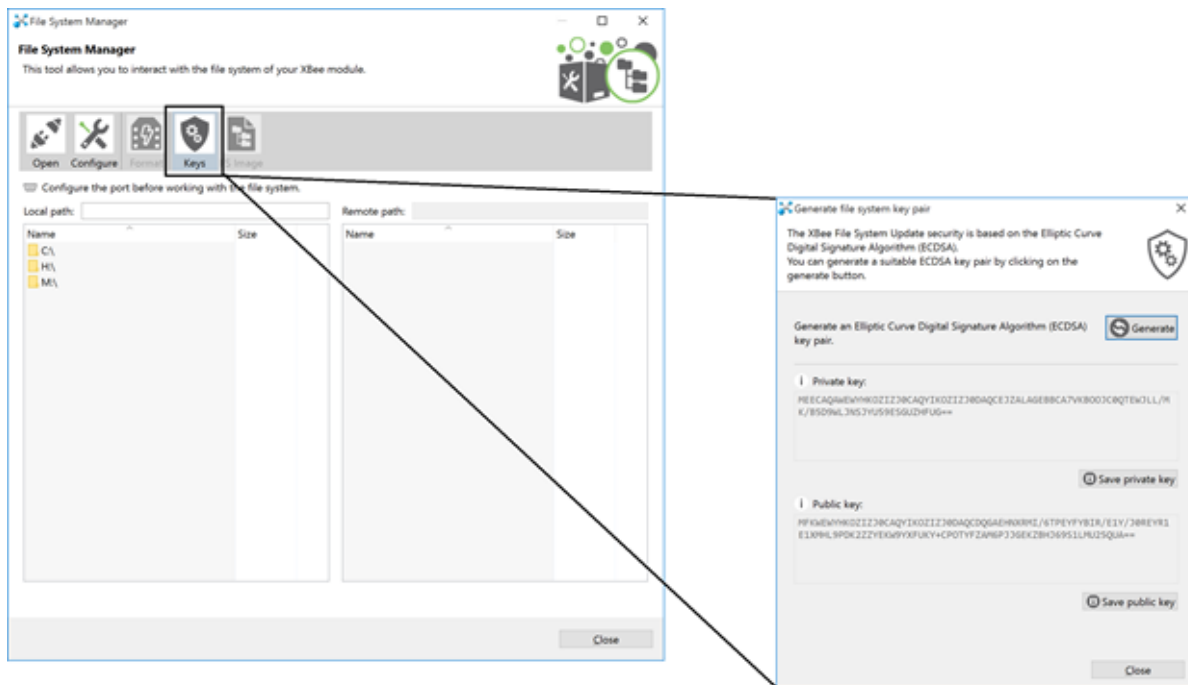
Use the following steps to perform a file system update OTA using XCTU:

1. [Generate a public/private key pair](#)
2. [Set the public key on the XBee3 device](#)
3. [Create the OTA file system image](#)
4. [Perform the OTA file system update](#)

Generate a public/private key pair

XCTU provides an ECDSA key pair generator that you can use to store a public/private key pair in .pem files. To access the **Generate file system key pair** dialog:

1. Open the **File System Manager** dialog box.
2. Click **Keys** as shown below.



3. Click **Generate** in the **Generate file system key pair** dialog.
4. Save both the keys in a safe location and close the dialog box.

Set the public key on the XBee3 device

1. Open the configuration view of the target device in XCTU and go to the **File System** category.
2. In the **File System Public Key** row, click **Configure**.



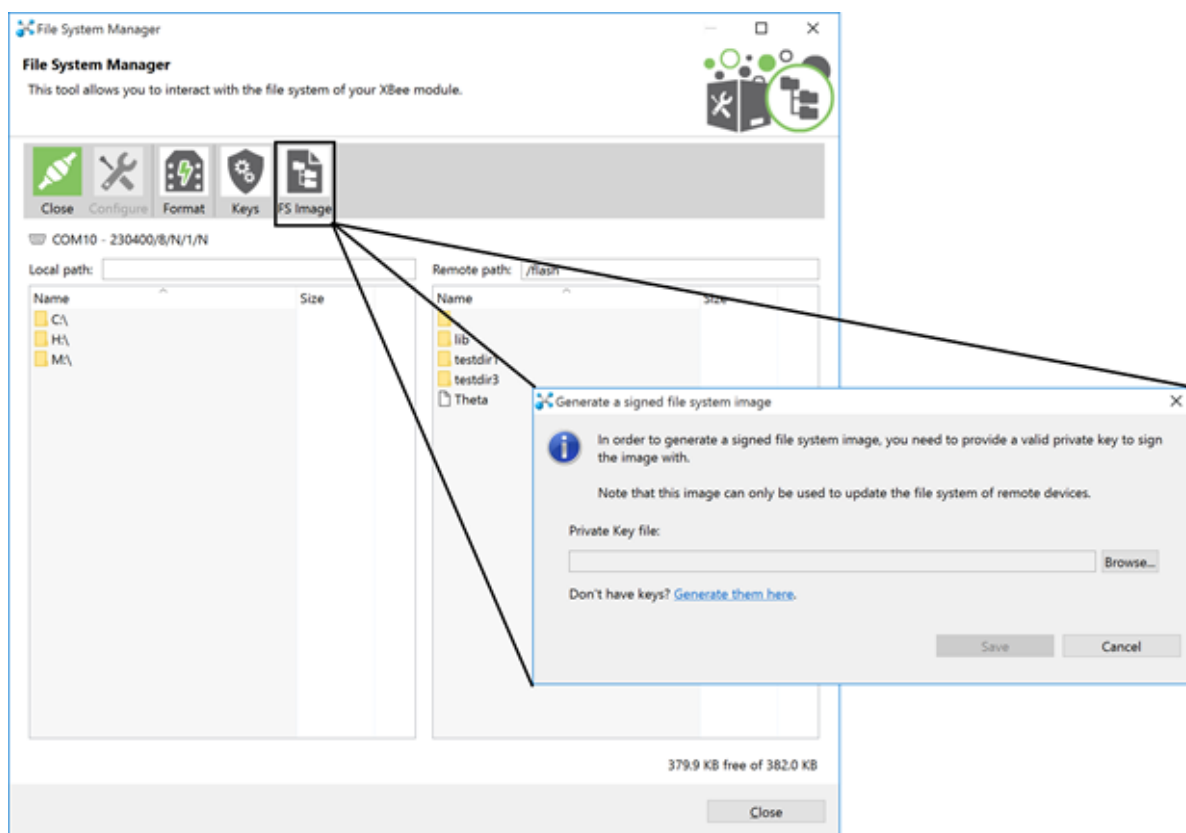
3. In the **Configure File System Public Key** dialog box, click **Browse** and choose the .pem file that you saved the public key into. Once this is done, the HEX value of the public key is visible under the **Public key** section on the dialog box as shown.
4. Click **OK** to ensure that the key gets written into the device.

Note This can be only be done locally. XBee3 firmware **DOES NOT** support remotely setting the file system public key at this time.

Create the OTA file system image

To create the OTA file system image:

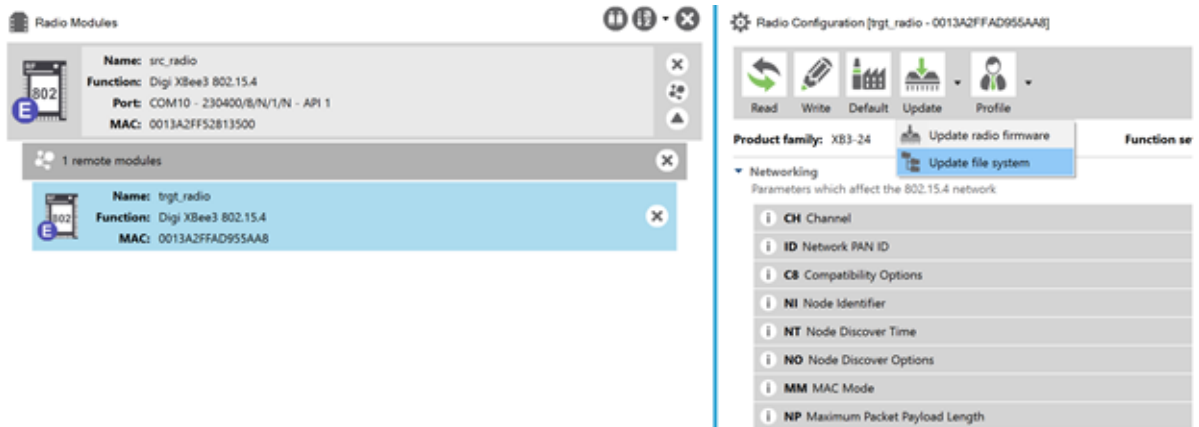
1. Open the **File System Manager** dialog box.
2. Open a connection on the device that you want to generate the OTA file system image from.
3. Click **FS Image**.
4. In the **Generate a signed file system image** window that displays, click **Browse** and choose the .pem file that the private key was stored in.
5. Once the path shows up on the **Private Key file** field, click **Save** to assign the .fs.ota an appropriate file name and location.
6. Save the file.



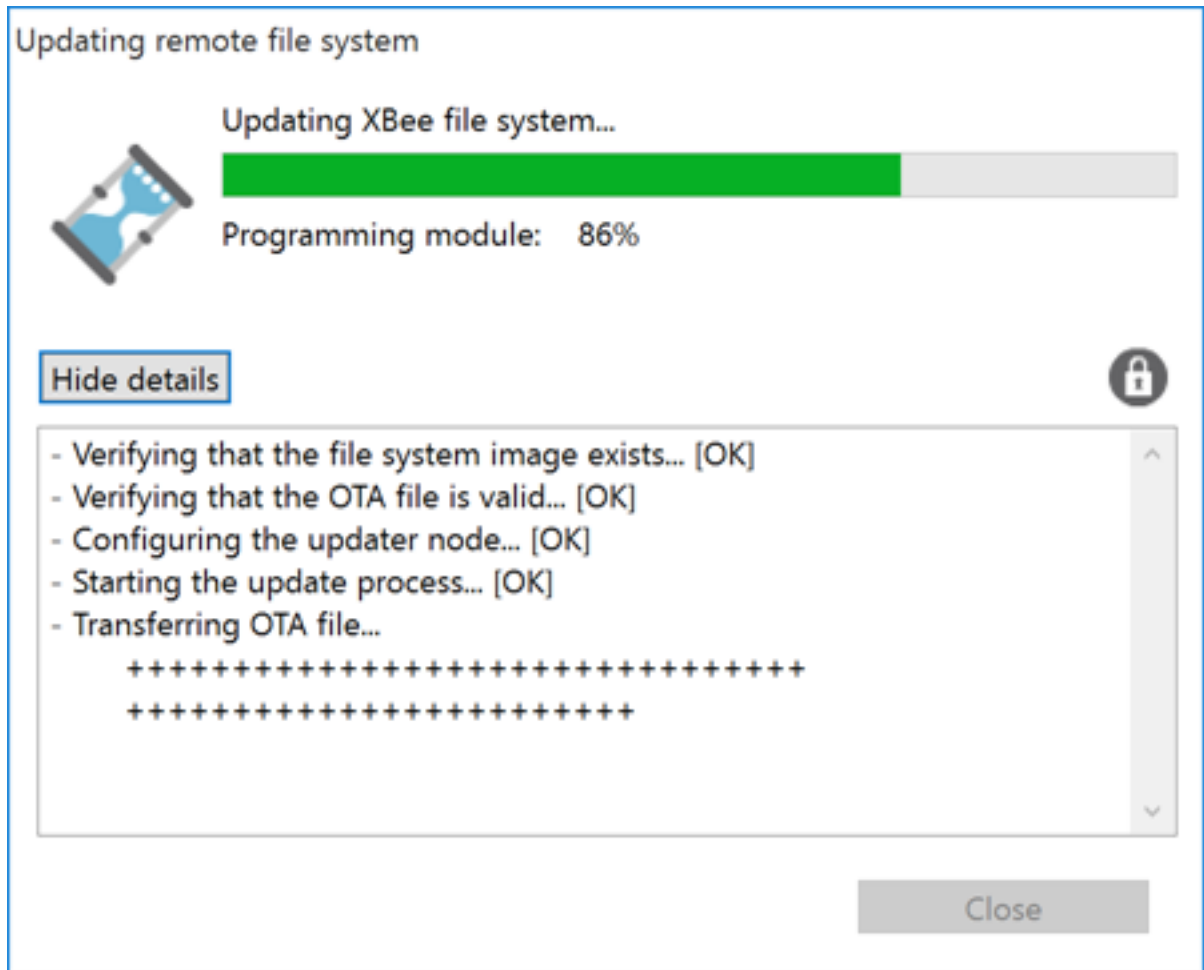
You will be prompted with a **File system image successfully saved** dialog box if the file was successfully generated.

Perform the OTA file system update

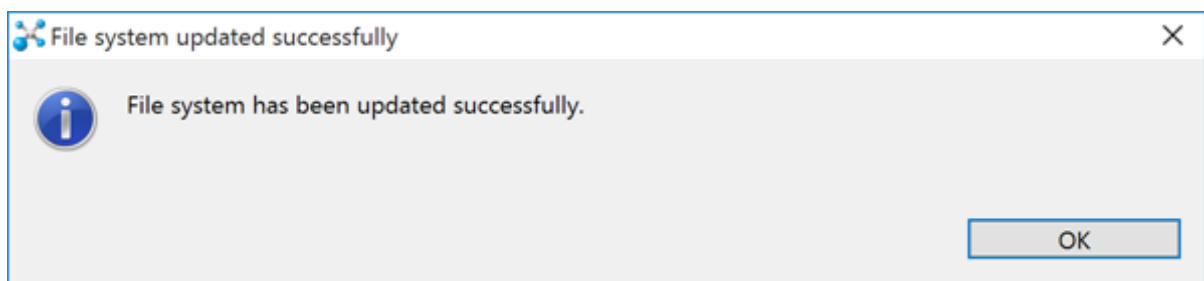
1. To add the target device, click **Discover radios in the same network** from the source device.
2. Enter Configuration mode on the remote device.
3. Click the down arrow next to the **Update** button and choose **Update File System**.



4. Choose the OTA file system image (.fs.ota) that the target node needs to be updated to.
5. Click **Open**.



Once the file system image is completely transferred and mounted on the remote device, XCTU informs you that the file system has been updated successfully.



OTA file system updates: OEM

Use the following steps to perform a file system update OTA using OEM tools:

1. [Generate a public/private key pair](#)
2. [Set the public key on the XBee3 device](#)

3. [Create the OTA file system image](#)
4. [Perform the OTA file system update](#)

Generate a public/private key pair

Generate ECDSA signing keys using secp256r1 curve parameters (also known as prime256v1 or NIST P-256).

To generate a public/private key pair using OpenSSL, run the following command:

```
openssl ecparam -name prime256v1 -genkey -outform pem -out keypair.pem
```

To extract the private key from the key pair generated above:

```
openssl pkcs8 -topk8 -inform pem -in pair.pem -outform pem -nocrypt -out private.pem
```

To extract the public key from the key pair generated above:

```
openssl ec -in keypair.pem -pubout -out public.pem
```

Set the public key on the XBee3 device

The public keys generated by XCTU and OpenSSL are stored in *.pem files. These files need to be parsed to get the value to use when setting **FK**. To parse a public key file, run:

```
openssl asn1parse -in public.pem -dump
```

The command will produce something like the following output:

```
0:d=0 hl=2 l= 89 cons: SEQUENCE
 2:d=1 hl=2 l= 19 cons: SEQUENCE
 4:d=2 hl=2 l= 7 prim: OBJECT          :id-ecPublicKey
13:d=2 hl=2 l= 8 prim: OBJECT          :prime256v1
23:d=1 hl=2 l= 66 prim: BIT STRING
0000 - 00 04 95 50 aa 55 b6 f5-5d 99 4d d8 15 d1 71 57   ...P.U...].M...qW
0010 - 51 80 d5 14 ec 1f 6a 15-51 a2 c4 b8 0f 77 10 8a   Q.....j.Q....w..
0020 - 33 a3 80 07 47 40 14 8b-5c a7 4c 78 02 fc 4d 82   3...G@...\.Lx..M.
0030 - 90 4b 39 98 62 a1 1d 97-6e 78 fb 54 62 06 d2 41   .K9.b...nx.Tb..A
0040 - c7 3b
```

The public key should be 65 bytes long - it is the BIT STRING value at the end, with the leading 00 omitted; in this case:

```
049550aa55b6f55d994dd815d171575180d514ec1f6a1551a2c4b80f77108a33a380074740148b5ca
74c7802fc4d82904b399862a11d976e78fb546206d241c73b
```

Create the OTA file system image

You can create a file system image outside of XCTU using any utility that can perform ECDSA signing. These instructions show how to do so using OpenSSL. To create an OTA file system image, use the following steps.

Create a staged file system

In order to create a usable file system image, first create a 'staged' copy of the file system you want to send on a local device.

Use the **FS** command or MicroPython to load all of the files that you want to send onto the local staging device.

Note The staging device must have the same firmware version installed as the target device or the file system will be rejected. Use the **VR** command to check the version number on both the staging and target devices.

Download the file system image

Run the command **ATFS GET /sys/xbfs.bin** to download an image of the file system from the staging device. The file is transferred using the YMODEM protocol. See [File system](#) for more information on downloading files using **FS GET**.

Pad the file system image

The file system image must be a multiple of 2048 bytes long before it is signed. Using hex editing software, add 0xFF bytes to the end of the downloaded image until size of the file is a multiple of 2048 (0x800 in hex).

Calculate the image signature

Once the image has been padded to a multiple of 2048 bytes, it is ready to be signed. The ECDSA signature should be calculated using SHA256 as the hash algorithm.

Assuming a public/private key pair has been generated as described in [Generate a public/private key pair](#), that the private key is named `private.pem`, and that the padded image is named **xbfs.bin**; this can be done using OpenSSL with the following command:

```
openssl dgst -sha256 -sign private.pem -binary -out sig.bin xbfs.bin
```

`sig.bin` will contain the signature for the image.

Append the calculated signature to the image

The signature should be between 70 and 72 bytes, and it should be appended to the padded image.

Create the OTA file

Put the image into an OTA file that follows the format specified in [ZigBee Document 095264r23](#). The file should consist of:

- An OTA header
- An upgrade image sub-element tag
- The padded, signed image data

The OTA file must begin with an OTA header. See [The OTA header](#) for information on the format of the header. The image type should be **0x0100** for a file system image upgrade.

The sub-element tag should come before the image data. The sub-element tag follows the format described in section **6.3.3** of [ZigBee Document 095264r23](#). It consists of 6 bytes: the first 2 bytes are the tag id and should be set to **0x0000**. The next 4 bytes contain the length of the file system image in little-endian format.

Perform the OTA file system update

The process for performing an OTA file system update is the same as the process for performing an OTA firmware upgrade, as described in [Over-the-air firmware/file system upgrade process for](#)

[DigiMesh 2.4](#). Note that the data that goes in the image blocks starts at the beginning of the image data, after the OTA header and sub-element tag.