XBee/XBee-PRO DigiMesh 2.4

Radio Frequency (RF) Module

User Guide

Revision history—90000991

Revision	Date	Description
S	January 2016	Updated several AT commands.
T	February 2016	Editorial revision to AT commands.
U	June 2016	Removed the **1S** command. Fixed an error in the 0x90 frame table. Clarified the routing table size.
V	June 2017	Modified regulatory and certification information as required by RED (Radio Equipment Directive).
W	May 2018	Added note on range estimation. Changed IC to ISED.

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XBee/XBee-PRO DigiMesh 2.4 RF Module User Guide

The XBee/XBee-PRO DigiMesh 2.4 supports the unique needs of low-cost, low-power, wireless sensor networks. The devices require minimal power and provide reliable data delivery between remote devices. The devices operate within the ISM 2.4 MHz frequency band.

These devices support routing table sizes of 32 nodes. Networks larger than this send a route discovery before each transmission. For larger networks this can be bandwidth expensive, so we offer RF optimization services to help you properly configure a network.

Worldwide acceptance

We manufacture and certify the XBee/XBee-PRO DigiMesh 2.4s to certain industry standards. These standards enable you to understand what the devices can do and where you can use them.

The Federal Communications Commission (FCC) approves the devices for use in the United States. For details, see United States (FCC). If a system contains XBee/XBee-PRO DigiMesh 2.4s, the system inherits Digi's certifications.

The devices are certified to operate in the industrial, scientific, and medical (ISM) 2.4 GHz frequency band.

We manufacture the devices under International Organization for Standardization (ISO) 9001:2000 registered standards.

We optimize the devices for use in the United States and Canada. For a complete list of agency approvals, see Regulatory information.

Antenna options

Digi devices come in a variety of antenna options. The options that allow you to connect an external antenna are reverse polarity standard subminiature assembly (RPSMA) and U.FL. Typically, you make connections with either a dipole antenna with a U.FL connection, or a U.FL to RPSMA antenna adapter cable.

RPSMA is the more traditional antenna connector, however, if the device is going to be inside of an enclosure, you would need to locate the device near the edge of the enclosure to allow the connector to pass through an available bulkhead. The RPSMA connector uses the same body as a regular SMA connector, but changes the gender of the center conductor. The female RPSMA actually has a male center conductor. We equip the XBee devices with an RPSMA female plug, while the antenna is an RPSMA male jack.

The U.FL connection allows for connectivity to an external antenna. U.FL is a small antenna connection for use with a pigtail connector. A pigtail is a short (typically 4 - 6 in) cable that either terminates into an external antenna port such as an RPSMA, N or TNC connection or an antenna. You would attach the RPSMA connector to a bulkhead. These options allow you to mount the device away from the edge of the enclosure in your product and centrally locate the radio. U.FL is fragile and is not designed for multiple insertions without a specialized tool to separate the pigtail without damaging the connector; for more information, see http://www.digikey.com/product-detail/en/U.FL-LP(V)-N-2/HR5017-ND/513034.

The other available antenna options are printed circuit board (PCB) and wire antennas. We form the PCB antenna directly on the device with conductive traces. A PCB antenna performs about the same as a wire antenna.

An integrated wire antenna consists of a small wire (about 80 mm) sticking up perpendicular to the PCB. It uses a 1/4-wave wire that we solder directly to the PCB of the OEM device.

All Digi devices with antenna connectors have less than 0.1 dB loss; we do not consider one to be "better" than the other in terms of reliability or insertion loss. RF device specifications such as -110 dBm receiver sensitivity, +3 0 dBm TX power, and so forth, already include any insertion loss due to the soldered RF connector.

Part numbers

The part numbers for these devices are available at the following link:

www.digi.com/products/xbee-rf-solutions/modules/xbee-digimesh-2-4#partnumbers

Technical specifications

The following tables provide the device's technical specifications.

Performance specifications

The following table describes the performance specifications for the devices.

Note Range figure estimates are based on free-air terrain with limited sources of interference. Actual range will vary based on transmitting power, orientation of transmitter and receiver, height of transmitting antenna, height of receiving antenna, weather conditions, interference sources in the area, and terrain between receiver and transmitter, including indoor and outdoor structures such as walls, trees, buildings, hills, and mountains.

Specification	XBee	XBee-PRO
Indoor / urban range	Up to 100 ft (30 m)	Up to 300 ft (90 m) standard or up to 200 ft (60 m) international variant
Outdoor RF line of sight range	Up to 300 ft (90 m)	Up to 1 mile (1.5 km), with a 2.0 dB dipole antenna. Up to 6 miles (10 km) with a high gain antenna.
Transmit power output	1 mW (0 dBm)	63 mW (18 dBm) standard or 10 mW (10 dBm) for the international variant
RF data rate	250 kb/s	250 kb/s
Serial interface data rate (software selectable)	1200 bps - 250 kb/s (devices also support non-standard baud rates)	1200 bps - 250 kb/s (devices also support non-standard baud rates)
Receiver sensitivity	-92 dBm (1% packet error rate)	-100 dBm (1% packet error rate)

Power requirements

The following table describes the power requirements for the XBee/XBee-PRO DigiMesh 2.4.

Specification	XBee	XBee-PRO
Supply voltage	2.8 - 3.4 VDC	2.8 - 3.4 VDC
Transmit current	45 mA (@ 3.3 V)	250 mA (@ 3.3 V) (150 mA for the international variant) RPSMA device only: 340 mA (@ 3.3 V) (180 mA for the international variant)
Idle / receive current	50 mA (@ 3.3 V)	55 mA (@ 3.3 V)
Power down current (pin sleep)	<10 µA	<10 µA
Power down current (cyclic sleep)	<50 µA	<50 µA

General specifications

The following table describes the general specifications for the devices.

Specification	XBee	XBee-PRO
Operating frequency band	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	2.438 cm x 2.761 cm (0.960 in x 1.087 in)	2.438 cm x 3.294 cm (0.960 in x 1.297 in)
Operating temperature	-40 to 85 °C (industrial)	-40 to 85 °C (industrial)
Relative humidity	0 to 95% non-condensing	0 to 95% non-condensing
Antenna options	1/4 wave wire antenna, embedded PCB antenna, RPSMA RF connector, U.FL RF connector	1/4 wave wire antenna, RPSMA RF connector, U.FL RF connector

Networking and security specifications

The following table describes the networking and security specifications for the devices.

Specification	XBee	XBee-PRO
Supported network topologies	Mesh, point-to-point, point-to-multipoint, peer-to-peer	Mesh, point-to-point, point-to-multipoint, peer-to-peer
Number of channels (software selectable)	16 direct sequence channels	12 direct sequence channels
Addressing options	PAN ID, channel and 64-bit addresses	PAN ID, channel and 64-bit addresses
Encryption	128 bit Advanced Encryption Standard (AES)	128 bit AES

Regulatory conformity summary

This table describes the agency approvals for the devices.

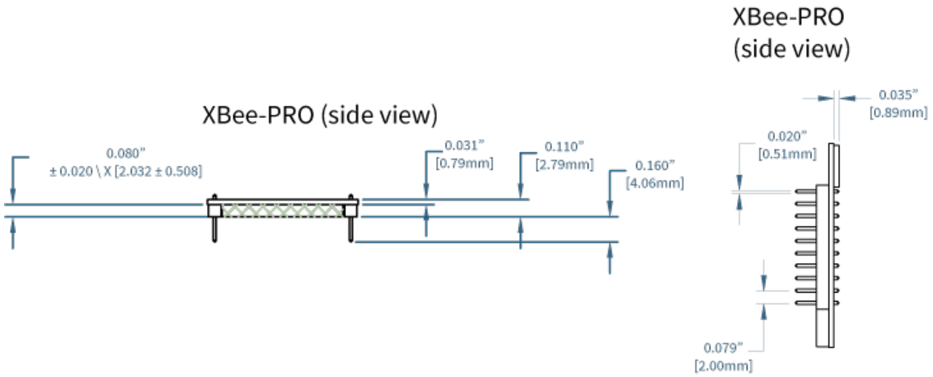
Specification	XBee	XBee-PRO
United States (FCC Part 15.247)	OUR-XBEE	OUR-XBEEPRO
Innovation, Science and Economic Development Canada (ISED)	4214A-XBEE	4214A-XBEEPRO
Europe (CE)	Yes	Yes (maximum 10 dBm transmit power output)
RoHS	Lead-free and RoHS compliant	Lead-free and RoHS compliant

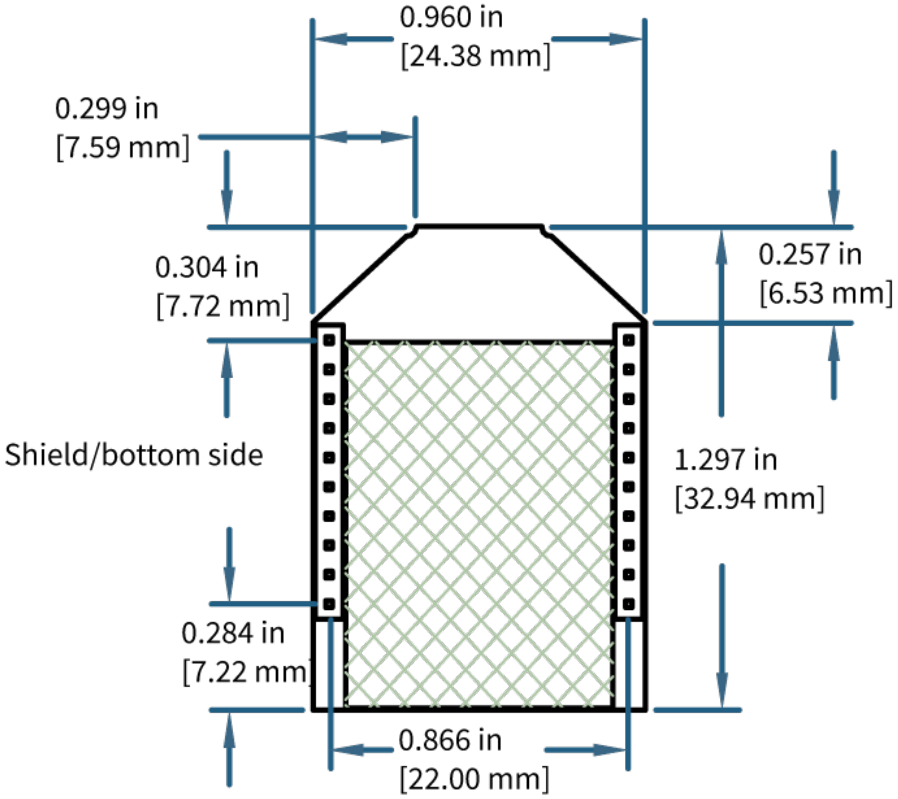
Specification	XBee	XBee-PRO
Japan	R201WW07215214	R201WW08215111 (maximum 10 dBm transmit power output)
Australia	C -Tick	C -Tick
Brazil	ANATEL 0369-15-1209	ANATEL 0378-15-1209
See Regulatory information for region-specific certification requirements.		

Hardware

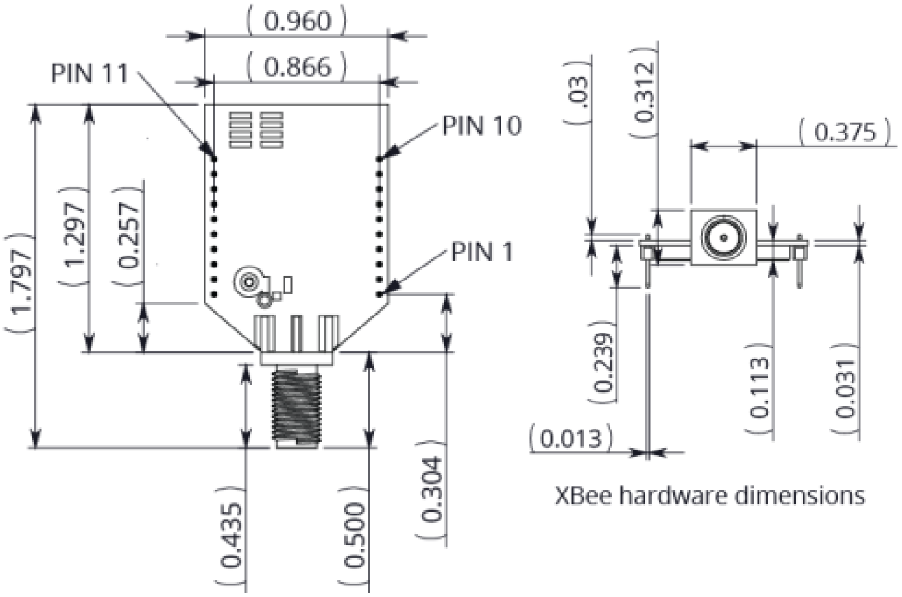
Mechanical drawings

The following figures show the mechanical drawings for the XBee/XBee-PRO DigiMesh 2.4. The drawings do not show antenna options.

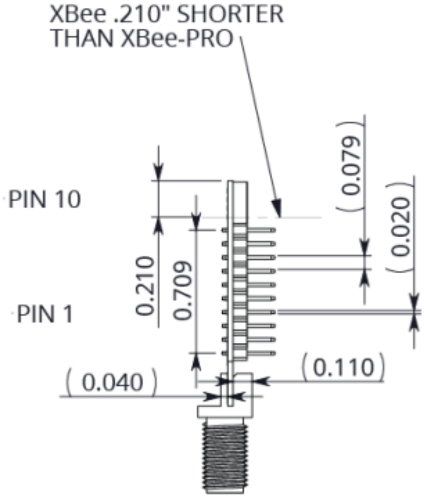




The following drawings show the RPSMA device.



XBee hardware dimensions

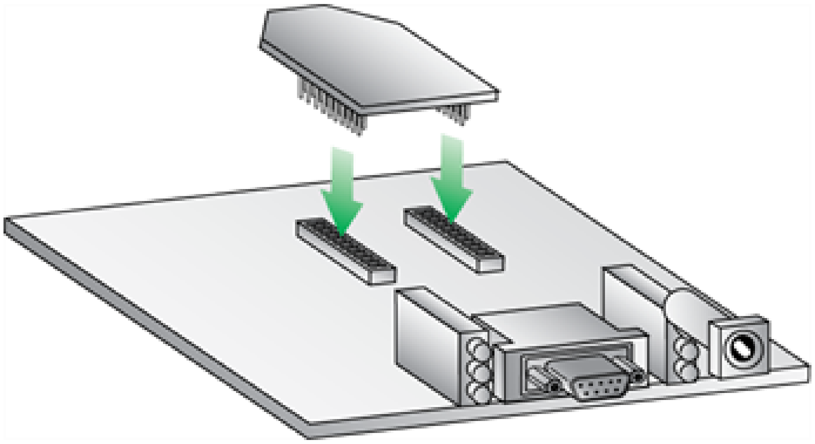


XBee hardware (side view)

Mounting considerations

We design the through-hole module to mount into a receptacle so that you do not have to solder the module when you mount it to a board. The development kits may contain RS-232 and USB interface boards that use two 20-pin receptacles to receive modules.

The following illustration shows the module mounting into the receptacle on the RS-232 interface board.

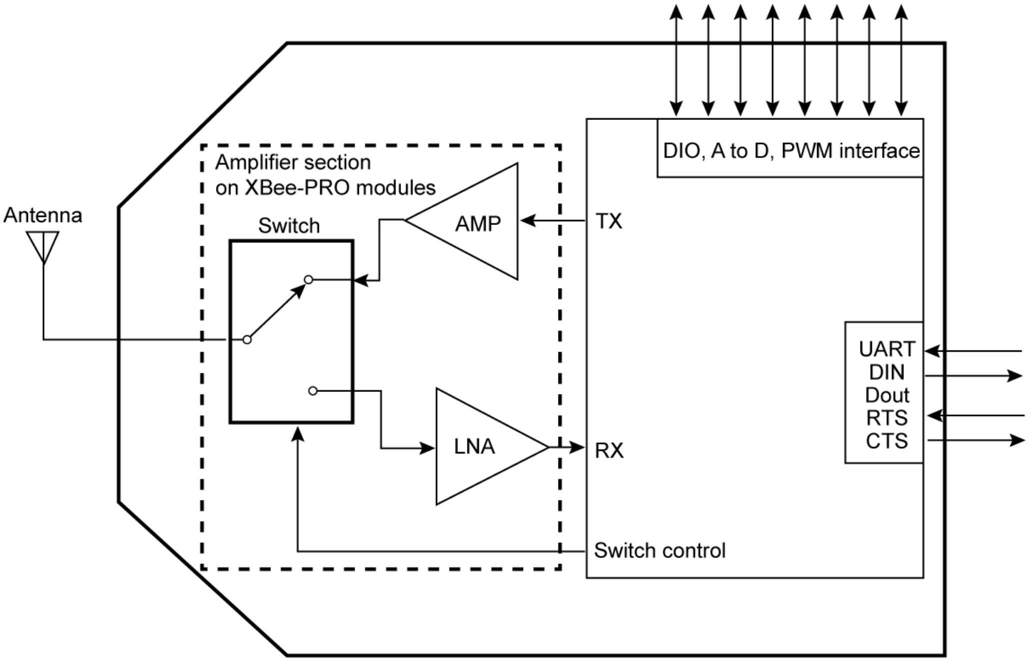


- Through-hole single-row receptacles: Samtec part number: MMS-110-01-L-SV (or equivalent)
- Surface-mount double-row receptacles: Century Interconnect part number: CPRMSL20-D-0-1 (or equivalent)
- Surface-mount single-row receptacles: Samtec part number: SMM-110-02-SM-S

Note We recommend that you print an outline of the module on the board to indicate the correct orientation for mounting the module.

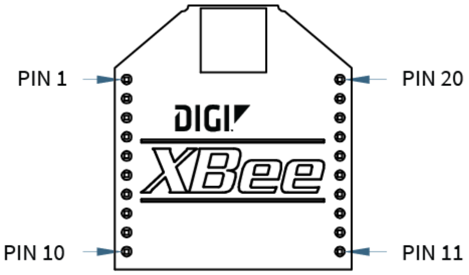
Hardware diagram

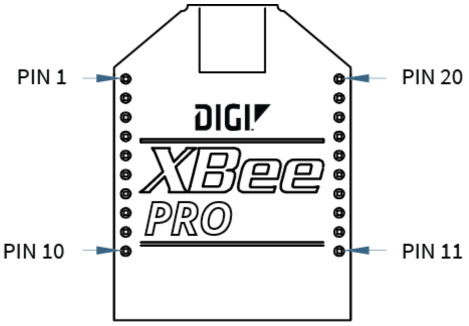
The following diagram shows a simplified view of XBee/XBee-PRO DigiMesh 2.4 hardware.



Pin signals

The following table shows the pin signals and their descriptions.





Pin #	Pin name	Direction	Description
1	Vcc	-	Power supply
2	DOUT	Output	UART data out
3	DIN/CONFIG	Input	UART data in
4	DIO12	Either	Digital I/O 12
5	RESET	Input/open drain output	Device reset. The reset pulse must be at least 100 µs. Drive this line as an open drain/collector. The device drives this line low when a reset occurs. Never drive this line high.
6	PWM0/RSSI/DIO10	Either	PWM output 0 / RX signal strength indicator / Digital I/O
7	PWM/DIO11	Either	PWM output 1 / Digital I/O 11
8	Reserved	-	Do not connect
9	$\overline{\text{DTR}}$ / SLEEP_ RQ / DIO8	Either	Pin sleep control line or Digital I/O 8
10	GND	-	Ground
11	AD4/ DIO4	Either	Analog input 4 or Digital I/O 4
12	$\overline{\text{CTS}}$/ DIO7	Either	Clear-to-send flow control or Digital I/O 7
13	ON/SLEEP	Output	Device Status Indicator or Digital I/O 9
14	VREF	-	You must connect this line if you want to use analog I/O sampling. Must be between 2.6 V and Vcc.
15	Associate / DIO5/ AD5	Either	Associated indicator, Digital I/O 5
16	$\overline{\text{RTS}}$/ DIO6	Either	Request-to-send flow control, Digital I/O 6
17	AD3 / DIO3	Either	Analog input 3 or Digital I/O 3
18	AD2 / DIO2	Either	Analog input 2 or Digital I/O 2

Pin #	Pin name	Direction	Description
19	AD1 / DIO1	Either	Analog input 1 or Digital I/O 1
20	AD0 / DIO0 / Commissioning Pushbutton	Either	Analog input 0, Digital I/O 0, or Commissioning Pushbutton

Notes

The table specifies signal direction with respect to the device.

The device includes a 50 kΩ pull-up resistor attached to RESET.

You can configure several of the input pull-ups using the PR command.

Leave any unused pins disconnected.

Recommended pin connections

The only required pin connections for two-way communication are VCC, GND, DOUT and DIN. To support serial firmware updates, you must connect VCC, GND, DOUT, DIN, RTS, and DTR.

Do not connect any pins that are not in use. Use the **PR** command to pull all inputs on the radio high with internal pull-up resistors. Unused outputs do not require any specific treatment.

For applications that need to ensure the lowest sleep current, never leave unconnected inputs floating. Use internal or external pull-up or pull-down resistors, or set the unused I/O lines to outputs.

You can connect other pins to external circuitry for convenience of operation including the Associate LED pin (pin 15) and the Commissioning pin (pin 20). The Associate LED pin flashes differently depending on the state of the module, and a pushbutton attached to pin 20 can enable various deployment and troubleshooting functions without you sending UART commands. For more information, see The Commissioning Pushbutton.

For analog sampling, attach the VREF pin (pin 14) to a voltage reference.

Design notes

The following guidelines help to ensure a robust design.

Power supply design

A poor power supply can lead to poor device performance, especially if you do not keep the supply voltage within tolerance or if it is excessively noisy. To help reduce noise, place a 1.0 µF and 8.2 pF capacitor as near as possible to pin 1 on the PCB. If you are using a switching regulator for the power supply, switch the frequencies above 500 kHz. Limit the power supply ripple to a maximum 100 mV peak to peak.

Board layout

We design XBee devices to be self sufficient and have minimal sensitivity to nearby processors, crystals or other printed circuit board (PCB) components. Keep power and ground traces thicker than signal traces and make sure that they are able to comfortably support the maximum current specifications. There are no other special PCB design considerations to integrate XBee devices, with the exception of antennas.

Antenna performance

Antenna location is important for optimal performance. The following suggestions help you achieve optimal antenna performance. Point the antenna up vertically (upright). Antennas radiate and receive the best signal perpendicular to the direction they point, so a vertical antenna's omnidirectional radiation pattern is strongest across the horizon.

Position the antennas away from metal objects whenever possible. Metal objects between the transmitter and receiver can block the radiation path or reduce the transmission distance. Objects that are often overlooked include:

- metal poles
- metal studs
- structure beams
- concrete, which is usually reinforced with metal rods

If you place the device inside a metal enclosure, use an external antenna. Common objects that have metal enclosures include:

- vehicles
- elevators
- ventilation ducts
- refrigerators
- microwave ovens
- batteries
- tall electrolytic capacitors

Do not place XBee devices with the chip or integrated PCB antenna inside a metal enclosure.

Do not place any ground planes or metal objects above or below the antenna.

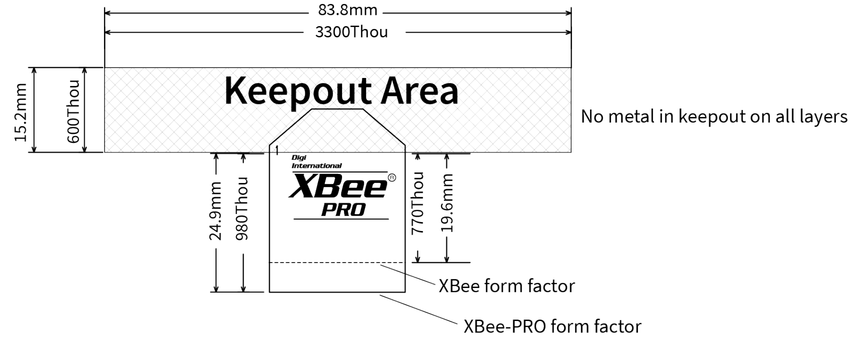
For the best results, mount the device at the edge of the host PCB. Ensure that the ground, power, and signal planes are vacant immediately below the antenna section.

Keepout area

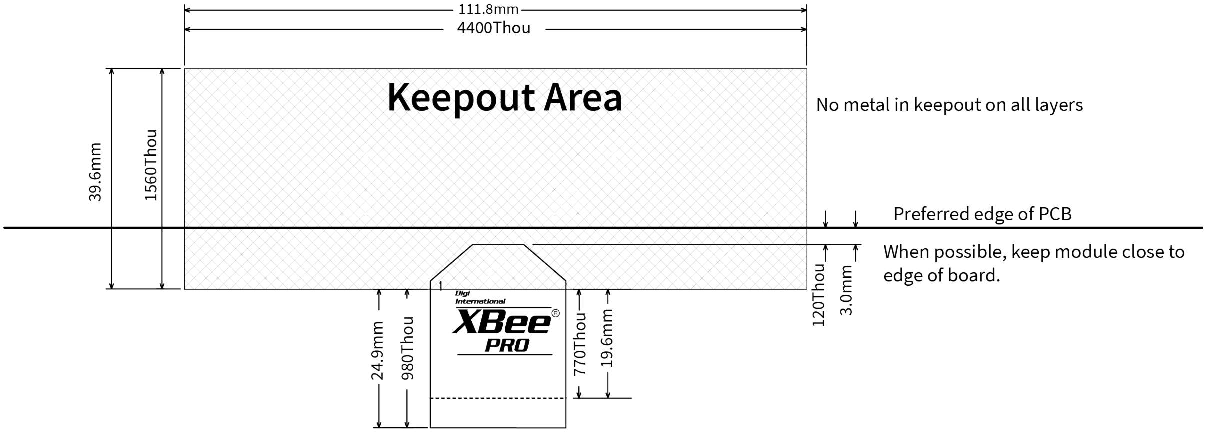
We recommend that you allow a “keepout” area, as shown in the following drawing.

Through-hole keepout

Minimum Keepout Area (All PCB layers)



Recommended Keepout Area (All PCB layers)



The antenna performance improves with a larger keepout area

Notes

1. We recommend non-metal enclosures. For metal enclosures, use an external antenna.
2. Keep metal chassis or mounting structures in the keepout area at least 2.54 cm (1 in) from the antenna.
3. Maximize the distance between the antenna and metal objects that might be mounted in the keepout area.
4. These keepout area guidelines do not apply for wire whip antennas or external RF connectors. Wire whip antennas radiate best over the center of a ground plane.

DC characteristics

The following table displays the DC characteristics (VCC = 2.8 - 3.4 VDC).

Symbols	Parameter	Condition	Min	Typical	Max	Units
V_{IL}	Input low voltage	All digital inputs	-	-	0.2[1] VCC	V
V_{IH}	Input high voltage	All digital inputs	0.8[2] VCC	-	-	V
V_{OL}	Output low voltage	I_{OL} = 2 mA, VCC >= 3.0 V	-	-	0.18[3] VCC	V
V_{OH}	Output high voltage	I_{OH} = 2 mA, VCC >= 3.0 V	0.82[4] VCC	-	-	V
II_{IN}	Input leakage current	V_{IN} = VCC or GND, all inputs, per pin	-	-	0.5	µA

ADC operating characteristics

The following table displays the ADC timing and performance characteristics.

Symbols	Parameter	Condition	Min	Typical	Max	Units
V_{REFH}	VREF-analog-to-digital converter reference range		2.08	-	V_{DDAD}	V
I_{REF}	VREF-reference supply current	Enabled	-	200	-	µA
		Disabled or sleep mode	-	< 0.01	0.02	µA
V_{INDC}[5]	Analog input voltage		V_{SSAD} - 0.3	-	V_{SSAD} + 0.3	V

[1] Maximum electrical operating range, not valid conversion range.

[2] Maximum electrical operating range, not valid conversion range.

[3] Maximum electrical operating range, not valid conversion range.

[4] Maximum electrical operating range, not valid conversion range.

[5] Analog input must be between V_{REFL} and V_{REFH} for valid conversion. Values greater than V_{REFH} will convert to $3FF.

ADC timing and performance characteristics

The following table displays the ADC timing and performance characteristics.[1]

Symbols	Parameter	Condition	Min	Typical	Max	Units
R_{AS}	Source impedance at input[2]		-	-	10	kΩ
RES	Ideal resolution (1 LSB)[3]	2.08V > V_{DDAD} > 3.6V	2.031		3.516	mV
DNL	Differential non-linearity[4]		-	±0.5	±1.0	LSB
INL	Integral non-linearity[5]		-	±0.5	±1.0	LSB
E_{ZS}	Zero-scale error[6]		-	±0.4	±1.0	LSB
F_{FS}	Full-scale error[7]		-	±0.4	±1.0	LSB
E_{IL}	Input leakage error[8]		-	±0.05	±5.0	LSB
E_{TU}	Total unadjusted error[9]		-	±1.1	±2.5	LSB

[1] All Accuracy numbers are based on processor and system being in WAIT state (very little activity and no I/O switching) and that adequate low-pass filtering is present on analog input pins (filter with 0.01 µF to 0.1 µF capacitor between analog input and V_{REFL}). Failure to observe these guidelines may result in system or microcontroller noise causing accuracy errors which will vary based on board layout and the type and magnitude of the activity. Data transmission and reception during data conversion may cause some degradation of these specifications, depending on the number and timing of packets. It is advisable to test the ADCs in your installation if best accuracy is required.

[2] RAS is the real portion of the impedance of the network driving the analog input pin. Values greater than this amount may not fully charge the input circuitry of the ATD resulting in accuracy error.

[3] The resolution is the ideal step size or 1LSB = (V_{REFH}–V_{REFL})/1024.

[4] Differential non-linearity is the difference between the current code width and the ideal code width (1LSB). The current code width is the difference in the transition voltages to and from the current code.

[5] Integral non-linearity is the difference between the transition voltage to the current code and the adjusted ideal transition voltage for the current code. The adjusted ideal transition voltage is (Current Code.1/2)*(1/((V_{REFH}+E_{FS}).(V_{REFL}+E_{ZS}))).

[6] Zero-scale error is the difference between the transition to the first valid code and the ideal transition to that code. The Ideal transition voltage to a given code is (Code.1/2)*(1/(V_{REFH}·V_{REFL})).

[7] Full-scale error is the difference between the transition to the last valid code and the ideal transition to that code. The ideal transition voltage to a given code is (Code.1/2)*(1/(V_{REFH}·V_{REFL})).

[8] Input leakage error is error due to input leakage across the real portion of the impedance of the network driving the analog pin. Reducing the impedance of the network reduces this error.

[9] Total unadjusted error is the difference between the transition voltage to the current code and the ideal straight-line transfer function. This measure of error includes inherent quantization error (1/2 LSB) and circuit error (differential, integral, zero-scale, and full-scale) error. The specified value of E_{TU} assumes zero E_{IL} (no leakage or zero real source impedance).

Modes

The XBee/XBee-PRO DigiMesh 2.4 is in Receive Mode when it is not transmitting data. The device shifts into the other modes of operation under the following conditions:

- Transmit mode (Serial data in the serial receive buffer is ready to be packetized)
- Sleep mode
- Command Mode (Command mode sequence is issued (not available when using the SPI port))

Transparent and API operating modes

The firmware operates in several different modes. Two top-level modes establish how the device communicates with other devices through its serial interface: Transparent operating mode and API operating mode.

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.

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 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
- You can query or set a configuration parameter while a pending command—for example **ND**—is in progress. This cannot be done in Command mode.

For more information, see API frame specifications.

Comparing Transparent and API modes

The XBee/XBee-PRO DigiMesh 2.4 can use its serial connection in two ways: Transparent mode or API operating mode. You can use a mixture of devices running API mode and transparent mode in a network.

The following table provides a comparison of the two modes.

Transparent operating mode	API operating mode
When to use: ■ The conditions for using API mode do not apply.	When to use: ■ The device sends wireless data to multiple destinations. ■ The device configures remote devices in the network. ■ The device receives wireless data packets from multiple XBee devices, and the application needs to identify which devices send each packet. ■ The device receives I/O samples from remote XBee devices.

Transparent operating mode	API operating mode
Advantages: ■ Provides a simple interface. ■ It is easy for an application to support; what you send is exactly what other modules get, and vice versa. ■ Works very well for two-way communication between XBee devices.	Advantages: ■ You can set or read the configuration of remote XBee devices in the network. ■ You can transmit data to one or multiple destinations; this is much faster than Transparent mode where the configuration must be updated to establish a new destination. ■ Received data includes the sender's address. ■ Received data includes transmission details and reasons for success or failure. ■ This mode has several advanced features, such as advanced networking diagnostics, and firmware upgrades.
Disadvantages: ■ You cannot set or read the configuration of remote XBee devices in the network. ■ You must first update the configuration to establish a new destination and transmit data. ■ You cannot identify the source of received data, as it does not include the sender's address. ■ Received data does not include transmission details or the reasons for success or failure. ■ This mode does not offer the advanced features of API mode, including advanced networking diagnostics, and firmware upgrades.	Disadvantages: ■ The interface is more complex; data is structured in packets with a specific format. ■ This mode is more difficult to support; transmissions are structured in packets that need to be parsed (to get data) or created (to transmit data). ■ Sent data and received data are not identical; received packets include some control data and XTend vB information.

Additional modes

In addition to the serial communication modes, several modes apply to how devices communicate with each other.

Command mode

Command mode is a state in which the firmware interprets incoming characters as commands. Command mode allows you to modify the device's firmware using parameters you can set using AT commands. When you want to read or set any setting of the device, you have to send it an AT command. Every AT command starts with the letters "AT", followed by the two characters that identify the command that is being sent and then by some optional configuration values. For more details, see Enter Command mode.

Idle mode

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

Receive mode

If a destination node receives a valid RF packet, the destination node transfers the data to its serial transmit buffer. For the serial interface to report receive data on the RF network, that data must meet the following criteria:

- ID match
- Channel match
- Address match

Sleep modes

Sleep modes allows the device to enter states of low power consumption when not in use. The device is almost completely off during sleep, and is incapable of sending or receiving data until it wakes up. XBee devices support both pin sleep, where the module enters sleep mode upon pin transition, and cyclic sleep, where the module sleeps for a fixed time. While asleep, nodes cannot receive RF messages or read commands from the UART port.

The sleep modes are:

- Normal mode. Normal mode is the default for a newly powered-on node. In this mode, a node does not sleep. Normal mode nodes should be mains-powered.
- Asynchronous Pin Sleep mode. This mode allows the device to sleep and wake according to the state of the Sleep_RQ pin (pin 9).
- Asynchronous Cyclic Sleep Mode. This mode allows the device to sleep for a specified time and wake for a short time to poll.
- Asynchronous Cyclic Sleep with Pin Wake Up mode. In this mode you can wake the device up prematurely using the Sleep_RQ pin.
- Synchronous Sleep Support mode. A node in this mode synchronizes itself with a sleeping network, but does not sleep itself. At any time, the node responds to new nodes that attempt to join the sleeping network using a sync message.

- Synchronous Cyclic Sleep mode. A node 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.

Transmit mode

When the device receives serial data and is ready to packetize it, it exits Idle mode and attempts to transmit the serial data.

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 XBee/XBee-PRO DigiMesh 2.4 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 XBee/XBee-PRO DigiMesh 2.4 are controlled by the AP (API Mode) 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 XBee/XBee-PRO DigiMesh 2.4 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 Times).

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:

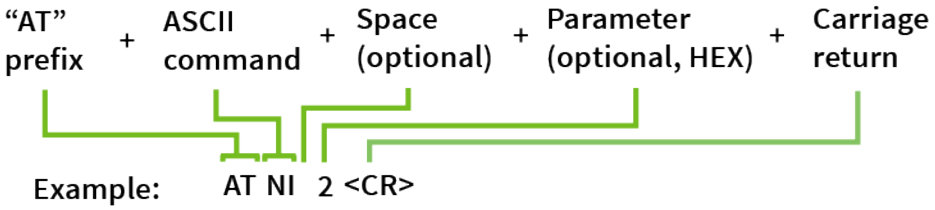
- A serial break for six seconds enters Command mode. You can issue the "break" command from a serial console, it is often a button or menu item.
- Asserting DIN (serial break) upon power up or reset enters Command mode. XCTU guides you through a reset and automatically issues the break when needed.

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.



The preceding example changes NI (Node 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 hexidecimal 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 XBee/XBee-PRO DigiMesh 2.4 responds with **OK<cr>** if successful and **ERROR<cr>** if not.

For devices with a file system:

ATAP1<cr>

OK<cr>

When reading parameters, the device returns the current parameter value instead of an **OK** message.

ATAP<cr>

1<cr>

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.

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.

Configure the XBee/XBee-PRO DigiMesh 2.4

Software libraries

One way to communicate with the XBee/XBee-PRO DigiMesh 2.4 is by using a software library. The libraries available for use with the XBee/XBee-PRO DigiMesh 2.4 include:

- XBee Java library
- XBee Python library
- XBee ANSI C 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.

The XBee ANSI C Library project is a collection of portable ANSI C code for communicating with the devices in API mode.

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.

Click **Discover devices** and follow the instructions. XCTU should discover the connected XBee/XBee-PRO DigiMesh 2.4s using the provided settings.

Click **Add selected devices**.The devices appear in the **Radio Modules** list. You can click a module to view and configure its individual settings. For more information on these items, see AT commands.

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.

Serial communication

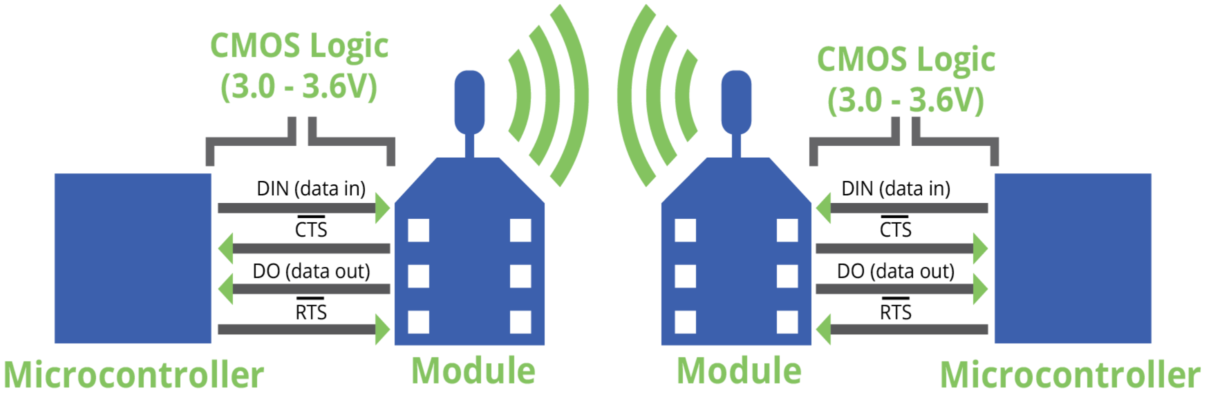
Serial interface

The XBee/XBee-PRO DigiMesh 2.4 provides a serial interface to an RF link. The XBee/XBee-PRO DigiMesh 2.4 converts serial data to RF data and sends that data to any device in an RF network. The device can communicate through its serial port with any logic and voltage compatible universal asynchronous receiver/transmitter (UART) or through a level translator to any serial device.

UART data flow

The XBee/XBee-PRO DigiMesh 2.4 device’s UART performs tasks such as checking timing and parity, which is required for data communications.

Devices that have a UART interface connect directly to the pins of the XBee/XBee-PRO DigiMesh 2.4 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.

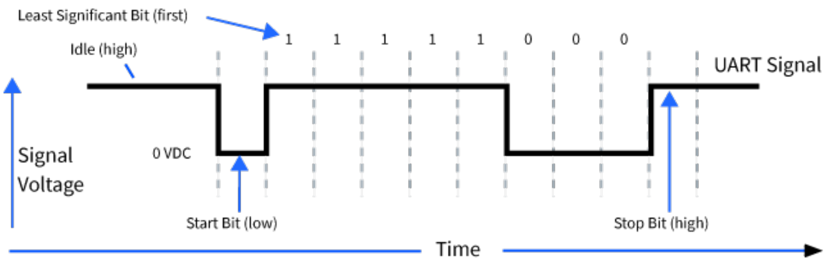


Serial data

A device sends data to the XBee/XBee-PRO DigiMesh 2.4's UART through pin 3 DIN as an asynchronous serial signal. When the device is not transmitting data, the signals should idle high.

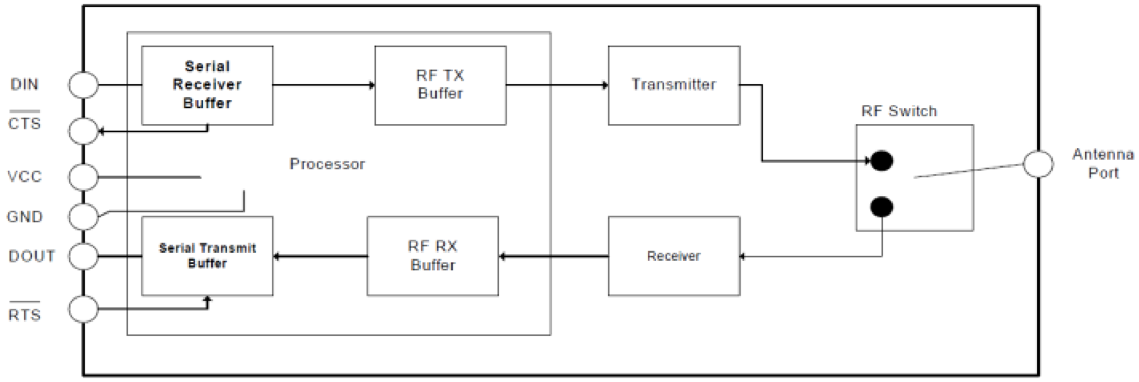
For serial communication to occur, you must configure the UART of both devices (the microcontroller and the XBee/XBee-PRO DigiMesh 2.4) with compatible settings for the baud rate, parity, start bits, stop bits, and data bits.

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.



Serial buffers

The XBee/XBee-PRO DigiMesh 2.4 maintains internal 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.



Serial buffer issues

There are potential overflow and dropped packet issues, which the following section describes.

Serial receive buffer

Under certain conditions, the device may not be able to process data in the serial receive buffer immediately. If a host sends large amounts of serial data to the device, the device may require CTS flow control to avoid overflowing the serial receive buffer.

Cases in which the serial receive buffer may become full and possibly overflow:

1. If the device receives a continuous stream of RF data, it does not transmit the data in the serial receive buffer until the device stops receiving RF data.
2. For mesh networking firmware, if the device transmits an RF data packet, the device may need to discover the destination address or establish a route to the destination. After transmitting the data, the device may need to retransmit the data if it does not receive an acknowledgment, or if the transmission is a broadcast. These issues could delay the processing of data in the serial receive buffer.

Serial transmit buffer

If the serial transmit buffer becomes full enough that all of the data in a received RF packet will not fit in the serial transmit buffer, it drops the entire RF data packet.

Cases in which the serial transmit 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.

Serial flow control

The RTS and CTS device pins provide RTS and/or CTS flow control. CTS flow control signals the host to stop sending serial data to the device. RTS flow control lets the host signal the device so it will not send the data in the serial transmit buffer out the UART. Use the **D6** and **D7** commands to enable RTS and CTS flow control.

CTS flow control

CTS flow control is enabled by default; you can disable it with the **D7** command. When the serial receive buffer fills with the number of bytes specified by the **FT** parameter, the device de-asserts CTS (sets it high) to signal the host device to stop sending serial data. The device re-asserts CTS when less than FT-16 bytes are in the UART receive buffer; for more information, see FT (Flow Control Threshold).

RTS flow control

If you send the **D6** command to enable 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.

Work with networked devices

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.

Local configuration

You can configure devices locally using serial commands in Transparent or API mode, or remotely using remote API 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 - 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.

The firmware only supports unicasts of remote commands. You cannot broadcast remote commands.

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.

Establish and maintain network links

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 send 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 0xFFFE. 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 - 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 example three, below.

Example three:

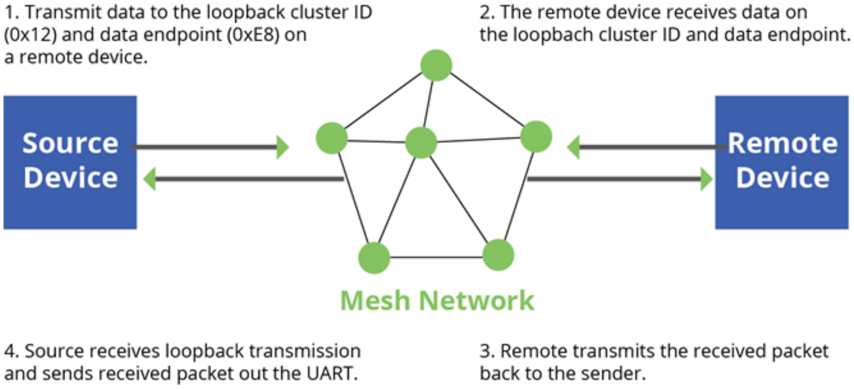
This example shows how to cause all devices to update their **DH** and **DL** registers to the MAC address of the sending device. In this case, assume you are using a device with a serial number of 0x0013A200 4052C507 as a network aggregator, and the sending device has a MAC address of 0x0013A200 F5E4D3B2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

To measure the performance of a network, you can send unicast data through the network from one device to another to determine the success rate of several transmissions. To simplify link testing, the devices support a Loopback cluster ID (0x12) on the data endpoint (0xE8). The cluster ID on the data endpoint sends any data transmitted to it back to the sender.

The following figure demonstrates how you can use the Loopback cluster ID and data endpoint to measure the link quality in a mesh network.


1. Transmit data to the loopback cluster ID (0x12) and data endpoint (0xE8) on a remote device.
2. The remote device receives data on the loopbach cluster ID and data endpoint.
Source Device
Remote Device
Mesh Network
4. Source receives loopback transmission and sends received packet out the UART.
3. Remote transmits the received packet back to the sender.

The configuration steps for sending data to the loopback cluster ID depend on what mode the device is in. For details on setting the mode, see AP (API Mode). The following sections list the steps based on the device's mode.

Transparent operating mode configuration (AP = 0)

To send data to the loopback cluster ID on the data endpoint of a remote device:

1. Set the **CI** command to **0x12**.
2. Set the **DH** and **DL** commands to the address of the remote device.

After exiting Command mode, the device transmits any serial characters it received to the remote device, which returns those characters to the sending device.

API operating mode configuration (AP = 1 or AP = 2)

Send an Explicit Addressing Command Request - 0x11 using **0x12** as the cluster ID and **0xE8** as both the source and destination endpoint.

The remote device echoes back the data packets it receives to the sending 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.

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. Use the **PO** command to enable the RSSI pulse-width modulation (PWM) functionality.
2. Use the RSSI/PWM module pin (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.

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 (Node 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 delay window for all devices in the network.
- The default **NT** value is 0x82 (13 seconds).

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) frame contains 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.
- Other link quality information.

For a full description of the Route Information Packet frame, see Route Information - 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.

Discover devices within RF range

- 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 Local AT Command Request - 0x08.

To use **FN** remotely, send the target node a Remote AT Command Request - 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 Local AT Command Response - 0x88.

NACK messages

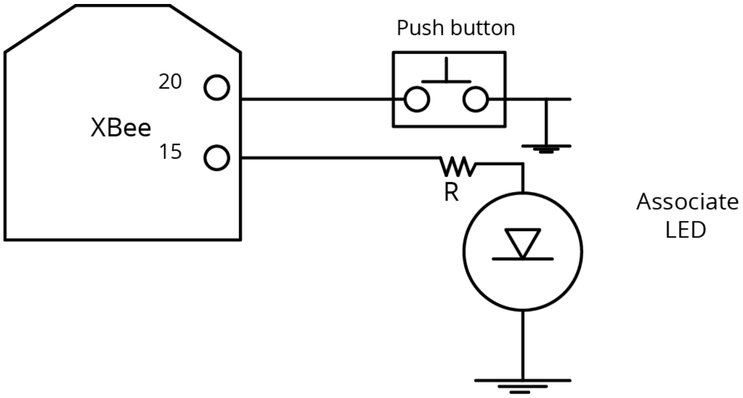
Transmit Request (0x10 and 0x11) frames contain a negative-acknowledge character (NACK) API option (Bit 2 of the Transmit Options field).

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.

The Commissioning Pushbutton

The XBee/XBee-PRO DigiMesh 2.4 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 **D0** command to 1. The functionality is enabled by default.

You must perform multiple button presses within two seconds.

The following table provides the pushbutton definitions.

Button presses	Sleep configuration and sync status	Action
1	Not configured for sleep	Immediately sends a Node Identification broadcast transmission. All devices that receive this transmission blink their Associate LED rapidly for one second. All devices in API operating mode that receive this transmission send a Node Identification Indicator frame (0x95) out their UART.

Button presses	Sleep configuration and sync status	Action
1	Configured for asynchronous sleep	Wakes the device for 30 seconds. Immediately sends a Node Identification broadcast transmission. All devices that receive this transmission blink their Associate LED rapidly for one second. All devices in API operating mode that receive this transmission send a Node Identification Indicator frame (0x95) out their UART.
1	Configured for synchronous sleep	Wakes the module for 30 seconds or until the synchronized network goes to sleep. Queues a Node Identification broadcast transmission that it sends at the beginning of the next network wake cycle. All devices that receive this transmission blink their Associate LED rapidly for one second. All devices in API operating mode that receive this transmission send a Node Identification Indicator frame (0x95) out their UART.
2	Not configured for synchronous sleep	No effect.
2	Configured for synchronous sleep	Causes a node configured with sleeping router nomination enabled to immediately nominate itself as the network sleep coordinator. For more information, see SO (Sleep Options).
4	Any	Sends an **RE** command to restore device parameters to default values.

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 - 0x95 is similar to Remote AT Command Response- 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.

If you enable the Commissioning Pushbutton during sleep, it increases the sleeping current draw, especially in Asynchronous pin sleep (**SM** = **1**) mode. When asleep, hold down the Commissioning Pushbutton for up to two seconds to wake the device from sleep, then issue the two or four button presses.

Associate LED

The Associate pin (pin 15) provides an indication of the device's sleep status and diagnostic information. 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 Associate pin indicates the synchronization status of a sleep compatible XBee/XBee-PRO DigiMesh 2.4. If a device is not sleep compatible, 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: 500 ms for a sleep coordinator, 250 ms otherwise.

The following table describes the Associate LED functionality.

Sleep mode	LED status	Meaning
0	On, blinking	The device has power and is operating properly
1, 4, 5	Off	The device is in a low power mode
1, 4, 5	On, blinking	The device has power, is awake and is operating properly
7	On, solid	The network is asleep, or the device has not synchronized with the network, or has lost synchronization with the network
7, 8	On, slow blinking (500 ms blink time)	The device is acting as the network sleep coordinator and is operating properly
7, 8	On, fast blinking (250 ms blink time)	The device is properly synchronized with the network
8	Off	The device is in a low power mode
8	On, solid	The device has not synchronized or has lost synchronization with the network

Diagnostics support

The Associate pin works with the Commissioning Pushbutton to provide additional diagnostic behaviors to aid in deploying and testing a network. If you press the Commissioning Pushbutton once, the device transmits a broadcast Node Identification Indicator (0x95) frame at the beginning of the next wake cycle if the device is sleep compatible, or immediately if the device is not sleep compatible. If you enable the Associate LED functionality using the **D5** command, a device that receives this transmission blinks its Associate pin rapidly for one second.

Monitor I/O lines

Pin command parameter	Description
0	Unmonitored digital input
1	Reserved for pin-specific alternate functionality
2	Analog input (A/D pins) or PWM output (PWM pins)
3	Digital input, monitored
4	Digital output, low
5	Digital output, high
6-9	Alternate functionality, where applicable

The following table provides the pin configurations when you set the configuration command for a particular pin.

Device pin name	Device pin number	Configuration command
CD / DIO12	4	**P2**
PWM0 / RSSI / DIO10	6	**P0**
PWM1 / DIO11	7	**P1**
$\overline{\text{DTR}}$ / SLEEP_RQ / DIO8	9	**D8**
AD4 / DIO4	11	**D4**
$\overline{\text{CTS}}$/ DIO7	12	**D7**
ON/$\overline{\text{SLEEP}}$/ DIO9	13	**D9**
ASSOC / AD5 / DIO5	15	**D5**
$\overline{\text{RTS}}$ / DIO6	16	**D6**
AD3 / DIO3	17	**D3**
AD2 / DIO2	18	**D2**
AD1 / DIO1	19	**D1**
AD0 / DIO0 / Commissioning Pushbutton	20	**D0**

Use the **PR** command to enable internal pull up/down resistors for each digital input. Use the **PD** command to determine the direction of the internal pull up/down resistor.

Queried sampling

You can use the **IS** command to query the current state of all digital input and ADC lines on the device. If no inputs are defined, the command returns with an ERROR.

If you send the **IS** command from Command mode, then the device returns a carriage return delimited list containing the following fields.

Field	Name	Description
1	Sample sets	Number of sample sets in the packet. Always set to 1.
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 = AD0/DIO0 bit 1 = AD1/DIO1 bit 2 = AD2/DIO2 bit 3 = AD3/DIO3 bit 4 = DIO4 bit 5 = ASSOC/DIO5 bit 6 = RTS/DIO6 bit 7 = CTS/GPIO7 bit 8 = DTR / SLEEP_RQ / DIO8 bit 9 = ON_SLEEP / DIO9 bit 10 = RSSI/DIO10 bit 11 = PWM/DIO11 bit 12 = CD/DIO12 For example, a digital channel mask of 0x002F means DIO0,1,2,3, and 5 are enabled as digital I/O.
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. bit 0 = AD0/DIO0 bit 1 = AD1/DIO1 bit 2 = AD2/DIO2 bit 3 = AD3/DIO3 bit 4 = AD4/DIO4 bit 5 = ASSOC/AD5/DIO5
Variable	Sampled data set	If you enable any digital I/O lines, the first two bytes of the data set indicate the state of all enabled digital I/O. Only digital channels that you enable in the Digital channel mask bytes have any meaning in the sample set. If do not enable any digital I/O on the device, it omits these two bytes. Following the digital I/O data (if there is any), each enabled analog channel returns two bytes. The data starts with AIN0 and continues sequentially for each enabled analog input channel up to AIN5.

Example	Sample AT response
0x01	[1 sample set]
0x0C0C	[Digital Inputs: DIO 2, 3, 10, 11 enabled]
0x03	[Analog Inputs: A/D 0, 1 enabled]

Example	Sample AT response
0x0408	[Digital input states: DIO 3, 10 high, DIO 2, 11 low]
0x03D0	[Analog input: ADIO 0 = 0x3D0]
0x0124	[Analog input: ADIO 1 =0x120]

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. Use the **IR** command to set the periodic sample rate.

- To disable periodic sampling, set **IR** to **0**.
- For all other **IR** values, the firmware samples data when **IR** milliseconds elapse and the sample data transmits to a remote device.

The **DH** and **DL** commands determine the destination address of the I/O samples.

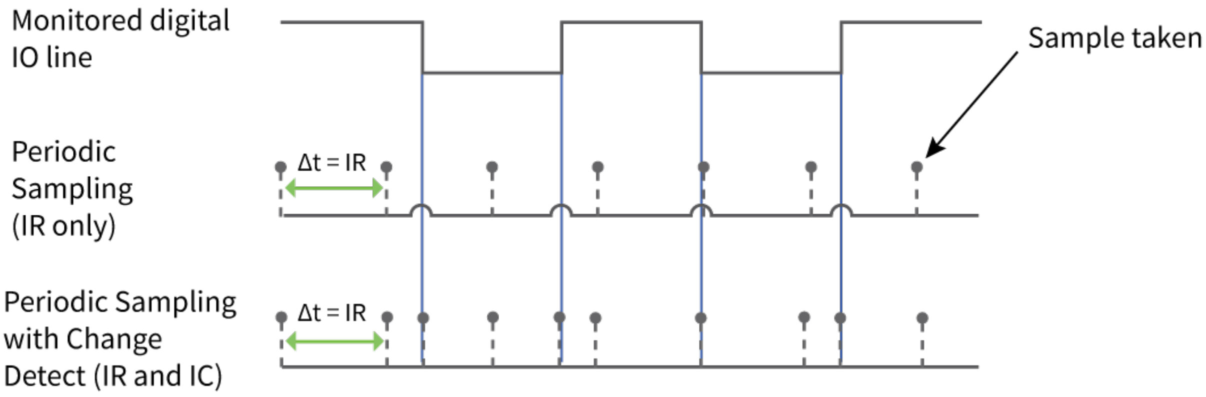
Only devices with API operating mode enabled send I/O data samples out their serial interface. Devices that are in Transparent mode (**AP** = **0**) discard the I/O data samples they receive. You must configure at least one pin as a digital or ADC input to generate sample data.

A device with sleep enabled transmits periodic I/O samples at the **IR** rate until the **ST** time expires and the device can resume sleeping. For more information about setting sleep modes, see Sleep modes.

Detect digital I/O changes

You can configure devices to transmit a data sample immediately whenever a monitored digital I/O pin changes state. The **IC** command is a bitmask that you use to set 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 in one of the monitored digital I/O lines using edge detection.

The figure below shows how I/O change detection can work with periodic sampling. 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 **IR** samples, the bottom graph shows a combination of **IR** samples and **IC** (Change Detect). 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.


Monitored digital IO line
Sample taken
Periodic Sampling (IR only)
Δt = IR
Periodic Sampling with Change Detect (IR and IC)
Δt = IR

Note Use caution when combining Change Detect sampling with sleep modes. **IC** only causes a sample to be generated if the change takes place during a wake period. If the device is sleeping when the digital input transition occurs, then no change is detected and an I/O sample is not generated.

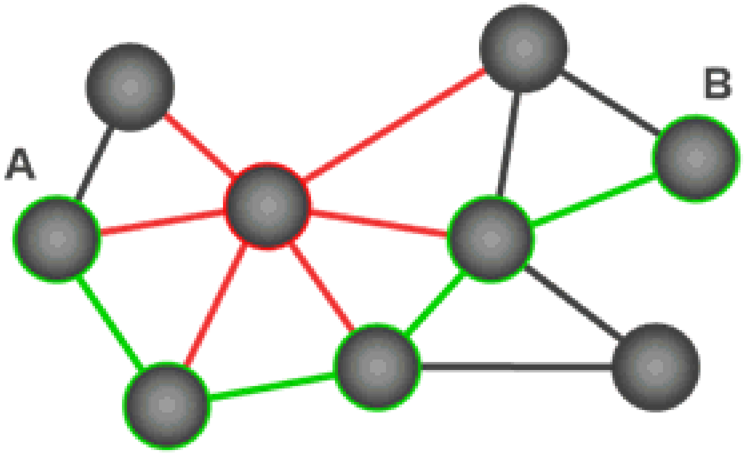
Use **IR** in conjunction with **IC** in this instance, since **IR** generates an I/O sample upon wakeup and ensures that the change is properly observed.

Network configurations

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.
- **Sleep modes.** Low power sleep modes with synchronized wake are supported with variable sleep and wake times.



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 administration and therefore have less available for payloads.

Routers and end devices

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.

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 XBee/XBee-PRO DigiMesh 2.4 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. XBee devices support all 16 channels and XBee-PRO devices support 12 of the 16 channels.

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).

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.

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.

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.

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.

DigiMesh throughput

Throughput in a DigiMesh network can vary due to a number of variables, including:

- The number of hops.
- If you enable or disable encryption.
- Sleeping end devices.
- Failures and route discoveries.

Our empirical testing shows the following throughput performance in a robust operating environment with low interference.

Configuration	Data throughput
1 hop, encryption disabled	27.0 kb/s
3 hop, encryption disabled	10.9 kb/s
6 hop, encryption disabled	5.78 kb/s
1 hop, encryption enabled	20.5 kb/s
3 hop, encryption enabled	9.81 kb/s
6 hop, encryption enabled	4.70 kb/s

We performed data throughput measurements with the serial interface rate set to 115200 b/s, and measured the time to send 100,000 bytes from the source to the destination. During the test, there were no route discoveries or failures.

Transmission timeouts

When a device in API operating mode receives a Transmit Request (0x10, 0x11) frame, or a device in Transparent operating mode meets the packetization requirements (**RO**, **RB**), the time required to route the data to its destination depends on:

- A number of configured parameters.
- Whether the transmission is a unicast or a broadcast.
- If the route to the destination address is known.

Timeouts or timing information is provided for the following transmission types:

- Broadcast transmission
- Unicast transmission on a known route

- Unicast transmission on an unknown route
- Unicast transmission on a broken route

Note The timeouts in this documentation are theoretical timeouts and are not precisely accurate. Your application should pad the calculated maximum timeouts by a few hundred milliseconds. When you use API operating mode, use Extended Transmit Status - 0x8B as the primary method to determine if a transmission is complete.

Unicast one hop time

unicastOneHopTime is a building block of many of the following calculations. It represents the amount of time it takes to send a unicast transmission between two adjacent nodes. The amount of time depends on the **RR** parameter.

DigiMesh networks assume that the average number of MAC-level retries across a multi-hop wireless link will be three or less. The following table defines the retires and the associated time.

RR (mac retries)	Unicast one hop time
0	unicastOneHopTime = 5 ms
1	unicastOneHopTime = 24 ms
2	unicastOneHopTime = 40 ms
3	unicastOneHopTime = 63 ms

Transmit a broadcast

All of the routers in a network must relay a broadcast transmission.

The maximum delay occurs when the sender and receiver are on the opposite ends of the network.

The **NH** and **%H** parameters define the maximum broadcast delay as follows:

BroadcastTxTime = NH * NN * %8

Unless **BH** < **NH**, in which case the formula is:

BroadcastTxTime = BH * NN * %8

Transmit a unicast with a known route

When a device knows a route to a destination node, the transmission time is largely a function of the number of hops and retries. The timeout associated with a unicast assumes that the maximum number of hops is necessary, as specified by the **NH** command.

You can estimate the timeout in the following manner:

knownRouteUnicastTime=2*NH*MR*unicastOneHopTime

Transmit a unicast with an unknown route

If the transmitting device does not know the route to the destination, it begins by sending a route discovery. If the route discovery is successful, then the transmitting device transmits data. You can estimate the timeout associated with the entire operation as follows:

unknownRouteUnicastTime=BroadcastTxTime+
(**NH***unicastOneHopTime)+knownRouteUnicastTime

Transmit a unicast with a broken route

If the route to a destination node changes after route discovery completes, a node begins by attempting to send the data along the previous route. After it fails, it initiates route discovery and, when the route discovery finishes, transmits the data along the new route. You can estimate the timeout associated with the entire operation as follows:

brokenRouteUnicastTime=BroadcastTxTime+(NH*unicastOneHopTime)+
(2*knownRouteUnicastTime)

Sleep modes

About sleep modes

A number of low-power modes exist to enable devices to operate for extended periods of time on battery power. Use the **SM** command to enable these sleep modes. The sleep modes are characterized as either:

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

In DigiMesh 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** parameter set so that it will not participate in coordinator 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 does not apply in a mesh network. It can only operate over one hop where a designated node holds messages for the sleeping node.

Asynchronous modes

- Do not use asynchronous sleep modes in a synchronous sleeping network, and vice versa.
- 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 the **CE** command. This prevents the node from attempting to route data.

Synchronous 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 forms a cyclic sleeping network.

- 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 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.

Normal mode

Set **SM** to 0 to enter Normal mode.

Normal mode is the default sleep mode. If a device is in this mode, it does not sleep and is always awake.

Use mains-power for devices in Normal mode.

A device in Normal mode synchronizes to a sleeping network, but does not observe synchronization data routing rules; it routes data at any time, regardless of the network's wake state.

When synchronized, a device in Normal mode relays sync messages that sleep-compatible nodes generate, but does not generate sync messages itself.

Once a device in Normal mode synchronizes with a sleeping network, you can put it into a sleep-compatible sleep mode at any time.

Asynchronous pin sleep mode

Set **SM** to 1 to enter asynchronous pin sleep mode.

Pin sleep allows the device to sleep and wake according to the state of the $\overline{\text{SLEEP\_RQ}}$ pin (pin 9).

When you assert SLEEP_RQ (high), the device finishes any transmit or receive operations and enters a low-power state.

When you de-assert SLEEP_RQ (low), the device wakes from pin sleep.

Asynchronous cyclic sleep mode

Set **SM** to 4 to enter asynchronous cyclic sleep mode.

Cyclic sleep allows the device to sleep for a specific time and wake for a short time to poll.

If the device receives serial or RF data while awake, it extends the time before it returns to sleep by the specific amount the **ST** command provides. Otherwise, it enters sleep mode immediately.

The ON_$\overline{\text{SLEEP}}$ line (pin 13) is asserted (high) when the device wakes, and is de-asserted (low) when the device sleeps.

If you use the **D7** command to enable hardware flow control, the $\overline{\text{CTS}}$ pin asserts (low) when the device wakes and can receive serial data, and de-asserts (high) when the device sleeps.

Asynchronous cyclic sleep with pin wake up mode

Set **SM** to 5 to enter asynchronous cyclic sleep with pin wake up mode.

This mode is a slight variation on asynchronous cyclic sleep mode (**SM** = 4) that allows you to wake a device prematurely by asserting the SLEEP_RQ pin (pin 9).

In this mode, you can wake the device after the sleep period expires, or if a high-to-low transition occurs on the SLEEP_RQ pin.

Synchronous sleep support mode

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

A device in synchronous sleep support mode synchronizes itself with a sleeping network, but does not sleep itself. At any time, the node responds to new nodes that attempt to join the sleeping network with a sync message. A sleep support node only transmits normal data when the other nodes in the sleeping network are awake.

Sleep support nodes are especially useful:

- When you use them as preferred sleep coordinator nodes.
- As aids in adding new nodes to a sleeping network.

Note Because sleep support nodes do not sleep, they should be mains powered.

Synchronous cyclic sleep mode

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_$\overline{\text{SLEEP}}$ enabled) on a cyclic sleep node, the ON_$\overline{\text{SLEEP}}$ line asserts when the device is awake and de-asserts when the device is asleep.

If **D7** = 1, the device de-asserts $\overline{\text{CTS}}$ 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.

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 DigiMesh 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 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.

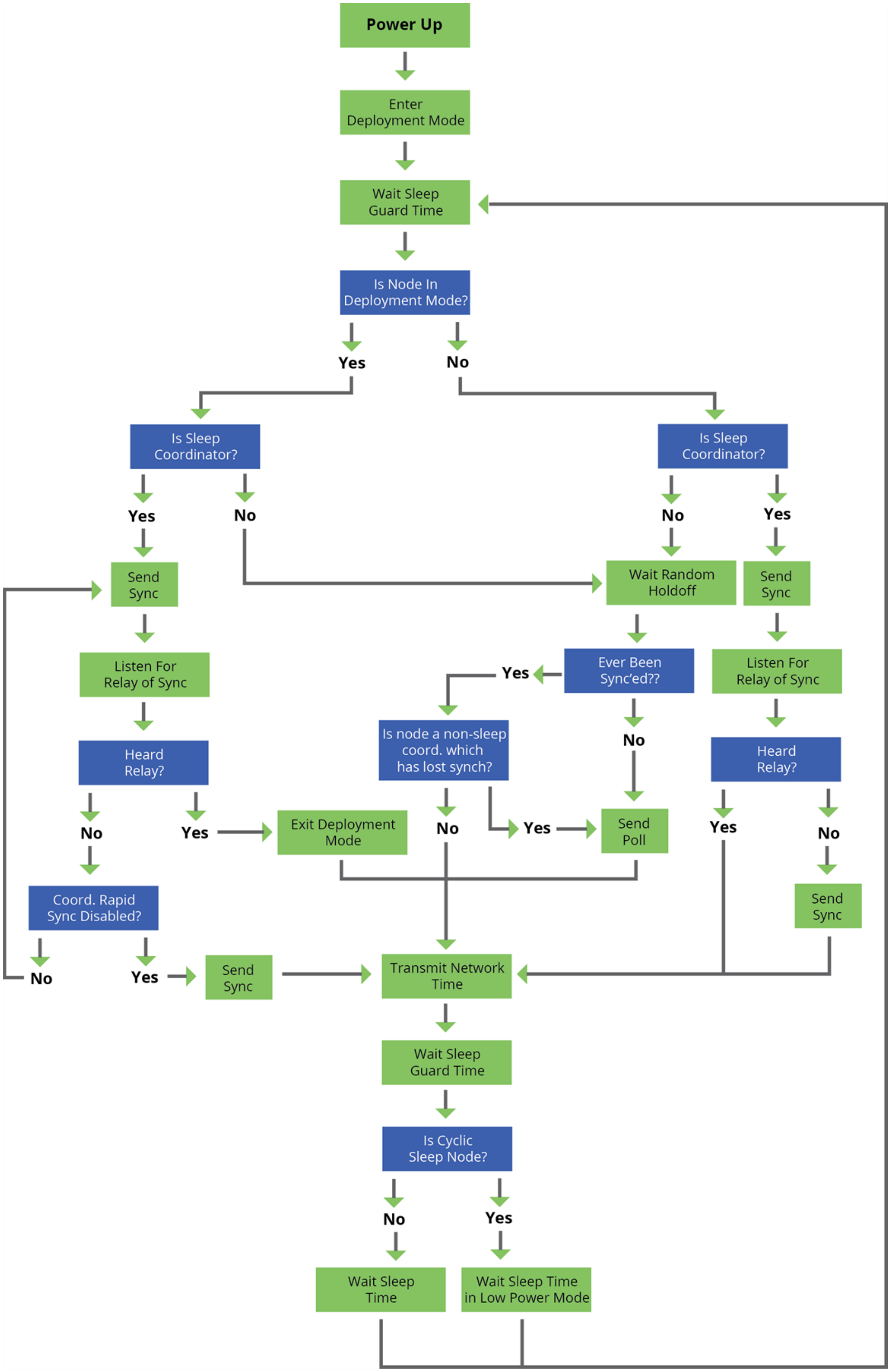
Use the **SO** (sleep options) command to disable deployment mode. This option is enabled by default.

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.


Power Up
Enter Deployment Mode
Wait Sleep Guard Time
Is Node In Deployment Mode?
Yes
No
Is Sleep Coordinator?
Yes
No
Is Sleep Coordinator?
No
Yes
Send Sync
Wait Random Holdoff
Send Sync
Listen For Relay of Sync
Yes
Ever Been Sync'ed??
Listen For Relay of Sync
Is node a non-sleep coord. which has lost synch?
No
Heard Relay?
Heard Relay?
No
Yes
Exit Deployment Mode
No
Yes
Send Poll
Yes
No
Coord. Rapid Sync Disabled?
Send Sync
No
Yes
Send Sync
Transmit Network Time
Wait Sleep Guard Time
Is Cyclic Sleep Node?
No
Yes
Wait Sleep Time
Wait Sleep Time in Low Power Mode

Become a sleep coordinator

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

- Define a preferred 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

Preferred sleep coordinator option

You can specify that a node always act as a sleep coordinator. To do this, set the preferred 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 preferred 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 preferred 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, it is best to disable the preferred sleep coordinator bit.

Resolution criteria and selection option

There is an optional selection process with resolution criteria that occurs on a node if it loses contact with the network sleep coordinator. By default, this process is disabled. Use the **SO** command to enable this process. This process occurs automatically if a node loses contact with the previous sleep coordinator.

If you enable the process on any sleep compatible node, it is eligible to become the sleep coordinator for the network.

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

- Misses three or more sync messages.
- It is not configured as a non-coordinator by setting bit 1 of **SO**.

If such a node wins out in 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 always take priority over older sleep parameters. The age of the sleep parameters is determined by a sequence number that increments when an overriding sync is sent.
2. Otherwise, the node with the preferred sleep coordinator bit set takes precedence.
3. Otherwise, a sleep support node—**SM 7**—takes priority over a node that is not a sleep support node—**SM 8**.
4. Otherwise, the node with highest serial number becomes the sleep coordinator.

Commissioning Pushbutton option

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 potential 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**, than 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 will not 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 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:
   SMPT = **NN***NH***(**MT**+1)*18 ms.
3. Select the duty cycle you want.
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 preferred 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 preferred sleep coordinator option bit on the sleep coordinator unless you want a preferred 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 preferred sleep coordinator in the network, deploy it first.
2. If there will not be a preferred 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 holding down the Commissioning Pushbutton for two seconds, or until the node wakes. 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 use a preferred 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 sleep parameters, that node becomes the network's sleep coordinator unless it has the non-sleep coordinator option selected. It sends a sync message with the new sleep settings to the entire network at the beginning of the next wake cycle. The network immediately begins using the new sleep parameters after it sends this sync.

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.

When you use the default DigiMesh sleep parameters, separated subnets do not drift out of phase with each other. Subnets can drift out of phase with each other if you configure the network in one of the following ways:

- If you disable the non-sleep coordinator bit in the **SO** command on multiple devices in the network, they are eligible for the network to nominate them as a sleep coordinator. For more details, see SO (Sleep Options).
- If the devices in the network do not use the auto early wake-up sleep option.

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.

AT commands

Special commands

The following commands are special commands.

AC (Apply Changes)

Immediately applies new settings without exiting Command mode.

Parameter range

N/A

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

RE (Restore Defaults)

Restore device parameters to factory defaults.

Parameter range

N/A

Default

N/A

WR (Write)

Writes parameter values to non-volatile memory so that parameter modifications persist through subsequent resets.

Note Once you issue a **WR** command, do not send any additional characters to the device until after you receive the **OK** response.

Parameter range

N/A

Default

N/A

MAC/PHY commands

The following AT commands are MAC/PHY commands.

CH (Operating Channel)

Set or read the operating channel devices used to transmit and receive data. The channel is one of three addressing configurations available to the device. The other configurations are the PAN ID (**ID** command) and destination addresses (**DL** and **DH** commands).

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. Adjacent channel rejection is 23 dB.

The command uses 802.15.4 channel numbers. Center frequency = 2405 MHz + (**CH** - 11 decimal) * 5 MHz.

Parameter range

0xB - 0x1A

Default

0xC (12 decimal)

ID (Network ID)

Set or read the user network identifier.

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

Devices can only communicate with other devices that have the same network identifier and channel configured.

When receiving a packet, the device check this after the preamble ID. If you are using Original equipment manufacturer (OEM) network IDs, **0xFFFF** uses the factory value.

Parameter range

0 - 0xFFFF

Default

0x7FFF

MT (Broadcast Multi-Transmits)

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

Parameter range

0 - 0xF

Default

3

CA (CCA Threshold)

Set or read 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.

Setting the parameter to 0x00 disables CCA, otherwise the valid range is 0x24 - 0x50.

Parameter range

0x0 - 0x50 -dBm

Default

0x0 (CCA disabled)

Example

If you set the **CA** parameter to 60 (0x3C), the device does not transmit if it detects a signal greater than -60 dBm on the channel.

ETSI compliance (Europe)

Use the following settings for ETSI compliance.

Device	Hex value	Sets to level
XBee	0x3A	-58 dBm
XBee-PRO	0x43	-67 dBm

PL (TX Power Level)

Sets or displays the power level at which the device transmits conducted power. Power levels are approximate.

For XBee, **PL** = **4**, **PM** = **1** is tested at the time of manufacturing. Other power levels are approximate.

On channel 26, transmitter power will not exceed -4 dBm.

Parameter range

0 - 4

These parameters equate to the following settings for the XBee RF module:

Setting	Power level
0	-7 dBm
1	-1.7 dBm
2	-0.77 dBm
3	+0.62 dBm
4	+1.42 dBm

These parameters equate to the following settings for the XBee-PRO RF module:

Setting	Power level
0	+10 dBm
1	+12 dBm
2	+14 dBm
3	+16 dBm
4	+18 dBm

Default

4

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)

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 - 0x3A98 (15 seconds)

Default

N/A

BC (Bytes Transmitted)

The number of RF bytes transmitted. The firmware counts every byte of every packet, including MAC/PHY headers and trailers. The purpose of this count is to estimate battery life by tracking time spent performing transmissions.

This number rolls over to **0** from **0xFFFF**.

You can reset the counter to any unsigned 16-bit value by appending a hexadecimal parameter to the command.

Parameter range

0 - 0xFFFF

Default

0

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 XBee/XBee-PRO DigiMesh 2.4 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

N/A

Default

0

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

N/A

Default

N/A

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

Default

Parameter range

N/A

Default

N/A

TR (Transmission Failure Count)

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

Parameter range

N/A

Default

N/A

UA (Unicasts Attempted Count)

The number of unicast transmissions expecting an acknowledgment (when **RR** > 0).

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

Parameter range

0 - 0xFFFF

Default

0

%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.

Parameter range

[read-only]

Default

N/A

0x267

%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.

Parameter range

[read-only]

Default

N/A

Network commands

The following commands are network commands.

CE (Routing / Messaging Mode)

The routing and messaging mode of the device.

End devices do not propagate broadcasts and will not become intermediate nodes on a route.

Parameter range

0 - 2

Parameter	Description	Routes packets
0	Standard router	Yes
1	N/A	N/A
2	End device	No

Default

0

BH (Broadcast Hops)

The maximum transmission hops for broadcast data transmissions.

If you set **BH** greater than **NH**, the device uses the value of **NH**.

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. 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.

Parameter range

1 - 0x20 (1 - 32 hops)

Default

7

DM (DigiMesh Options)

A bit field mask that you can use to enable or disable DigiMesh 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

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

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

Addressing commands

The following AT commands are addressing commands.

SH (Serial Number High)

Displays the upper 32 bits of the unique IEEE 64-bit extended address assigned to the product family 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 extended address assigned to the product family 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.

The destination address is also used for I/O sampling in both Transparent and API modes.

To transmit using a 16-bit address, set **DH** to 0 and **DL** less than 0xFFFF.

0x000000000000FFFF is the broadcast address.

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.

The destination address is also used for I/O sampling in both Transparent and API modes.

0x000000000000FFFF is the broadcast address.

Parameter range

0 - 0xFFFFFFFF

Default

0xFFFF

NI (Node 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 0 to 20 bytes in length. A carriage return or a comma automatically ends the command.

Default

0x20 (an ASCII space character)

NT (Network Discovery Back-off)

Sets or displays the network discovery back-off parameter for a device. This sets the maximum value for the random delay that the device uses to send network discovery responses.

The **ND**, **DN**, and **FN** commands use **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 the **ND** (Network Discovery) command 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)

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

CI (Cluster ID)

The application layer cluster ID value. The device uses this value as the cluster ID for all data transmissions.

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)

DE (Destination Endpoint)

Sets or displays the application layer destination ID value. The value is used as the destination endpoint for all data transmissions. The default value (0xE8) is the Digi data endpoint.

Parameter range

0 - 0xFF

Default

0xE8

SE (Source Endpoint)

Sets or displays the application layer source endpoint value. The value is used as the source endpoint for all data transmissions. The default value (0xE8) is the Digi data endpoint.

This command only affects outgoing transmissions in transparent mode (**AP** = **0**).

0xE8 is the Digi data endpoint used for outgoing data transmissions.

0xE6 is the Digi device object endpoint used for configuration and commands.

Parameter range

0 - 0xFF

Default

0xE8

Diagnostic - addressing commands

The following AT command is a Diagnostic - addressing command.

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

[read-only]

Default

0x3D6A

Addressing discovery/configuration commands

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.

Note The **AG** command is only available on products that support DigiMesh.

Parameter range

Any 64-bit address

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 device sets **DL** and **DH** to the extended (64-bit) address of the device with the matching **NI** string.
2. The receiving device returns **OK** (or **ERROR**).
3. The device exits Command mode to allow for immediate communication. If an ERROR is received, then Command mode does not exit.

When **DN** is sent as a Local AT Command Request - 0x08:

1. The receiving device returns 0xFFFE followed by its 64-bit extended addresses in a Remote AT Command Response- 0x97.
2. The device returns an **ERROR** message if it is given without a destination node (that is without a parameter) or if the given destination node does not respond within **N?** milliseconds.

Parameter range

20-byte ASCII string

Default

N/A

ND (Network Discover)

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

For each discovered device, the following information is returned:

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.)

After (**NT** * 100) milliseconds, the command ends by returning a <CR>. **ND** also accepts NI (Node Identifier) as a parameter (optional). In this case, only a device that matches the supplied identifier responds.

If you send **ND** through a local API frame, the device returns each response as a separate AT_CMD_Response packet. The data consists of the bytes listed above without the carriage return delimiters. The **NI** string ends in a **0x00** null character.

Parameter range

N/A

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 (Network Discovery Options) settings.)

RSSI OF LAST HOP<CR> (1 byte. Optionally included based on NO (Network Discovery Options) 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.

Parameter range

N/A

Default

N/A

Security commands

The following AT commands are security commands.

EE (Encryption Enable)

Enables or disables Advanced Encryption Standard (AES) encryption.

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)

Sets the network security key value that the device uses for encryption and decryption.

This command is write-only. 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

128-bit value

Default

N/A

Serial interfacing commands

The following AT commands are serial interfacing commands.

BD (Baud Rate)

Sets or displays the serial interface baud rate for communication between the device's serial port and the host.

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 - 0x7

Non-standard baud rates: 0x39 to 0xF4240 if the host supports it

Value	Description
0x0	1,200 b/s
0x1	2,400 b/s
0x2	4,800 b/s
0x3	9,600 b/s
0x4	19,200 b/s
0x5	38,400 b/s
0x6	57,600 b/s
0x7	115,200 b/s
0x39 to 0xF4240 if the host supports it.	

Default

0x03 (9600 b/s)

NB (Parity)

Set or read the serial parity settings for UART communications.

Parameter range

0x00 - 0x04

Parameter	Description
0x00	No parity
0x01	Even parity
0x02	Odd parity

Parameter	Description
0x03	Mark parity (forced high)
0x04	Space parity (forced low)

Default

0x00

RO (Packetization Timeout)

Set or read the number of character times of inter-character silence required before transmission begins when operating in Transparent mode.

Set **RO** to **0** to transmit characters as they arrive instead of buffering them into one RF packet.

Parameter range

0 - 0xFF (x character times)

Default

3

FT (Flow Control Threshold)

Set or display the flow control threshold.

The device de-asserts $\overline{\text{CTS}}$ and/or send XOFF when **FT** bytes are in the UART receive buffer. It re-asserts $\overline{\text{CTS}}$ when less than **FT**-16 bytes are in the UART receive buffer.

Parameter range

0x11 - 0xEE bytes

Default

0xBE

AP (API Mode)

Set or read the API mode setting. The device can format the RF packets it receives into API frames and send 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	Transparent mode, API mode is off. All UART input and output is raw data and the device uses the **RO** parameter to delineate packets.

Parameter	Description
1	API Mode Without Escapes. The device packetizes all UART input and output data in API format, without escape sequences.
2	API Mode With Escapes. The device is in API mode and inserts escaped sequences to allow for control characters. The device passes XON (0x11), XOFF (0x13), Escape (0x7D), and start delimiter 0x7E as data.

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 - 2

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

I/O settings commands

The following AT commands are I/O settings commands.

CB (Commissioning Pushbutton)

Use **CB** to simulate commissioning pushbutton presses in software.

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.

See The Commissioning Pushbutton.

See Commissioning pushbutton.

Parameter range

0 - 4

Default

N/A

D0 (DIO0/AD0)

Sets or displays the DIO0/AD0 configuration (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/AD1)

Sets or displays the DIO1/AD1 configuration (pin 19).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A
1	Commissioning button
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high
6	PTI_EN

Default

0

D2 (DIO2/AD2)

Sets or displays the DIO2/AD2 configuration (pin 18).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D3 (DIO3/AD3)

Sets or displays the DIO3/AD3 configuration (pin 17).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D4 (DIO4/AD4)

Sets or displays the DIO4/AD4 configuration (pin 11).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A

Parameter	Description
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D5 (DIO5/AD5/ASSOCIATED_INDICATOR)

Sets or displays the DIO5/AD5/ASSOCIATED_INDICATOR configuration (pin 15).

Parameter range

Parameter	Description
0	Disabled
1	Associate LED indicator - blinks when associated
2	ADC
3	Digital input
4	Digital output, default low
5	Digital output, default high

Default

1

D6 (DIO6/RTS)

Sets or displays the DIO6/$\overline{\text{RTS}}$ configuration (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)

Sets or displays the DIO7/$\overline{\text{CTS}}$ configuration (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 Tx enable, low Tx (0 V on transmit, high when idle)
7	RS-485 Tx enable high, high Tx (high on transmit, 0 V when idle)

Default

0x1

D8 (DIO8/SLEEP_REQUEST)

Sets or displays the DIO8/SLEEP_REQUEST configuration (pin 9).

This line is also used with Pin Sleep, but pin sleep ignores the **D8** configuration. It is always used to control pin sleep, regardless of configuration of **D8**.

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

D9 (ON_SLEEP)

Sets or displays the ON/$\overline{\text{SLEEP}}$ configuration (pin 13).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	ON/$\overline{\text{SLEEP}}$ output
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 PWM0/RSSI/DIO10 configuration (pin 6).

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	RSSI PWM0 output
2	PWM0 output
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

P1 (DIO11/PWM1 Configuration)

Sets or displays the DIO11/PWM1 configuration (pin 7).

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	N/A
2	PWM1 output
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

P2 (DIO12 Configuration)

Sets or displays the DIO12 configuration (pin 4).

Parameter range

1, 3 - 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

PR (Pull-up/Down Resistor Enable)

PR and **PD** only affect lines that are configured as digital inputs or disabled.

The following table defines the bit-field map for **PR** and **PD** commands.

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 resistor; 0 specifies no internal pull-up. The following table defines the bit-field map for both the **PR** and **PD** commands.

Bit	I/O line
0	DIO4/AD4
1	DIO3/AD3
2	DIO2/AD2
3	DIO1/AD1
4	DIO0/AD0
5	DIO6/$\overline{\text{RTS}}$
6	DIO8/SLEEP_REQUEST
7	DIO14/DIN/CONFIG
8	DIO5/AD6/ASSOCIATE
9	DIO9/On/$\overline{\text{SLEEP}}$
10	DIO12
11	DIO10/RSSI/PWM0
12	DIO11/PWM1
13	DIO7/$\overline{\text{CTS}}$
14	DOUT (pin 2)

Parameter range

0 - 0x7FFF (bit field)

Default

0x1FFF

M0 (PWM0 Duty Cycle)

The duty cycle of the PWM0 line (pin 6).

Use the **P0** command to configure the line as a PWM output.

Parameter range

0 - 0x3FF

Default

0

M1 (PWM1 Duty Cycle)

The duty cycle of the PWM1 line (pin 7).

Use the **P1** command to configure the line as a PWM output.

Parameter range

0 - 0x3FF

Default

0

LT (Associate LED Blink Time)

Set or read the Associate LED blink time. If you use the **D5** command 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: 500 ms for a sleep coordinator, 250 ms for all other nodes.

For all other **LT** values, the firmware measures **LT** in 10 ms increments.

Parameter range

0x14 - 0xFF (x 10 ms)

Default

0

RP (RSSI PWM Timer)

The PWM timer expiration in 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)

Default

0x28 (four seconds)

I/O sampling commands

The following AT commands configure I/O sampling parameters.

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** - **P2**). If you enable a pin as a digital I/O, use the **IC** command to force an immediate I/O sample transmission when the DIO state changes. 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 DIO12 can be sampled using a Change Detect.

Set unused bits to 0.

Bit	I/O line	Module pin
0	DIO0	33
1	DIO1	32
2	DIO2	31
3	DIO3	30
4	DIO4	24
5	DIO5	28
6	DIO6	29
7	DIO7	25
8	DIO8	10
9	DIO9	26
10	DIO10	7
11	DIO11	8
12	DIO12	5

Parameter range

0 - 0xFFFF (bit field)

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**.

Parameter range

0 - 0xFF

Default

1

IR (Sample Rate)

Set or read the I/O sample rate to enable periodic sampling. When set, this parameter causes the device to sample all enabled DIO and ADC at a specified interval.

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 (see D0 (DIO0/AD0) -D9 (ON_SLEEP), P0 (DIO10/RSSI/PWM0 Configuration)- P2 (DIO12 Configuration).

WARNING! If you set **IR** to 1 or 2, the device will not keep up and many samples will be lost.

Parameter range

0 - 0xFFFF (x 1 ms)

Default

0

IS (Force Sample)

Forces a read of all enabled digital and analog input lines. The data is returned through the UART or SPI.

When operating in Transparent mode (**AP** = 0), the data is returned in the following format:

All bytes are converted to ASCII:

number of samples<CR>

channel mask<CR>

DIO data<CR> (If DIO lines are enabled)

ADC channel Data<CR> (This will repeat for every enabled ADC channel)

<CR> (end of data noted by extra <CR>)

When operating in API mode (**AP** = 1), the command immediately returns an **OK** response. The data follows in the normal API format for DIO data.

Parameter range

N/A

Default

N/A

Sleep commands

The following AT commands are sleep commands.

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 **SM**8 nodes. Synchronized Cyclic Sleep nodes sleep for **SP** and wake for **ST** time.

Synchronous modes are not compatible with asynchronous modes.

Parameter range

0, 1, 4, 5, 7, 8

Parameter	Description
0	Normal.
1	Asynchronous Pin Sleep. In this mode, the SLEEP_RQ line controls the sleep/wake state of the device.
2	N/A
3	N/A
4	Asynchronous Cyclic Sleep. In this mode, the device periodically sleeps and wakes based on the **SP** and **ST** commands.
5	Asynchronous Cyclic Sleep Pin Wake. When you assert the SLEEP_RQ pin, the device enters a cyclic sleep mode similar to Asynchronous Cyclic Sleep. When you de-assert the SLEEP_RQ pin, the device immediately wakes up. The device does not sleep when you de-assert the SLEEP_RQ pin.
6	N/A
7	Sleep Support
8	Synchronized Cyclic Sleep

Default

0

SO (Sleep Options)

Set or read the sleep options bit field of a device. This command is a bitmask.

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

0x0 - 0xFFFF

For synchronous sleep devices, the following sleep bit field options are defined:

Bit	Option
0	Preferred 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 lone coordinator sync repeat

For asynchronous sleep devices, the following sleep bit field options are defined:

Bit	Option
8	Always wake for **ST** time

Default

0x2 (non-sleep coordinator)

SN (Number of Cycles Between ON_SLEEP)

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 Cyclic Sleep. This allows external circuitry to sleep longer than the **SP** time.

During cycles when ON_SLEEP is de-asserted, the device wakes up and checks for any serial or RF data. If it receives any such data, then it asserts the ON_SLEEP line and the device wakes up fully. Otherwise, the device returns to sleep after checking.

This command does not work with synchronous sleep devices.

Parameter range

1 - 0xFFFF

Default

1

Example

Set to 1 to set ON_SLEEP high after each **SP** time (default).

If **SN** = 3, the ON_SLEEP line asserts only every third wakeup; **SN** = 9, every ninth wakeup; and so forth.

SP (Sleep Time)

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

Parameter range

0x1 - 0x15F900 (x 10 ms)

Default

0xC8

ST (Wake Time)

Sets or displays the wake time of the device.

For devices in asynchronous sleep, **ST** defines the amount of time that a device stays awake after it receives RF or serial data.

For devices in synchronous sleep, **ST** defines the amount of time that a device stays awake when operating in cyclic sleep mode. The command adjusts the value upwards automatically if it is too small to function properly based on other settings.

For devices in synchronous sleep, the minimum wake time is a function of **MT**, **SP**, **NH**, **NN**, and platform dependent values. If you increase **SP**, **NH**, **NN**, or **MT**, the **ST** value raises automatically. The maximum value is one hour (0x36EE80 ms).

Parameter range

0x1 - 0x36EE80 (x 1 ms) (one hour)

Default

0x7D0 (3 seconds)

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.

When in synchronous sleep, the device shortens its sleep period by the **WH** value to ensure it is prepared to communicate when the network wakes up. When in this sleep mode, the device always stays awake for the **WH** time plus the amount of time it takes to transmit a one-hop unicast to another node.

Parameter range

0 - 0xFFFF (x 1 ms)

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 in its wake state.
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 **CB**2 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

[read-only]

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

N/A

Default

N/A

Command mode options

The following commands are Command mode option commands.

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.

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 Idle mode from Command mode.

Parameter range

2 - 0x1770 (x 100 ms)

Default

0x64 (10 seconds)

CN (Exit Command Mode)

Immediately exits Command Mode and applies pending changes.

Parameter range

N/A

Default

N/A

GT (Guard Times)

Set the 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.

Parameter range

0x2 - 0xCE4 (x 1 ms)

Default

0x3E8 (one second)

Firmware version/information commands

The following AT commands are firmware commands.

VL (Version Long)

Shows detailed version information including the application build date and time.

Parameter range

N/A

Default

N/A

VR (Firmware Version)

Reads the firmware version on a device.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

HV (Hardware Version)

Display the hardware version number of the device.

Parameter range

0 - 0xFFFF [read-only]

Default

Set in firmware

DD (Device Type Identifier)

Stores the Digi device type identifier value. Use this value to differentiate between multiple XBee devices.

Parameter range

0 - 0xFFFFFFFF

Default

0x50000

NP (Maximum Packet Payload Bytes)

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

Using APS encryption (API transmit option bit enabled), reduces the maximum payload size by 9 bytes.

Using source routing (**AR** < 0xFF), further reduces the maximum payload size.

Note **NP** returns a hexadecimal value. For example, if **NP** returns 0x54, this is equivalent to 84 bytes.

Parameter range

0 - 0xFFFF (bytes) [read-only]

Default

N/A

CK (Configuration CRC)

Displays the cyclic redundancy check (CRC) of the current AT command configuration settings.

This command allows you to detect an unexpected configuration change on a device. Use the code that the device returns to determine if a node has the configuration you want.

After a firmware update this command may return a different value.

Parameter range

0 - 0xFFFFFFFF

Default

N/A

Operate in API mode

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 firmware, so build the ability to filter out additional API frames with unknown frame types into your software interface.

API frame specifications

The firmware supports two API operating modes: without escaped characters and with escaped characters. Use the **AP** command to enable either mode. To configure a device to one of these modes, set the following **AP** parameter values:

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.

The firmware silently discards any data it receives prior to the start delimiter. If the device does not receive the frame correctly or if the checksum fails, the device discards the frame.

API operation (AP parameter = 1)

We recommend this 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 - n	API-specific structure
Checksum	n + 1	1 byte

API operation-with escaped characters (AP parameter = 2)

Set API to 2 to allow 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, refer to the following knowledge base article:

http://knowledge.digi.com/articles/Knowledge_Base_Article/Escaped-Characters-and-API-Mode-2

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	

Escape characters

When sending or receiving a UART data frame, you must escape (flag) specific data values 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 XOR'd with 0x20. If not escaped, 0x11 and 0x13 are sent as is.

Data bytes that need to be escaped:

- 0x7E – Frame delimiter
- 0x7D – Escape
- 0x11 – XON
- 0x13 – XOFF

Example - Raw UART data frame (before escaping interfering bytes): 0x7E 0x00 0x02 0x23 0x11 0xCB

0x11 needs to be escaped which results in the following frame: 0x7E 0x00 0x02 0x23 0x7D 0x31 0xCB

Note In the previous example, the length of the raw data (excluding the checksum) is 0x0002 and the checksum of the non-escaped data (excluding frame delimiter and length) is calculated as:
0xFF - (0x23 + 0x11) = (0xFF - 0x34) = 0xCB.

Start delimiter

This field indicates the beginning of a frame. It is always 0x7E. This allows the device to easily detect a new incoming frame.

Length

The length field specifies the total number of bytes included in the frame's data field. Its two-byte value excludes the start delimiter, the length, and the checksum.

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.

Checksum

Checksum is the last byte of the frame and helps test data integrity. It is calculated by taking the hash sum of all the API frame bytes that came before it, except the first three bytes (start delimiter and length).

The device does not process frames sent through the serial interface with incorrect checksums, and ignores their data.

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 0x47 (the two far right digits). Subtract 0x47 from 0xFF and you get 0xB8 (0xFF - 0x47 = 0xB8). 0xB8 is the checksum for this data packet.

If an API data packet is composed with an incorrect checksum, the XBee/XBee-PRO DigiMesh 2.4 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

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 (XOR'ed 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, XOR'ed 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.

Frame descriptions

The following sections describe the API frames.

API frame exchanges

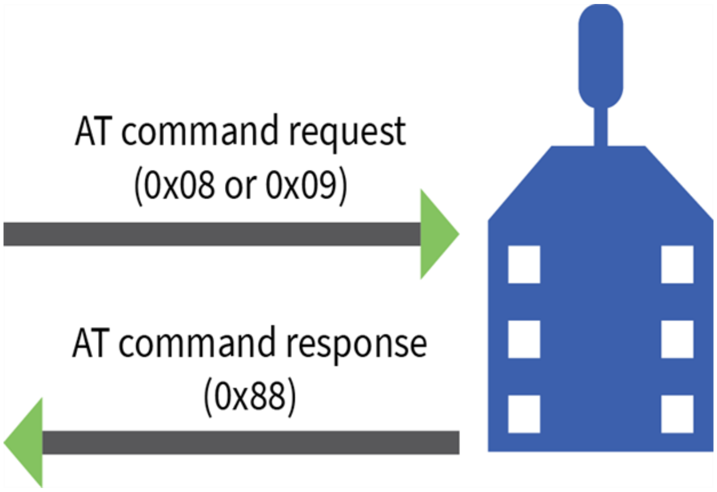
Every outgoing API frame has a corresponding response (or ACK) frame that indicates the success or failure of the outgoing API frame. This section details some of the common API exchanges that occur.

You can use the Frame ID field to correlate between the outgoing frames and associated responses.

Note Using a Frame ID of 0 disables responses, which can reduce network congestion for non-critical transmissions.

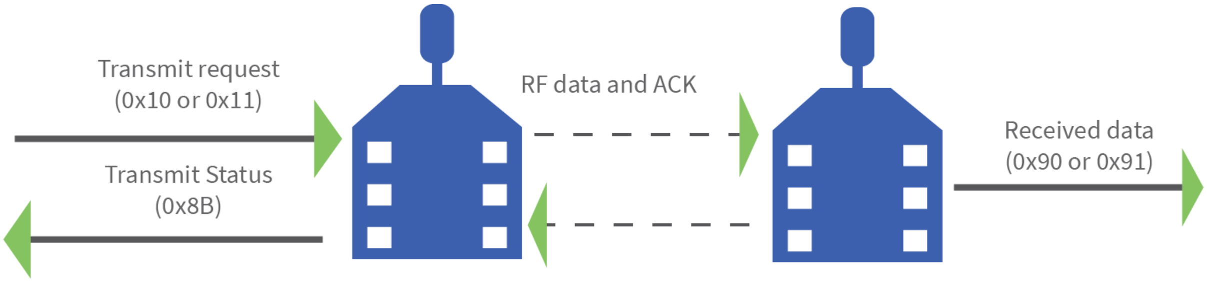
AT commands

The following image shows the API frame exchange that takes place at the UART when you send a 0x08 AT Command Request or 0x09 AT Command-Queue Request to read or set a device parameter. To disable the 0x88 AT Command Response, set the frame ID to 0 in the request.



Transmit and Receive RF data

The following image shows the API exchanges that take place on the serial interface when a device sends a 0x10, or 0x11 Transmit Request to another device.

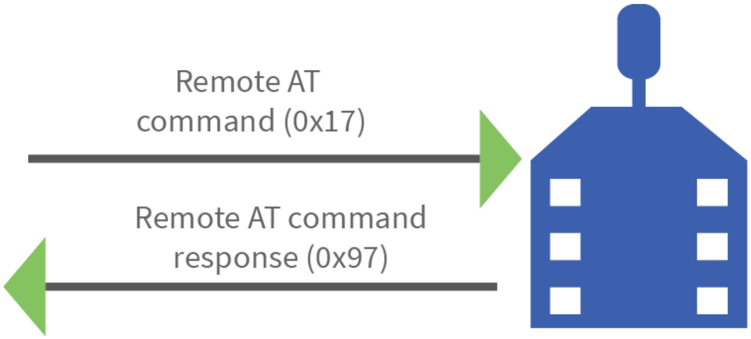


The device sends the 0x8B Transmit Status frame at the end of a data transmission unless you set the frame ID to 0 in the transmit request. If the packet cannot be delivered to the destination, the 0x8B Transmit Status frame indicates the cause of failure.

Use the **AP** command to choose the type of data frame you want to receive, either a (0x90) Receive Packet or a (0x91) Explicit Rx Indicator frame.

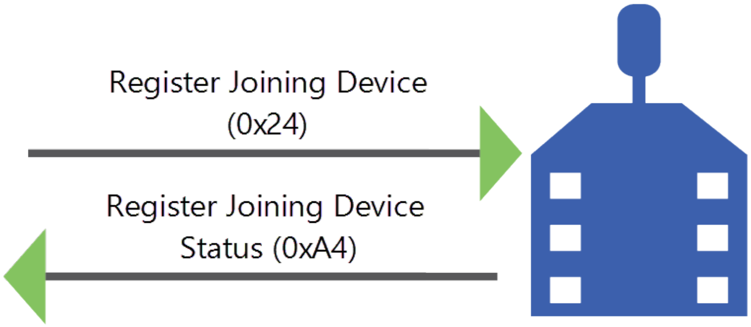
Remote AT commands

The following image shows the API frame exchanges that take place on the serial interface when you send a 0x17 Remote AT Command frame The 0x97 Remote AT Command Response is always generated and you can use it to identify if the remote device successfully received and applied the command.



Device Registration

The following image shows the API frame exchanges that take place at the serial interface when registering a joining device to a trust center.



Code to support future API frames

If your software application supports the API, you should make provisions that allow for new API frames in future firmware releases. For example, you can include the following section of code on a host microprocessor that handles serial API frames that are sent out the device's DOUT pin:

```
void XBee_HandleRxAPIFrame(_apiFrameUnion *papiFrame){
       switch(papiFrame->api_id){
               case RX_RF_DATA_FRAME:
                       //process received RF data frame
                       break;

               case RX_IO_SAMPLE_FRAME:
                       //process IO sample frame
                       break;

               case NODE_IDENTIFICATION_FRAME:
                       //process node identification frame
                       break;


               default:
                       //Discard any other API frame types that are not being used
                       break;
       }
}
```

Frame descriptions

The following sections describe the API frames.

Local AT Command Request - 0x08

Response frame: Local AT Command Response - 0x88

Description

This frame type is used to query or set command parameters on the local device. 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 Queue Local AT Command Request - 0x09 instead.

When querying parameter values, this frame behaves identically to Queue Local AT Command Request - 0x09: You can query parameter values by sending this frame with a command but no parameter value field—the two-byte AT command is immediately followed by the frame checksum. When an AT command is queried, a Local AT Command Response - 0x88 frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x88 response is the same one set by the command in the 0x08 request frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Local AT Command Request - **0x08**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to**0**, the device will not emit a response frame.
5	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
7-n	variable	**Parameter value (optional)**	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the current parameter value and returns the result in the response.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set the local command parameter

Set the **NI** string of the radio to "**End Device**".

The corresponding Local AT Command Response - 0x88 with a matching Frame ID will indicate whether the parameter change succeeded.

```
7E 00 0E 08 A1 4E 49 45 6E 64 20 44 65 76 69 63 65 38
```

Frame type	Frame ID	AT command	Parameter value
0x08	0xA1	0x4E49	0x456E6420446576696365
Request	*Matches response*	*"NI"*	*"End Device"*

Query local command parameter

Query the temperature of the module—**TP** command.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID will return the temperature value.

```
7E 00 04 08 17 54 50 3C
```

Frame type	Frame ID	AT command	Parameter value
0x08	0x17	0x5450	(omitted)
Request	*Matches response*	*"TP"*	*Query the parameter*

Queue Local AT Command Request - 0x09

Response frame: Local AT Command Response - 0x88

Description

This frame type is used to query or set queued command parameters on the local device. In contrast to Local AT Command Request - 0x08, this frame queues new parameter values and does not apply them until you either:

- Issue a Local AT Command using the 0x08 frame
- Issue an **AC** command—queued or otherwise

When querying parameter values, this frame behaves identically to Local AT Command Request - 0x08: You can query parameter values by sending this frame with a command but no parameter value field—the two-byte AT command is immediately followed by the frame checksum. When an AT command is queried, a Local AT Command Response - 0x88 frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x88 response is the same one set by the command in the 0x09 request frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Queue Local AT Command Request - **0x09**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to**0**, the device will not emit a response frame.
5	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
7-n	variable	**Parameter value (optional)**	If present, indicates the requested parameter value to set the given register at a later time. If no characters are present, it queries the current parameter value and returns the result in the response.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Queue setting local command parameter

Set the UART baud rate to 115200, but do not apply changes immediately.

The device will continue to operate at the current baud rate until the change is applied with a subsequent **AC** command.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID will indicate whether the parameter change succeeded.

```
7E 00 05 09 53 42 44 07 16
```

Frame type	Frame ID	AT command	Parameter value
0x09	0x53	0x4244	0x07
Request	*Matches response*	*"BD"*	*7 = 115200 baud*

Query local command parameter

Query the temperature of the module (**TP** command).

The corresponding Local AT Command Response - 0x88 frame with a matching Frame ID will return the temperature value.

```
7E 00 04 09 17 54 50 3B
```

Frame type	Frame ID	AT command	Parameter value
0x09	0x17	0x5450	(omitted)
Request	*Matches response*	*"TP"*	*Query the parameter*

Transmit Request - 0x10

Response frame: Extended Transmit Status - 0x8B

Description

This frame type is used to send payload data as an RF packet to a specific destination. This frame type is typically used for transmitting serial data to one or more remote devices.

The endpoints used for these data transmissions are defined by the **SE** and **EP** commands and the cluster ID defined by the **CI** command—excluding 802.15.4. To define the application-layer addressing fields on a per-packet basis, use the Explicit Addressing Command Request - 0x11 instead.

Query the **NP** command to read the maximum number of payload bytes that can be sent.

64-bit addressing

- 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

Format

The following table provides the contents of the frame. For details on the frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Transmit Request - **0x10**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response frame. If set to **0**, the device will not emit a response frame.
5	64-bit	**64-bit destination address**	Set to the 64-bit IEEE address of the destination device. Broadcast address is **0x000000000000FFFF**.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
15	8-bit	**Broadcast radius**	Sets the maximum number of hops a broadcast transmission can traverse. This parameter is only used for broadcast transmissions. If set to**0**—recommended—the value of **NH**specifies the broadcast radius.

Offset	Size	Frame Field	Description
16	8-bit	**Transmit options**	See the Transmit options bit field table below for available options. If set to **0**, the value of **TO** specifies the transmit options.
17-n	variable	**Payload data**	Data to be sent to the destination device. Up to **NP** bytes per packet.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Transmit options bit field

The available transmit options vary depending on the protocol being used. Bitfield options can be combined. Set all unused bits to **0**.

DigiMesh

Bit	Meaning	Description
0	Disable ACK [**0x01**]	Disable acknowledgments on all unicasts.
1	Disable route discoveries [**0x02**]	Disable Route Discovery on all DigiMesh unicasts.
2	Unicast NACK [**0x04**]	Enable unicast NACK messages on DigiMesh transmissions When set, a failed transmission will generate a Route Information - 0x8D frame for diagnosis.
3	Unicast trace route [**0x08**]	Enable a unicast Trace Route on DigiMesh transmissions When set, the transmission will generate a Route Information - 0x8D frame.
4	Secure Session Encryption [**0x10**]	Encrypt payload for transmission across a Secure Session. Reduces maximum payload size by 4 bytes.
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**]

Examples

Each example is written without escapes (**AP**=**1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

Sending a unicast transmission to a device with the 64-bit address of **0013A20012345678** with the serial data "**TxData**". Transmit options are set to **0**, which means the transmission will send using the options set by the **TO** command.

The corresponding Legacy TX Status frame - 0x89 response with a matching Frame ID will indicate whether the transmission succeeded.

```
7E 00 14 10 52 00 13 A2 00 12 34 56 78 FF FE 00 00 54 78 44 61 74 61 91
```

Frame type	Frame ID	64-bit dest	Reserved	Bcast radius	Options	RF data
0x10	0x52	0x0013A200 12345678	0xFFFE	0x00	0x00	0x547844617461
Request	*Matches response*	*Destination*	*Unused*	*N/A*	*Will use* ***TO***	*"TxData"*

64-bit broadcast

Sending a broadcast transmission of the serial data "**Broadcast**" to neighboring devices and suppressing the corresponding response by setting Frame ID to **0**.

```
7E 00 17 10 00 00 00 00 00 00 00 FF FF FF FE 01 00 42 72 6F 61 64 63 61 73 74 60
```

Frame type	Frame ID	64-bit dest	Reserved	Bcast radius	Tx Options	RF data
0x10	0x00	0x00000000 0000FFFF	0xFFFE	0x01	0x00	0x42726F616463617374
Request	*Suppress response*	*Broadcast address*	*Unused*	*Single hop broadcast*	*Will use* ***TO***	*"Broadcast"*

Explicit Addressing Command Request - 0x11

Response frame: Extended Transmit Status - 0x8B

Description

This frame type is used to send payload data as an RF packet to a specific destination using application-layer addressing fields. The behavior of this frame is similar to Transmit Request - 0x10, but with additional fields available for user-defined endpoints, cluster ID, and profile ID.

This frame type is typically used for OTA updates, and serial data transmissions.

Query NP (Maximum Packet Payload Bytes) to read the maximum number of payload bytes that can be sent.

64-bit addressing

- 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

Reserved endpoints

For serial data transmissions, the **0xE8** endpoint should be used for both source and destination endpoints.

The active Digi endpoints are:

- **0xE8** - Digi Data endpoint
- **0xE6** - Digi Device Object (DDO) endpoint
- **0xE5** - XBee3 - Secure Session Server endpoint
- **0xE4** - XBee3 - Secure Session Client endpoint
- **0xE3** - XBee3 - Secure Session SRP authentication endpoint

Reserved cluster IDs

For serial data transmissions, the **0x0011** cluster ID should be used.

The following cluster IDs can be used on the **0xE8** data endpoint:

- **0x0011**- Transparent data cluster ID
- **0x0012** - Loopback cluster ID:The destination node echoes any transmitted packet back to the source device. Cannot be used on XBee 802.15.4 firmware.

Reserved profile IDs

The Digi profile ID of **0xC105** should be used when sending serial data between XBee devices.

Format

The following table provides the contents of the frame. For details on the frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Explicit Addressing Command Request - **0x11**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to**0**, the device will not emit a response frame.
5	64-bit	**64-bit destination address**	Set to the 64-bit IEEE address of the destination device. Broadcast address is **0x000000000000FFFF**. Zigbee coordinator address is **0x0000000000000000**. When using 16-bit addressing, set this field to **0xFFFFFFFFFFFFFFFF**.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
15	8-bit	**Source Endpoint**	Source endpoint for the transmission. Serial data transmissions should use **0xE8**.
16	8-bit	**Destination Endpoint**	Destination endpoint for the transmission. Serial data transmissions should use **0xE8**.
17	16-bit	**Cluster ID**	The Cluster ID that the host uses in the transmission. Serial data transmissions should use **0x11**.
19	16-bit	**Profile ID**	The Profile ID that the host uses in the transmission. Serial data transmissions between XBee devices should use **0xC105**.
21	8-bit	**Broadcast radius**	Sets the maximum number of hops a broadcast transmission can traverse. This parameter is only used for broadcast transmissions. If set to **0** (recommended), the value of **NH** specifies the broadcast radius.
22	8-bit	**Transmit options**	See the Transmit options bit field table below for available options. If set to **0**, the value of **TO** specifies the transmit options.
23-n	variable	**Command data**	Data to be sent to the destination device. Up to **NP** bytes per packet.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Transmit options bit field

The available transmit options vary depending on the protocol being used. Bitfield options can be combined. Set all unused bits to **0**.

DigiMesh

Bit	Meaning	Description
0	Disable ACK [**0x01**]	Disable acknowledgments on all unicasts.
1	Disable route discoveries [**0x02**]	Disable Route Discovery on all DigiMesh unicasts.
2	Unicast NACK [**0x04**]	Enable unicast NACK messages on DigiMesh transmissions When set, a failed transmission will generate a Route Information - 0x8D frame for diagnosis.
3	Unicast trace route [**0x08**]	Enable a unicast Trace Route on DigiMesh transmissions When set, the transmission will generate a Route Information - 0x8D frame.
4	Secure Session Encryption [**0x10**]	Encrypt payload for transmission across a Secure Session Reduces maximum payload size by 4 bytes.
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**]

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

Sending a unicast transmission to an XBee device with the 64-bit address of **0013A20012345678** with the serial data "**TxData**". Transmit options are set to **0**, which means the transmission will send using the options set by the **TO** command. This transmission is identical to a Transmit Request - 0x10 using default settings.

The corresponding Extended Transmit Status - 0x8B response with a matching Frame ID will indicate whether the transmission succeeded.

```
7E 00 1A 11 87 00 13 A2 00 12 34 56 78 FF FE E8 E8 00 11 C1 05 00 00 54 78 44 61
74 61 B4
```

Frame type	Frame ID	64-bit dest	Reserved	Source EP	Dest EP	Cluster	Profile	Bcast radius	Tx options	Command data
0x11	0x87	0x0013A200 12345678	0xFFFE	0xE8	0xE8	0x0011	0xC105	0x00	0x00	0x547844617461

Frame type	Frame ID	64-bit dest	Reserved	Source EP	Dest EP	Cluster	Profile	Bcast radius	Tx options	Command data
Explicit request	*Matches response*	*Destination*	*Unused*	*Digi data*	*Digi data*	*Data*	*Digi profile*	*N/A*	*Use* ***TO***	*"TxData"*

Loopback Packet

Sending a loopback transmission to an device with the 64-bit address of **0013A20012345678** using Cluster ID **0x0012**. To better understand the raw performance, retries and acknowledgements are disabled.

The corresponding Extended Transmit Status - 0x8B response with a matching Frame ID can be used to verify that the transmission was sent.

The destination will not emit a receive frame, instead it will return the transmission back to the sender. The source device will emit the receive frame—the frame type is determined by the value of **AO**—if the packet looped back successfully.

```
7E 00 1A 11 F8 00 13 A2 00 12 34 56 78 FF FE E8 E8 00 12 C1 05 00 01 54 78 44 61
74 61 41
```

Frame type	Frame ID	64-bit dest	Reserved	Source EP	Dest EP	Cluster	Profile	Bcast radius	Tx options	Command data
0x11	0xF8	0x0013A200 12345678	0xFFFE	0xE8	0xE8	0x0012	0xC105	0x00	0x01	0x547844617461
Explicit request	*Matches response*	*Destination*	*Unused*	*Digi data*	*Digi data*	*Data*	*Digi profile*	*N/A*	*Disable retries*	*"TxData"*

Remote AT Command Request - 0x17

Response frame: Remote AT Command Response- 0x97

Description

This frame type is used to query or set AT command 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.

When querying parameter values you can query parameter values by sending this framewith a command but no parameter value field—the two-byte AT command is immediately followed by the frame checksum. When an AT command is queried, a Remote AT Command Response- 0x97 frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x97 response is the same one set by the command in the 0x17 request frame.

Note Remote AT Command Requests should only be issued as unicast transmissions to avoid potential network disruption. Broadcasts are not acknowledged, so there is no guarantee all devices will receive the request. Responses are returned immediately by all receiving devices, which can cause congestion on a large network.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Remote AT Command Request - **0x17**.
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to **0**, the device will not emit a response frame.
5	64-bit	**64-bit destination address**	Set to the 64-bit IEEE address of the destination device.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.

Offset	Size	Frame Field	Description
15	8-bit	**Remote command options**	Bit field of options that apply to the remote AT command request: ■ **Bit 0**: Disable ACK [**0x01**] ■ **Bit 1**: Apply changes on remote [**0x02**] • If not set, changes will not applied until the device receives an **AC** command or a subsequent command change is received with this bit set ■ Bit 2: Reserved (set to 0) ■ Bit 3: Reserved (set to 0) ■ **Bit 4**: Send the remote command securely [**0x10**] **Note** Option values may be combined. Set all unused bits to 0.
16	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
18-n	variable	**Parameter value (optional)**	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the current parameter value and returns the result in the response.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes—**AP** = **1**—and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set remote command parameter

Set the **NI** string of a device with the 64-bit address of **0013A20012345678** to "**Remote**" and apply the change immediately.

The corresponding Remote AT Command Response- 0x97 with a matching Frame ID will indicate success.

```
7E 00 15 17 27 00 13 A2 00 12 34 56 78 FF FE 02 4E 49 52 65 6D 6F 74 65 F6
```

Frame type	Frame ID	64-bit dest	Reserved	Command options	AT command	Parameter value
0x17	0x27	0x0013A20012345678	0xFFFE	0x02	0x4E49	0x52656D6F7465
Request	*Matches response*		*Unused*	*Apply Change*	*"NI"*	*"Remote"*

Queue remote command parameter change

Change the PAN ID of a remote device so it can migrate to a new PAN, since this change would cause network disruption, the change is queued so that it can be made active later with a subsequent **AC** command or written to flash with a queued **WR** command so the change will be active after a power cycle.

The corresponding Remote AT Command Response- 0x97 with a matching Frame ID will indicate success.

```
7E 00 11 17 68 00 13 A2 00 12 34 56 78 FF FE 00 49 44 04 51 D8
```

Frame type	Frame ID	64-bit dest	Reserved	Command options	AT command	Parameter value
0x17	0x68	0x0013A200 12345678	0xFFFE	0x00	0x4944	0x0451
Request	*Matches response*		*Unused*	*Queue Change*	*"ID"*	

Query remote command parameter

Query the temperature of a remote device—**TP** command.

The corresponding Remote AT Command Response- 0x97 with a matching Frame ID will return the temperature value.

```
7E 00 0F 17 FA 00 13 A2 00 12 34 56 78 FF FE 00 54 50 84
```

Frame type	Frame ID	64-bit dest	Reserved	Command options	AT command	Parameter value
0x17	0xFA	0x0013A200 12345678	0xFFFE	0x00	0x5450	(omitted)
Request	*Matches response*		*Unused*	*N/A*	*"TP"*	*Query the parameter*

Local AT Command Response - 0x88

Request frames:

- Local AT Command Request - 0x08
- Queue Local AT Command Request - 0x09

Description

This frame type is emitted in response to a local AT Command request. Some commands send back multiple response frames; for example, ND (Network Discover). Refer to individual AT command descriptions for details on API response behavior.

This frame is only emitted if the Frame ID in the request is non-zero.

Format

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Local AT Command Response - **0x88**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a prior request.
5	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
7	8-bit	**Command status**	Status code for the host's request: **0** = OK **1** = ERROR **2** = Invalid command **3** = Invalid parameter
8-n	variable	**Command data (optional)**	If the host requested a command parameter change, this field will be omitted. If the host queried a command by omitting the parameter value in the request, this field will return the value currently set on the device.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set local command parameter

Host set the NI string of the local device to "**End Device**" using a 0x08 request frame.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID is emitted as a response:

```
7E 00 05 88 01 4E 49 00 DF
```

Frame type	Frame ID	AT command	Command Status	Command data
0x88	0xA1	0x4E49	0x00	(omitted)
Response	*Matches request*	*"NI"*	*Success*	*Parameter changes return no data*

Query local command parameter

Host queries the temperature of the local device—**TP** command—using a 0x08 request frame.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID is emitted with the temperature value as a response:

```
7E 00 07 88 01 54 50 00 FF FE D5
```

Frame type	Frame ID	AT command	Command Status	Command data
0x88	0x17	0x5450	0x00	0xFFFE
Response	*Matches request*	*"TP"*	*Success*	*-2 °C*

Modem Status - 0x8A

Description

This frame type is emitted in response to specific conditions. The status field of this frame indicates the device behavior.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Modem Status - **0x8A**

Offset	Size	Frame Field	Description
4	8-bit	**Modem status**	Complete list of modem statuses: **0x00** = Hardware reset or power up **0x01** = Watchdog timer reset **0x02** = Joined network **0x03** = Left network **0x06** = Coordinator started **0x07** = Network security key was updated **0x0B** = Network woke up **0x0C** = Network went to sleep **0x0D** = Voltage supply limit exceeded **0x0E** = Remote Manager connected **0x0F** = Remote Manager disconnected **0x11** = Modem configuration changed while join in progress **0x12** = Access fault **0x13** = Fatal error **0x3B** = Secure session successfully established **0x3C** = Secure session ended **0x3D** = Secure session authentication failed **0x3E** = Coordinator detected a PAN ID conflict but took no action **0x3F** = Coordinator changed PAN ID due to a conflict **0x32** = BLE Connect **0x33** = BLE Disconnect **0x34** = Bandmask configuration failed **0x35** = Cellular component update started **0x36** = Cellular component update failed **0x37** = Cellular component update completed **0x38** = XBee firmware update started **0x39** = XBee firmware update failed **0x3A** = XBee firmware update applying **0x40** = Router PAN ID was changed by coordinator due to a conflict **0x42** = Network Watchdog timeout expired **0x80** through **0xFF** = Stack error Refer to the tables below for a filtered list of status codes that are appropriate for specific devices.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Modem status codes

Statuses for specific modem types are listed here.

XBee DigiMesh

0x00 = Hardware reset or power up

0x01 = Watchdog timer reset

0x0B = Network woke up

0x0C = Network went to sleep

0x0D = Voltage supply limit exceeded

0x3B = XBee 3 - Secure session successfully established

0x3C = XBee 3 - Secure session ended

0x3D = XBee 3 - Secure session authentication failed

0x32 = XBee 3 - BLE Connect

0x33 = XBee 3 - BLE Disconnect

0x34 = XBee 3 - No Secure Session Connection

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Boot status

When a device powers up, it returns the following API frame:

```
7E 00 02 8A 00 75
```

Frame type	Modem Status
0x8A	0x00
Status	*Hardware Reset*

Extended Transmit Status - 0x8B

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type is emitted when a network transmission request completes. The status field of this frame indicates whether the request succeeded or failed and the reason. This frame type provides additional networking details about the transmission.

This frame is only emitted if the Frame ID in the request is non-zero.

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 specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Transmit Status - **0x8B**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a prior request.
5	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
7	8-bit	**Transmit retry count**	The number of application transmission retries that occur.

Offset	Size	Frame Field	Description
8	8-bit	**Delivery status**	Complete list of delivery statuses: **0x00** = Success **0x01** = MAC ACK failure **0x02** = CCA/LBT failure **0x03** = Indirect message unrequested / no spectrum available **0x21** = Network ACK failure **0x25** = Route not found **0x31** = Internal resource error **0x32** = Resource error lack of free buffers, timers, etc. **0x74** = Data payload too large **0x75** = Indirect message unrequested
9	8-bit	**Discovery status**	Complete list of delivery statuses: **0x00** = No discovery overhead **0x02** = Route discovery
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Route Information - 0x8D

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type contains the DigiMesh routing information for a remote device on the network. This route information can be used to diagnose marginal links between devices across multiple hops.

This frame type is emitted in response to a DigiMesh unicast transmission request which has Trace Routing or NACK enabled. See Trace route option and NACK messages for more information.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Route Information - **0x8D**
4	8-bit	**Source event**	Event that caused the route information to be generated: **0x11** = NACK **0x12** = Trace route
5	8-bit	**Data length**	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.
6	32-bit	**Timestamp**	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.
10	8-bit	**ACK timeout count**	The number of MAC ACK timeouts that occur.
11	8-bit	**TX blocked count**	The number of times the transmission was blocked due to reception in progress.
12	8-bit	**Reserved**	Not used.

Offset	Size	Frame Field	Description
14	64-bit	**Destination address**	The 64-bit IEEE address of the final destination node of this network-level transmission.
21	64-bit	**Source address**	The 64-bit IEEE address of the source node of this network-level transmission.
29	64-bit	**Responder address**	The 64-bit IEEE address of the node that generates this Route Information packet after it sends (or attempts to send) the data packet to the next hop (the Receiver node).
37	64-bit	**Receiver address**	The 64-bit IEEE address of the node that the device sends (or attempts to send) the data packet.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Routing information

The following example represents a possible Route Information Packet. A device emits this frame when it performs a trace route enabled transmission from one device—serial number 0x0013A200 4052AAAA—to another—serial number 0x0013A200 4052DDDD—across a DigiMesh network.

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.

```
7E 00 2A 8D 12 27 6B EB CA 93 00 00 00 00 13 A2 00 40 52 DD DD 00 13 A2 00 40 52
AA AA 00 13 A2 00 40 52 BB BB 00 13 A2 00 40 52 CC CC 4E
```

Frame type	Source event	Data length	Timestamp	ACK timeout	TX Blocked	Reserved	Dest address	Source address	Responder address	Receiver address
0x8D	0x12	0x27	0x6BEBCA93	0x00	0x00	0x00	0x0013A200 4052DDDD	0x0013A200 4052AAAA	0x0013A200 4052BBBB	0x0013A200 4052CCCC
Route	*Trace Route*		*~30 minutes*	*No retries this hop*	*No error*	*N/A*	*Destination*	*Source*	*Node that sent this information*	*Next hop*

Aggregate Addressing Update - 0x8E

Description

This frame type is emitted on devices that update it addressing information in response to a network aggregator issuing an addressing update. A network aggregator is defined by a device on the network who has had the AG (Aggregator Support) command issued. A device on the network who's current **DH** and **DL** matches the address provided in the **AG** command request will update **DH** and **DL** and emit this frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Aggregate Addressing Update - **0x8E**
4	8-bit	**Reserved**	Reserved for future functionality. This field returns 0.
5	64-bit	**New address**	Address to which **DH** and **DL** are being set.
13	64-bit	**Old address**	Address to which **DH** and **DL** were previously set.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Aggregate address update

In the following example, a device with destination address (**DH**/**DL**) of 0x0013A200 4052AAAA updates its destination address to 0x0013A200 4052BBBB.

```
7E 00 12 8E 00 00 13 A2 00 40 52 BB BB 00 13 A2 00 40 52 AA AA 19
```

Frame type	Reserved	New address	Old address
0x8E	0x00	0x0013A200 4052BBBB	0x0013A200 4052AAAA
Update	*N/A*	*What **DH**/**DL** is now set to*	*What **DH**/**DL** was set to*

Receive Packet - 0x90

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type is emitted when a device configured with standard API output—AO (API Options) = **0**—receives an RF data packet.

Typically this frame is emitted as a result of a device on the network sending serial data using the Transmit Request - 0x10 or Explicit Addressing Command Request - 0x11 addressed either as a broadcast or unicast transmission.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Receive Packet - **0x90**
4	64-bit	**64-bit source address**	The sender's 64-bit address.
12	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.

Offset	Size	Frame Field	Description
14	8-bit	**Receive options**	Bit field of options that apply to the received message: ■ **Bit 0**: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] ■ **Bit 2**: Reserved ■ **Bit 3**: Reserved ■ **Bit 4**: Reserved ■ **Bit 5**: Reserved ■ **Bit 6**: Reserved ■ **Bit 6, 7**: DigiMesh delivery method • b’00 = <invalid option> • b’01 = Point-multipoint [**0x40**] • b’10 = Directed Broadcast [**0x80**] • b’11 = DigiMesh [**0xC0**] **Note** Option values may be combined.
15-n	variable	**Received data**	The RF payload data that the device receives.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

A device with the 64-bit address of **0013A20041AEB54E** sent a unicast transmission to a specific device with the payload of "**TxData**". The following frame is emitted if the destination is configured with **AO** = **0**.

```
7E 00 12 90 00 13 A2 00 41 AE B5 4E FF FE C1 54 78 44 61 74 61 C4
```

Frame type	64-bit source	Reserved	Rx options	Received data
0x90	0x0013A200 41AEB54E	0x5614	0xC1	0x547844617461
Output		*Unused*	*ACK was sent in DigiMesh mode*	*"TxData"*

Explicit Receive Indicator - 0x91

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type is emitted when a device configured with explicit API output—AO (API Options) bit1 set—receives a packet.

Typically this frame is emitted as a result of a device on the network sending serial data using the Transmit Request - 0x10 or Explicit Addressing Command Request - 0x11 addressed either as a broadcast or unicast transmission.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Explicit Receive Indicator - **0x91**
4	64-bit	**64-bit source address**	The sender's 64-bit address.
12	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
14	8-bit	**Source endpoint**	Endpoint of the source that initiated transmission.
15	8-bit	**Destination endpoint**	Endpoint of the destination that the message is addressed to.
16	16-bit	**Cluster ID**	The Cluster ID that the frame is addressed to.
18	16-bit	**Profile ID**	The Profile ID that the fame is addressed to.

Offset	Size	Frame Field	Description
20	8-bit	**Receive options**	Bit field of options that apply to the received message for packets sent using Digi endpoints (0xDC-0xEE): ■ **Bit 0**: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] ■ **Bit 2**: Reserved ■ **Bit 3**: Reserved ■ **Bit 4**: Reserved ■ **Bit 5**: Reserved ■ **Bit 6**: Reserved ■ **Bit 6, 7**: DigiMesh delivery method • b'00 = <invalid option> • b'01 = Point-multipoint [**0x40**] • b'10 = Directed Broadcast [**0x80**] • b'11 = DigiMesh [**0xC0**] **Note** Option values may be combined.
21-n	variable	**Received data**	The RF payload data that the device receives.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

A device with the 64-bit address of **0013A20087654321** sent a unicast transmission to a specific device with the payload of "**TxData**". The following frame is emitted if the destination is configured with **AO** > **1**.

```
7E 00 18 91 00 13 A2 00 41 AE B5 4E FF FE E8 E8 00 11 C1 05 C1 54 78 44 61 74 61
1C
```

Frame type	64-bit source	Reserved	Source EP	Dest EP	Cluster	Profile	Rx options	Received data
0x91	0x0013A200 41AEB54E	0x87BD	0xE8	0xE8	0x0011	0xC105	0xC1	0x547844617461
Explicit output		*Unused*	*Digi data*	*Digi data*	*Data*	*Digi profile*	*ACK was sent in DigiMesh network*	*"TxData"*

I/O Sample Indicator - 0x92

Description

This frame type is emitted when a device configured with standard API output—AO (API Options) = **0**—receives an I/O sample frame from a remote device. Only devices running in API mode will send I/O samples out the serial port.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	I/O Sample Indicator - **0x92**
4	64-bit	**64-bit source address**	The sender's 64-bit IEEE address.
12	16-bit	**Reserved**	Unused, but typically **0XFFFE**.
14	8-bit	**Receive options**	Bit field of options that apply to the received message: ■ **Bit 0**: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] Note Option values may be combined.
15	8-bit	**Number of samples**	The number of sample sets included in the payload. This field typically reports 1 sample.

Offset	Size	Frame Field	Description
16	16-bit	**Digital sample mask**	Bit field that indicates which I/O lines on the remote are configured as digital inputs or outputs, if any: **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 For example, a digital channel mask of **0x002F** means DIO **0**, **1**, **2**, **3**, and **5** are enabled as digital I/O.
18	8-bit	**Analog sample mask**	Bit field that indicates which I/O lines on the remote are configured as analog input, if any: **bit 0**: AD0 **bit 1**: AD1 **bit 2**: AD2 **bit 3**: AD3 **bit 7**: Supply Voltage (enabled with **V+** command)
19	16-bit	**Digital samples (if included)**	If the sample set includes any digital I/O lines (**Digital channel mask** > **0**), this field contain samples for all enabled digital I/O lines. If no digital lines are configured as inputs or outputs, this field will be omitted. DIO lines that do not have sampling enabled return 0. Bits in this field are arranged the same as they are in the Digital channel mask field.
22	16-bit variable	**Analog samples (if included)**	If the sample set includes any analog I/O lines (Analog channel mask > 0), each enabled analog input returns a 16-bit value indicating the ADC measurement of that input. Analog samples are ordered sequentially from AD0 to AD3.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

I/O sample

A device with the 64-bit address of **0013A20012345678** is configured to periodically send I/O sample data to a particular device. The device is configured with DIO3, DIO4, and DIO5 configured as digital

I/O, and AD1 and AD2 configured as an analog input.

The destination will emit the following frame:

```
7E 00 16 92 00 13 A2 00 12 34 56 78 FF FE C1 01 00 38 06 00 28 02 25 00 F8 E8
```

Frame type	64-bit source	Reserved	Rx options	Num samples	Digital channel mask	Analog channel mask	Digital samples	Analog sample 1	Analog sample 2
0x92	0x0013A200 12345678	0x87AC	0xC1	0x01	0x0038	0x06	0x0028	0x0225	0x00F8
Sample		*Unused*	*ACK was sent in mesh network*	*Single sample (typical)*	*b'00* ***111****000 DIO3, DIO4, and DIO5 enabled*	*b'0* ***11****0 AD1 and AD2 enabled*	*b'00* ***101****000 DIO3 and DIO5 are HIGH; DI04 is LOW*	*AD1 data*	*AD2 data*

Node Identification Indicator - 0x95

Description

This frame type is emitted when a node identification broadcast is received. The node identification indicator contains information about the identifying device, such as address, identifier string (**NI**), and other relevant data.

A node identifies itself to the network under these conditions:

- The commissioning button is pressed once.
- A **CB 1** command is issued.
- A synchronous sleep node stays awake for 30 seconds in order to receive a sync message. It also sends out an identifying message.

See ND (Network Discover) for information on the payload formatting.

See NO (Network Discovery Options) for configuration options that modify the output of this frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Node Identification Indicator - **0x95**
4	64-bit	**64-bit source address**	The sender's 64-bit address.
12	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.

Offset	Size	Frame Field	Description
14	8-bit	**Options**	Bit field of options that apply to the received message: ■ Bit 0: Reserved ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] ■ **Bit 2**: Reserved ■ Bit 4: Reserved ■ Bit 5: Reserved ■ **Bit 6, 7**: DigiMesh delivery method • b'00 = <invalid option> • b'01 = Point-multipoint [**0x40**] • b'10 = Directed Broadcast [**0x80**] • b'11 = DigiMesh [**0xC0**] **Note** Option values may be combined.
15	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
17	64-bit	**64-bit remote address**	The 64-bit address of the device that sent the Node Identification.
25	variable (2-byte minimum)	**Node identification string**	Node identification string on the remote device set by NI (Node Identifier). The identification string is terminated with a NULL byte (0x00).
27+NI	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
29+NI	8-bit	**Network device type**	What type of network device the remote identifies as: 0 = Coordinator 1 = Router 2 = End Device
30+NI	8-bit	**Source event**	The event that caused the node identification broadcast to be sent. 0 = Reserved 1 = Frame sent by node identification pushbutton event—see D0 (DIO0/AD0).
31+NI	16-bit	**Digi Profile ID**	The Digi application Profile ID—**0xC105**.
33+NI	16-bit	**Digi Manufacturer ID**	The Digi Manufacturer ID—**0x101E**.
35+NI	32-bit	**Device type identifier (optional)**	The user-defined device type on the remote device set by DD (Device Type Identifier). Only included if the receiving device has the appropriate NO (Network Discovery Options) bit set.

Offset	Size	Frame Field	Description
EOF-1	8-bit	**RSSI (optional)**	The RSSI of the last hop that relayed the message. Only included if the receiving device has the appropriate NO (Network Discovery Options) bit set.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte—between length and checksum.

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Identify remote device

A technician is replacing a DigiMesh device in the field and needs to have the its entry removed from a cloud server's database. The technician pushes the commissioning button on the old device once to send an identification broadcast. The server can use the broadcast to identify which device is being replaced and perform the necessary action.

When the node identification broadcast is sent, every device that receives the message will flash the association LED and emit the following information frame:

```
7E 00 27 95 00 13 A2 00 12 34 56 78 FF FE C2 FF FE 00 13 A2 00 12 34 56 78 4C 48
37 35 00 FF FE 01 01 C1 05 10 1E 00 14 00 08 0D
```

Frame type	64-bit source	Reserved	Options	64-bit remote	NI String	Reserved	Device type	Event	Profile ID	MFG ID
0x95	0x0013A200 12345678	0xFFFE	0xC2	0x0013A200 12345678	0x4C483735 00	0xFFFE	0x01	0x01	0xC105	0x101E
Identification		*Unused*	*DigiMesh broadcast*		*"LH75" + null*	*Unused*	*Router*	*Button press*	*Digi*	*Digi*

Remote AT Command Response- 0x97

Request frame: Remote AT Command Request - 0x17

Description

This frame type is emitted in response to a Remote AT Command Request - 0x17. Some commands send back multiple response frames; for example, the **ND** command. Refer to individual AT command descriptions for details on API response behavior.

This frame is only emitted if the Frame ID in the request is non-zero.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Remote AT Command Response - **0x97**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a prior request.
5	64-bit	**64-bit source address**	The sender's 64-bit address.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
15	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
17	8-bit	**Command status**	Status code for the host's request: **0x00** = OK **0x01** = ERROR **0x02** = Invalid command **0x03** = Invalid parameter **0x04** = Transmission failure **0x0C** = Encryption error
18-n	variable	**Parameter value (optional)**	If the host requested a command parameter change, this field will be omitted. If the host queried a command by omitting the parameter value in the request, this field will return the value currently set on the device.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set remote command parameter

Host set the **NI** string of a remote device to "**Remote**" using a Remote AT Command Request - 0x17.

The corresponding 0x97 Remote AT Command Response with a matching Frame ID is emitted as a response:

```
7E 00 0F 97 27 00 13 A2 00 12 34 56 78 12 7E 4E 49 00 51
```

Frame type	Frame ID	64-bit source	Reserved	AT command	Command Status	Command data
0x97	0x27	0x0013A200 12345678	0x127E	0x4E49	0x00	(omitted)
Response	*Matches request*		*Unused*	*"NI"*	*Success*	*Parameter changes return no data*

Transmission failure

Host queued the the PAN ID change of a remote device using a Remote AT Command Request - 0x17. Due to existing network congestion, the host will retry any failed attempts.

The corresponding 0x97 Remote AT Command Response with a matching Frame ID is emitted as a response:

```
7E 00 0F 97 27 00 13 A2 00 12 34 56 78 FF FE 49 44 04 EA
```

Frame type	Frame ID	64-bit source	Reserved	AT command	Command Status	Command data
0x97	0x27	0x0013A200 12345678	0xFFFE	0x4944	0x04	(omitted)
Response	*Matches request*		*Unused*	*"ID"*	*Transmission failure*	*Parameter changes return no data*

Query remote command parameter

Query the temperature of a remote device—.

The corresponding 0x97 Remote AT Command Response with a matching Frame ID is emitted with the temperature value as a response:

```
7E 00 11 97 27 00 13 A2 00 12 34 56 78 FF FE 54 50 00 00 2F A8
```

Frame type	Frame ID	64-bit source	Reserved	AT command	Command Status	Command data
0x97	0x27	0x0013A200 12345678	0x0013A200 12345678	0x4944	0x00	0x002F
Response	*Matches request*		*Unused*	*"TP"*	*Success*	*+47 °C*

Regulatory information

United States (FCC)

XBee/XBee-PRO RF Modules comply with Part 15 of the FCC rules and regulations. Compliance with the labeling requirements, FCC notices and antenna usage guidelines is required.

To fulfill FCC certification requirements, the OEM must comply with the following regulations:

- The system integrator must ensure that the text on the external label provided with this device is placed on the outside of the final product.
- XBee/XBee-PRO RF modules may only be used with antennas that have been tested and approved for use with this module; refer to FCC-approved antennas (2.4 GHz).

OEM labeling requirements

WARNING! As an Original Equipment Manufacturer (OEM) you must ensure that FCC labeling requirements are met. You must include a clearly visible label on the outside of the final product enclosure that displays the following content:

Contains FCC ID: OUR-XBEE/OUR-XBEEPRO[1]

The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: *(i.)* this device may not cause harmful interference and *(ii.)* this device must accept any interference received, including interference that may cause undesired operation.

FCC notices

IMPORTANT: The XBee / XBee-PRO RF Module has been certified by the FCC for use with other products without any further certification (as per FCC section 2.1091). Modifications not expressly approved by Digi could void the user's authority to operate the equipment.

IMPORTANT: OEMs must test final product to comply with unintentional radiators (FCC section 15.107 and 15.109) before declaring compliance of their final product to Part 15 of the FCC rules.

IMPORTANT: The RF module has been certified for remote and base radio applications. If the module will be used for portable applications, please take note of the following instructions:

- For XBee modules where the antenna gain is less than 13.8 dBi, no additional SAR testing is required. The 20 cm separation distance is not required for antenna gain less than 13.8 dBi.
- For XBee modules where the antenna gain is greater than 13.8 dBi and for all XBee-PRO modules, the device must undergo SAR testing.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

[1] The FCC ID for the XBee is “OUR-XBEE.” The FCC ID for the XBee-PRO is “OUR-XBEEPRO.”

- Re-orient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect equipment and receiver to outlets on different circuits.
- Consult the dealer or an experienced radio/TV technician for help.

RF exposure statement

If you are an integrating the XBee into another product, you must include the following Caution statement in product manuals to alert users of FCC RF exposure compliance:

⚠ **CAUTION!** To satisfy FCC RF exposure requirements for mobile transmitting devices, a separation distance of 20 cm or more should be maintained between the antenna of this device and persons during device operation. To ensure compliance, operations at closer than this distance is not recommended. The antenna used for this transmitter must not be co-located in conjunction with any other antenna or transmitter.

FCC-approved antennas (2.4 GHz)

You can install XBee and XBee-PRO RF modules using antennas and cables constructed with standard connectors (Type-N, SMA, TNC, and so forth) if you perform the installation professionally and according to FCC guidelines. If a non-professional performs the installation, you must use non-standard connectors (RPSMA, RPTNC, and so forth).

The modules are FCC-approved for fixed base station and mobile applications on channels 0x0B - 0x1A (XBee) and 0x0C - 0x17 (XBee-PRO). If you mount the antenna at least 20 cm (8 in) from nearby persons, the FCC considers the application to be a mobile application. You must test antennas that are not in the table to comply with FCC Section 15.203 (Unique Antenna Connectors) and Section 15.247 (Emissions).

XBee RF Modules (1 mW): XBee modules are tested and approved for use with the antennas listed in the first and second tables below.

XBee-PRO RF Modules (63 mW): XBee-PRO modules are tested and approved for use with the antennas listed in the first and third tables below.

The antennas in the following tables are approved for use with this module. We do not carry all of these antenna variants. Contact Digi Sales for the available antennas.

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Antennas approved for use with the XBee/XBee-PRO RF Modules (cable loss is not required)

Part number	Type (description)	Gain	Application*	Minimum separation
A24-HASM-450	Dipole (half-wave articulated RPSMA - 4.5”)	2.1 dBi	Fixed/mobile	20 cm

Part number	Type (description)	Gain	Application*	Minimum separation
29000095	Dipole (half-wave articulated RPSMA - 4.5”)	2.1 dBi	Fixed/mobile	20 cm
A24-HABSM*	Dipole (articulated RPSMA)	2.1 dBi	Fixed	20 cm
A24-HABUF-P5I	Dipole (half-wave articulated bulkhead mount U.FL. with 5” pigtail)	2.1 dBi	Fixed	20 cm
A24-HASM-525	Dipole (half-wave articulated RPSMA - 5.25")	2.1 dBi	Fixed/mobile	20 cm
A24-QI	Monopole (integrated whip)	1.5 dBi	Fixed	20 cm
A24-C1	Surface-mount	-1.5 dBi	Fixed/mobile	20 cm
29000430	Integrated PCB Antenna	-0.5 dBi	Fixed/mobile	20 cm
* If you are using the RF module in a portable application or if the module is used in a handheld device and the antenna is less than 20 cm from the human body when the device is in operation: The integrator may be responsible for passing additional Specific Absorption Rate (SAR) testing based on FCC rules 2.1091 and FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, OET Bulletin and Supplement C. See the note under FCC notices for more information. The testing results will be submitted to the FCC for approval prior to selling the integrated unit. The required SAR testing measures emissions from the module and how they affect the person.				

Antennas approved for use with the XBee RF Modules (cable loss is shown if required)

Part number	Type (description)	Gain	Application*	Minimum separation	Required cable loss
Yagi class antennas					
A24-Y4NF	Yagi (4-element)	6.0 dBi	Fixed	2 m	
A24-Y6NF	Yagi (6-element)	8.8 dBi	Fixed	2 m	1.7 dB
A24-Y7NF	Yagi (7-element)	9.0 dBi	Fixed	2 m	1.9 dB
A24-Y9NF	Yagi (9-element)	10.0 dBi	Fixed	2 m	2.9 dB

Part number	Type (description)	Gain	Application*	Minimum separation	Required cable loss
A24-Y10NF	Yagi (10-element)	11.0 dBi	Fixed	2 m	3.9 dB
A24-Y12NF	Yagi (12-element)	12.0 dBi	Fixed	2 m	4.9 dB
A24-Y13NF	Yagi (13-element)	12.0 dBi	Fixed	2 m	4.9 dB
A24-Y15NF	Yagi (15-element)	12.5 dBi	Fixed	2 m	5.4 dB
A24-Y16NF	Yagi (16-element)	13.5 dBi	Fixed	2 m	6.4 dB
A24-Y16RM	Yagi (16-element, RPSMA connector)	13.5 dBi	Fixed	2 m	6.4 dB
A24-Y18NF	Yagi (18-element)	15.0 dBi	Fixed	2 m	7.9 dB
Omni-directional class antennas					
A24-F2NF	Omni-directional (fiberglass base station)	2.1 dBi	Fixed/mobile	20 cm	
A24-F3NF	Omni-directional (fiberglass base station)	3.0 dBi	Fixed/mobile	20 cm	
A24-F5NF	Omni-directional (fiberglass base station)	5.0 dBi	Fixed/mobile	20 cm	
A24-F8NF	Omni-directional (fiberglass base station)	8.0 dBi	Fixed	2 m	
A24-F9NF	Omni-directional (fiberglass base station)	9.5 dBi	Fixed	2 m	0.2 dB

Part number	Type (description)	Gain	Application*	Minimum separation	Required cable loss
A24-F10NF	Omni-directional (fiberglass base station)	10.0 dBi	Fixed	2 m	0.7 dB
A24-F12NF	Omni-directional (fiberglass base station)	12.0 dBi	Fixed	2 m	2.7 dB
A24-F15NF	Omni-directional (fiberglass base station)	15.0 dBi	Fixed	2 m	5.7 dB
A24-W7NF	Omni-directional (base station)	7.2 dBi	Fixed	2 m	
A24-M7NF	Omni-directional (mag-mount base station)	7.2 dBi	Fixed	2 m	
Panel class antennas					
A24-P8SF	Flat panel	8.5 dBi	Fixed	2 m	1.5 dB
A24-P8NF	Flat panel	8.5 dBi	Fixed	2 m	1.5 dB
A24-P13NF	Flat panel	13.0 dBi	Fixed	2 m	6 dB
A24-P14NF	Flat panel	14.0 dBi	Fixed	2 m	7 dB
A24-P15NF	Flat panel	15.0 dBi	Fixed	2 m	8 dB
A24-P16NF	Flat panel	16.0 dBi	Fixed	2 m	9 dB
* If you are using the RF module in a portable application or if the module is used in a handheld device and the antenna is less than 20 cm from the human body when the device is in operation: The integrator may be responsible for passing additional Specific Absorption Rate (SAR) testing based on FCC rules 2.1091 and FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, OET Bulletin and Supplement C. See the note under FCC notices for more information. The testing results will be submitted to the FCC for approval prior to selling the integrated unit. The required SAR testing measures emissions from the module and how they affect the person.					

High gain antenna summary

The following antenna types have been tested and approved for use with the XBee module:

Antenna type: Yagi The XBee RF Module was tested and approved with 15 dBi antenna gainand with 7.9 dB cable loss. You can use any Yagi type antenna with 7.1 dBi gain or less with no cable loss.

Antenna type: omni-directional The XBee RF Module was tested and approved with 15 dBi antenna gain with 5.7 dB cable loss. You can use any omni-directional antenna with 9.3 dBi gain or less with no cable loss.

Antenna type: flat panel The XBee RF Module was tested and approved with 16 dBi antenna gain with 9.0 dB cable loss. You can use any flat panel antenna with 7.0 dBi gain or less with no cable loss.

Antennas approved for use with the XBee-PRO DigiMesh 2.4 RF Modules (cable loss is required)

Part number	Type (description)	Gain	Application*	Minimum separation	Required cable loss
Yagi class antennas					
A24-Y4NF	Yagi (4-element)	6.0 dBi	Fixed	2 m	8.1 dB
A24-Y6NF	Yagi (6-element)	8.8 dBi	Fixed	2 m	10.9 dB
A24-Y7NF	Yagi (7-element)	9.0 dBi	Fixed	2 m	11.1 dB
A24-Y9NF	Yagi (9-element)	10.0 dBi	Fixed	2 m	12.1 dB
A24-Y10NF	Yagi (10-element)	11.0 dBi	Fixed	2 m	13.1 dB
A24-Y12NF	Yagi (12-element)	12.0 dBi	Fixed	2 m	14.1 dB
A24-Y13NF	Yagi (13-element)	12.0 dBi	Fixed	2 m	14.1 dB
A24-Y15NF	Yagi (15-element)	12.5 dBi	Fixed	2 m	14.6 dB
A24-Y16NF	Yagi (16-element)	13.5 dBi	Fixed	2 m	15.6 dB
A24-Y16RM	Yagi (16-element, RPSMA connector)	13.5 dBi	Fixed	2 m	15.6 dB
A24-Y18NF	Yagi (18-element)	15.0 dBi	Fixed	2 m	17.1 dB
Omni-directional class antennas					
A24-F2NF	Omni-directional (fiberglass base station)	2.1 dBi	Fixed/Mobile	20 cm	4.2 dB

Part number	Type (description)	Gain	Application*	Minimum separation	Required cable loss
A24-F3NF	Omni-directional (fiberglass base station)	3.0 dBi	Fixed/Mobile	20 cm	5.1 dB
A24-F5NF	Omni-directional (fiberglass base station)	5.0 dBi	Fixed/Mobile	20 cm	7.1 dB
A24-F8NF	Omni-directional (fiberglass base station)	8.0 dBi	Fixed	2 m	10.1 dB
A24-F9NF	Omni-directional (fiberglass base station)	9.5 dBi	Fixed	2 m	11.6 dB
A24-F10NF	Omni-directional (fiberglass base station)	10.0 dBi	Fixed	2 m	12.1 dB
A24-F12NF	Omni-directional (fiberglass base station)	12.0 dBi	Fixed	2 m	14.1 dB
A24-F15NF	Omni-directional (fiberglass base station)	15.0 dBi	Fixed	2 m	17.1 dB
A24-W7NF	Omni-directional (base station)	7.2 dBi	Fixed	2 m	9.3 dB
A24-M7NF	Omni-directional (mag-mount base station)	7.2 dBi	Fixed	2 m	9.3 dB
Panel class antennas					
A24-P8SF	Flat panel	8.5 dBi	Fixed	2 m	8.6 dB
A24-P8NF	Flat panel	8.5 dBi	Fixed	2 m	8.6 dB
A24-P13NF	Flat panel	13.0 dBi	Fixed	2 m	13.1 dB

Part number	Type (description)	Gain	Application*	Minimum separation	Required cable loss
A24-P14NF	Flat panel	14.0 dBi	Fixed	2 m	14.1 dB
A24-P15NF	Flat panel	15.0 dBi	Fixed	2 m	15.1 dB
A24-P16NF	Flat panel	16.0 dBi	Fixed	2 m	16.1 dB
A24-P19NF	Flat panel	19.0 dBi	Fixed	2 m	19.1 dB

* If you are using the RF module in a portable application or if the module is used in a handheld device and the antenna is less than 20 cm from the human body when the device is in operation: The integrator may be responsible for passing additional Specific Absorption Rate (SAR) testing based on FCC rules 2.1091 and FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, OET Bulletin and Supplement C. See the note under FCC notices for more information. The testing results will be submitted to the FCC for approval prior to selling the integrated unit. The required SAR testing measures emissions from the module and how they affect the person.

Australia (C-Tick)

These products comply with requirements to be used in end products in Australia. All products with EMC and radio communications must have a registered C-Tick mark. Registration to use the compliance mark will only be accepted from Australian manufacturers or importers, or their agent, in Australia.

Labeling requirements

In order to place a C-Tick mark on an end product, a company must comply with 1 or 2 below:

1. Have a company presence in Australia.
2. Have a company, distributor, or agent in Australia that will sponsor importing the end product.

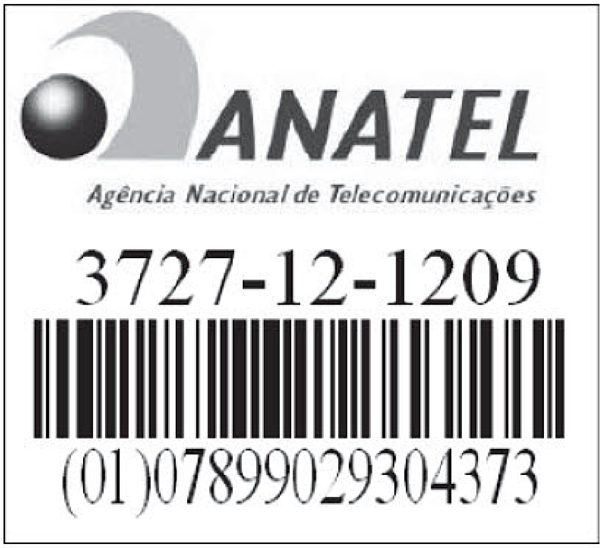
Contact Digi for questions about locating a contact in Australia.

Brazil ANATEL

The XBee RF modules with 802.15.4 or DigiMesh firmware (models noted in the following conformity information) comply with Brazil ANATEL standards in Resolution No. 506. The following information is required in the user manual for the product containing the radio and on the product containing the radio (in Portuguese):

The XBee-PRO RF modules with 802.15.4 or DigiMesh firmware (models noted in conformity information below) comply with Brazil ANATEL standards in Resolution No. 506. The following information is required in the user manual for the product containing the radio and on the product containing the radio (in Portuguese):

Modelo XBee-Pro S3B:



ANATEL

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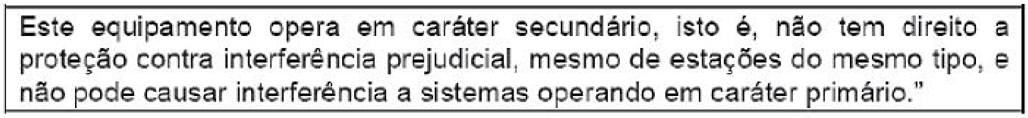


Este equipamento opera em caráter secundário, isto é, não tem direito a proteção contra interferência prejudicial, mesmo de estações do mesmo tipo, e não pode causar interferência a sistemas operando em caráter primário."

ISED (Innovation, Science and Economic Development Canada)

Labeling requirements

IC requires you to place a clearly visible label on the outside of the final product enclosure, displaying the following text:

Contains Model XBee Radio, IC: 4214A-XBEE

Contains Model XBee-PRO Radio, IC: 4214A-XBEEPRO

The integrator is responsible for its product to comply with IC ICES-003 & FCC Part 15, Sub. B - Unintentional Radiators. ICES-003 is the same as FCC Part 15 Sub. B and Industry Canada accepts FCC test report or CISPR 22 test report for compliance with ICES-003.

Europe

The RF Module is certified for use in several European countries; for a complete list, go to digi.com.

If the XBee/XBee-PRO DigiMesh 2.4 is incorporated into a product, the manufacturer must ensure compliance of the final product with articles 3.1a and 3.1b of the RE Directive (Radio Equipment Directive). A Declaration of Conformity must be issued for each of these standards and kept on file as described in the RE Directive (Radio Equipment Directive).

Furthermore, the manufacturer must maintain a copy of the RF Module user guide documentation and ensure the final product does not exceed the specified power ratings, antenna specifications, and/or installation requirements as specified in the user manual.

Maximum power and frequency specifications

For the XBee device:

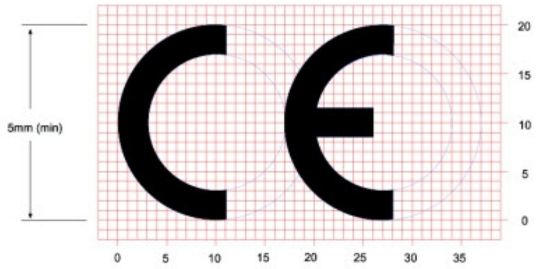
- Maximum power: 1.1 mW Equivalent Isotropically Radiated Power (EIRP).
- Frequencies: 5 MHz channel spacing, beginning at 2405 MHz and ending at 2480 MHz.

For the XBee-PRO device:

- Maximum power: 11.16 dBm Equivalent Isotropically Radiated Power (EIRP).
- Frequencies: 5 MHz channel spacing, beginning at 2410 MHz and ending at 2465 MHz.

OEM labeling requirements

The “CE” marking must be affixed to a visible location on the OEM product.



The CE mark shall consist of the initials “CE” taking the following form:

- If the CE marking is reduced or enlarged, the proportions given in the above graduated drawing must be respected.
- The CE marking must have a height of at least 5 mm except where this is not possible on account of the nature of the apparatus.
- The CE marking must be affixed visibly, legibly, and indelibly.

Restrictions

The power output of the XBee-PRO RF Modules must not exceed 10 dBm. The power level is set using the **PL** command. The International Variant of this product is internally limited to 10 dBm.

France imposes restrictions on the 2.4 GHz band. Go to art-telecom.Fr or contact Digi for more information.

Declarations of conformity

Digi has issued Declarations of Conformity for the (product name) concerning emissions, EMC, and safety. For more information, see https://www.digi.com/resources/certifications.

Important note

Digi customers assume full responsibility for learning and meeting the required guidelines for each country in their distribution market. Refer to the radio regulatory agency in the desired countries of operation for more information.

Approved antennas

When you integrate high-gain antennas, European regulations stipulate the EIRP power maximums. Use the following guidelines to determine which antennas to use when you design an application.

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

The following antenna types are tested and approved for use with the XBee Module:

Yagi

RF module was tested and approved with 15 dBi antenna gain with 1 dB cable-loss (EIRP Maximum of 14 dBm). Any Yagi type antenna with 14 dBi gain or less can be used with no cable-loss.

Omni-directional

RF module was tested and approved with 15 dBi antenna gain with 1 dB cable-loss (EIRP Maximum of 14 dBm). Any Omni-directional type antenna with 14 dBi gain or less can be used with no cable-loss.

Flat panel

RF module was tested and approved with 19 dBi antenna gain with 4.8 dB cable-loss (EIRP Maximum of 14.2 dBm). Any Flat Panel type antenna with 14.2 dBi gain or less can be used with no cable-loss.

The embedded XBee-PRO was tested and approved for use with the following antennas:

Note At 10 dBm transmit power, the **PL** parameter value must equal **0**, or you must use the international variant.

Dipole

2.1 dBi, omni-directional, articulated RPSMA, Digi part number **A24-HABSM***.

Chip antenna

-1.5 dBi.

Attached monopole whip

1.5 dBi.

Integrated PCB antenna

-0.5 dBi

The RF modem encasement was designed to accommodate the RPSMA antenna option.

Japan

In order to use the XBee-PRO in Japan, you must order the International version. The International XBee-PRO RF Modules are limited to a transmit power output of 10 dBm (10 mW).

Labeling requirements

A clearly visible label on the outside of the final product enclosure must display the following text:

R201WW07215214 (XBee)

R201WW08215111 (XBee-PRO)