XBee®/XBee-PRO® DigiMesh™ 2.4 RF Modules

XBee® DigiMesh 2.4 RF Modules

RF Module Operation

RF Module Configuration

RF Modules by Digi International
Firmware version:

8x4x XBee/XBee-PRO DigiMesh 2.4

28x4x XBee/XBee-PRO DigiMesh 2.4 (International variant)

Technical Support:	Phone: (801) 765-9885
	Live Chat: www.digi.com
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1.XBee/XBee-PRO DigiMesh 2.4 RF Modules

The XBee/XBee-PRO DigiMesh 2.4 RF Modules were engineered to support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between remote devices.

Key Features

Long-range Data Integrity

XBee

- Indoor/Urban: up to 100' (30 m)
- Outdoor line-of-sight: up to 300' (100m)
- Transmit Power: 1 mW (0dBm)
- Receiver Sensitivity: -92 dBm

XBee-PRO

- Indoor/Urban: up to 300' (100 m)
- Outdoor line-of-sight: up to 1 mile (1500m)
- Transmit Power: 100 mW (20dBm) EIRP
- Receiver Sensitivity: -100 dBm
- RF Data Rate: 250,000 bps

Advanced Networking & Security

- Retries and Acknowledgements
- Self-routing, self-healing mesh networking
- DSSS (Direct Sequence Spread Spectrum)

Low Power

XBee 2.4

- TX Peak Current: 45 mA (@3.3 V)
- RX Current: 50 mA (@3.3 V)
- Power-down Current: < 50 μA

XBee-PRO® 2.4

- TX Current: 210 mA (@3.3 V)
- RX Current: 80mA (@3.3 V)
- Power-down Current: < 50 μA

Easy-to-Use

- No configuration necessary for out-of box RF communications
- AT and API Command Modes for configuring module parameters
- Small form factor
- Extensive command set
- Free X-CTU Software (Testing and configuration software)

Worldwide Acceptance

FCC Approval (USA) Refer to Appendix B for FCC Requirements. Systems that contain XBee/XBee-PRO RF Modules inherit Digi Certifications. ISM (Industrial, Scientific & Medical) **2.4 GHz frequency band** Manufactured under **ISO 9001:2000** registered standards XBee/XBee-PRO RF Modules are optimized for use in the **United States, Canada, Australia, Japan and Europe**. (Contact Digi for complete list of government agency approvals.)

Specifications

Specifications of the XBee/XBee-PRO DigiMesh 2.4 RF Modules

Specification	XBee	XBee-PRO
Performance		
Indoor/Urban Range	Up to 100 ft (30 m)	Up to 300 ft. (90 m), up to 200 ft (60 m) International variant
Outdoor RF line-of-sight Range	Up to 300 ft (90 m)	Up to 1 mile (1500 m), up to 2500 ft (750 m) international variant
Transmit Power Output (software selectable)	1mW (0 dBm)	63mW (18dBm)* 10mW (10 dBm) for International variant
RF Data Rate	250,000 bps	250,000 bps
Serial Interface Data Rate (software selectable)	1200 bps - 250 kbps (non-standard baud rates also supported)	1200 bps - 250 kbps (non-standard baud rates also supported)
Receiver Sensitivity	-92 dBm (1% packet error rate)	-100 dBm (1% packet error rate)
Power Requirements		
Supply Voltage	2.8 – 3.4 V	2.8 – 3.4 V
Transmit Current (typical)	45mA (@ 3.3 V)	If PL=0 (10dBm): 137mA(@3.3V), 139mA(@3.0V) PL=1 (12dBm): 155mA (@3.3V), 153mA(@3.0V) PL=2 (14dBm): 170mA (@3.3V), 171mA(@3.0V) PL=3 (16dBm): 188mA (@3.3V), 195mA(@3.0V) PL=4 (18dBm): 215mA (@3.3V), 227mA(@3.0V) International variant: PL=4 (10dBm): 140mA (@3.3V)
Idle / Receive Current (typical)	50mA (@ 3.3 V)	55mA (@ 3.3 V)
Power-down Current	< 50 µA	< 50 µA
General		
Operating Frequency	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	0.960" x 1.087" (2.438cm x 2.761cm)	0.960" x 1.297" (2.438cm x 3.294cm)
Operating Temperature	-40 to 85° C (industrial)	-40 to 85° C (industrial)
Antenna Options	Integrated Whip, Chip or U.FL Connector	Integrated Whip, Chip or U.FL Connector
Networking & Security		
Supported Network Topologies	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 Addresses	PAN ID, Channel and Addresses
Agency Approvals		
United States (FCC Part 15.247)	OUR-XBEE	OUR-XBEEPRO
Industry Canada (IC)	4214A XBEE	4214A XBEEPRO
Europe (CE)	ETSI	ETSI (Max. 10 dBm transmit power output)*
Japan	R201WW07215214	R201WW08215111" (Max. 10 dBm transmit power output)**
Austraila	C-Tick	C-Tick

* When operating in Europe, XBee-PRO 802.15.4 modules must operate at or below a transmit power output level of 10dBm. Customers have two choices for transmitting at or below 10dBm:

a. Order the standard XBee-PRO module and change the PL command to "0" (10dBm),

b. Order the International variant of the XBee-PRO module, which has a maximum transmit output power of 10dBm (@ PL=4).

Additionally, European regulations stipulate an EIRP power maximum of 12.86 dBm (19 mW) for the XBee-PRO and 12.11 dBm for the XBee when integrating antennas.

** When operating in Japan, only the International variant of the XBee-PRO 802.15.4 module is approved for use.

Mechanical Drawings

Antenna Options: The ranges specified are typical when using the integrated Whip (1.5 dBi) and Dipole (2.1 dBi) anten-nas. The Chip antenna option provides advantages in its form factor; however, it typically yields shorter range than the Whip and Dipole antenna options when transmitting outdoors.For more information, refer to the "XBee Antennas" Knowl-edgebase Article located on Digi's Support Web site.

Mechanical drawings of the XBee/XBee-PRO DigiMesh 2.4 RF Modules (antenna options not shown)
The XBee and XBee-PRO RF Modules are pin-for-pin compatible.
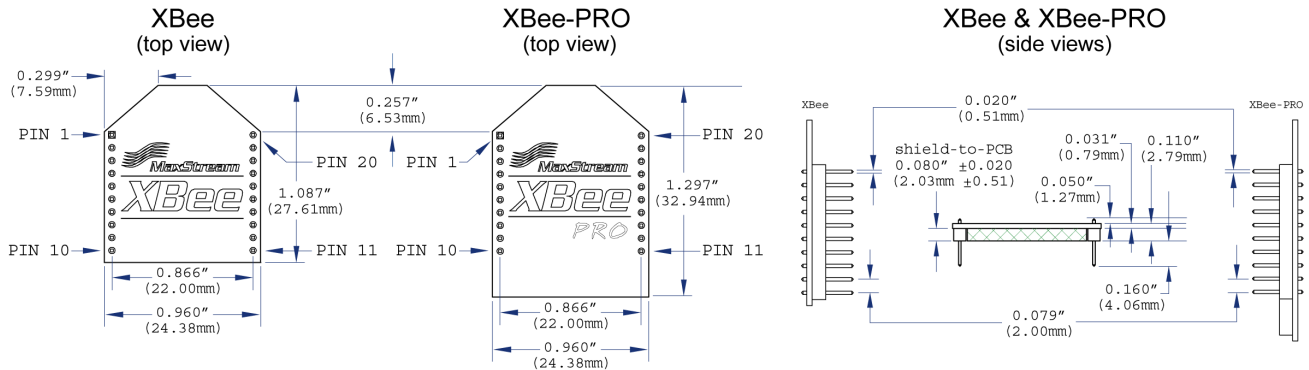
Mounting Considerations

The XBee/XBee-Pro DigiMesh 2.4 RF Module (through-hole) was designed to mount into a receptacle (socket) and therefore does not require any soldering when mounting it to a board. The Development Kits contain RS-232 and USB interface boards which use two 20-pin receptacles to receive modules.

XBee/XBee-Pro DigiMesh 2.4 Module Mounting to an RS-232 Interface Board.
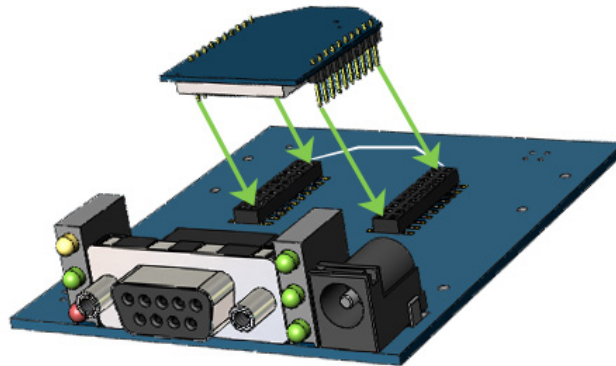
The receptacles used on Digi development boards are manufactured by Century Interconnect. Several other manu-facturers provide comparable mounting solutions; however, Digi currently uses the following receptacles:

• Through-hole single-row receptacles - Samtec P/N: MMS-110-01-L-SV (or equivalent)

• Surface-mount double-row receptacles - Century Interconnect P/N: CPRMSL20-D-0-1 (or equivalent)

• Surface-mount single-row receptacles - Samtec P/N: SMM-110-02-SM-S

Digi also recommends printing an outline of the module on the board to indicate the orientation the module should be mounted.

Pin Signals

Pin Assignments for the XBee/XBee-PRO 2.4 Modules
(Low-asserted signals are distinguished with a horizontal line above signal name.)

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	Module Reset (reset pulse must be at least 200 ns)
6	PWM0 / RSSI	Output	PWM Output 0 / RX Signal Strength Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	DTR / SLEEP_RQ / DI8	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	CTS / DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	ON / SLEEP	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate / AD5 / DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	RTS / AD6 / DIO6	Either	Request-to-Send Flow Control, Analog Input 6 or 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
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

* Function is not supported at the time of this release

Design Notes:

The XBee modules do not specifically require any external circuitry or specific connections for proper operation. However, there are some general design guidelines that are recommended to help with troubleshooting and building a robust design.

Power Supply Design

Poor power supply design can lead to poor radio performance, especially if the supply voltage is not kept within tolerance or is excessively noisy. To help reduce noise, we recommend that a 1.0 μF capacitor and an 8.2 pF capacitor be placed as near to pin1 on the PCB as possible. If you are using a switching regulator for your power supply, switching frequencies above 500 kHz are preferable. Power supply ripple should be limited to a maximum of 100 mV peak-to-peak.

Recommended Pin Connections

The only required pin connections are VCC, GND, DOUT and DIN. To support serial firmware updates, also connect RTS and DTR. **All unused pins should be left disconnected.** All inputs on the radio can be pulled high with internal pull-up resistors using the PR software command. No specific treatment is needed for unused outputs.

Other pins may be connected to external circuitry for convenience of operation, including the Associate LED pin (pin15) and the commissioning button pin (pin20). The Associate LED will flash differently depending on the state of the module, and a pushbutton attached to pin20 can enable various deployment and troubleshooting functions without having to send UART commands.

The combined source and sink capabilities of the module are limited to 120 mA for all pins on the module. Module pins 11 and 15 can source/sink a maximum of 2 mA; pins 9, 6 and 13 can source/sink a maximum of 16 mA; all other pins can source/sink a maximum of 8 mA.

If analog sampling is desired, the VREF pin (pin14) should be attached to a voltage reference.

Electrical Characteristics

DC Characteristics (VCC = 2.8 - 3.4 VDC)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
V_{IL}	Input Low Voltage	All Digital Inputs	-	-	0.35 * VCC	V
V_{IH}	Input High Voltage	All Digital Inputs	0.7 * VCC	-	-	V
V_{OL}	Output Low Voltage	I_{OL} = 2 mA, VCC >= 2.7 V	-	-	0.5	V
V_{OH}	Output High Voltage	I_{OH} = -2 mA, VCC >= 2.7 V	VCC - 0.5	-	-	V
II_{IN}	Input Leakage Current	V_{IN} = VCC or GND, all inputs, per pin	-	0.025	1	µA
II_{OZ}	High Impedance Leakage Current	V_{IN} = VCC or GND, all I/O High-Z, per pin	-	0.025	1	µA
TX	Transmit Current	VCC = 3.3 V	-	45 (XBee)	215, 140 (PRO, Int)	mA
RX	Receive Current	VCC = 3.3 V	-	50 (XBee)	55 (PRO)	mA
PWR-DWN	Power-down Current	SM parameter = 1	-	< 10	-	µA

ADC Characteristics (Operating)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
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}	Analog Input Voltage[1]		V_{SSAD} - 0.3	-	V_{DDAD} + 0.3	V

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

ADC Timing/Performance Characteristics[1]

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
R_{AS}	Source Impedance at Input[2]		-	-	10	kΩ
V_{AIN}	Analog Input Voltage[3]		V_{REFL}		V_{REFH}	V
RES	Ideal Resolution (1 LSB)[4]	2.08V ≤ V_{DDAD} ≤ 3.6V	2.031	-	3.516	mV
DNL	Differential Non-linearity[5]		-	±0.5	±1.0	LSB
INL	Integral Non-linearity[6]		-	±0.5	±1.0	LSB
E_{ZS}	Zero-scale Error[7]		-	±0.4	±1.0	LSB
F_{FS}	Full-scale Error[8]		-	±0.4	±1.0	LSB
E_{IL}	Input Leakage Error[9]		-	±0.05	±5.0	LSB
E_{TU}	Total Unadjusted Error[10]		-	±1.1	±2.5	LSB

1. All ACCURACY numbers are based on processor and system being in WAIT state (very little activity and no IO 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 VREFL). 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. R_{AS} 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. Analog input must be between V_{REFL} and V_{REFH} for valid conversion. Values greater than V_{REFH} will convert to $3FF.

4. The resolution is the ideal step size or 1LSB = $(V_{REFH} - V_{REFL})/1024$

5. 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.

6. 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 $(Current Code - 1/2)*(1/((V_{REFH} + E_{FS}) - (V_{REFL} + E_{ZS})))$.

7. 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 $(Code - 1/2)*(1/(V_{REFH} - V_{REFL}))$.

8. 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 $(Code - 1/2)*(1/(V_{REFH} - V_{REFL}))$.

9. 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.

10. 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 (1/2LSB) 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).

2. RF Module Operation

Serial Communications

The XBee/XBee-PRO 2.4 DigiMesh RF Modules interface to a host device through a logic-level asynchronous serial port. Through its serial port, the module can communicate with any logic and voltage compatible UART; or through a level translator to any serial device (For example: Through a Digi proprietary RS-232 or USB interface board).

UART Data Flow

Devices that have a UART interface can connect directly to the pins of the RF module as shown in the figure below.

System Data Flow Diagram in a UART-interfaced environment
(Low-asserted signals distinguished with horizontal line over signal name.)
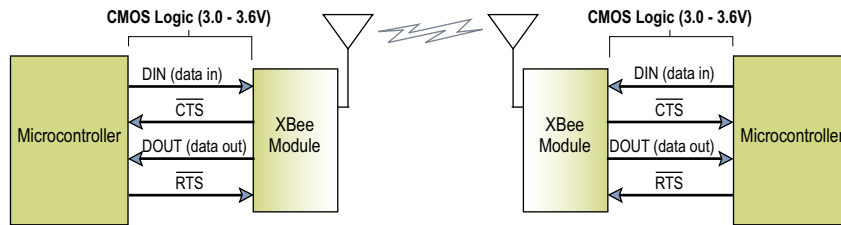
Serial Data

Data enters the module UART through the DIN (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following figure illustrates the serial bit pattern of data passing through the module.

UART data packet 0x1F (decimal number "31") as transmitted through the RF module
Example Data Format is 8-N-1 (bits - parity - # of stop bits)
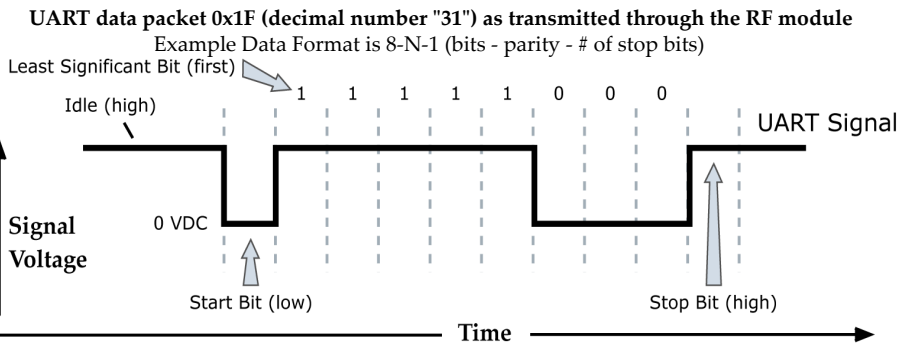
The module UART performs tasks, such as timing and parity checking, that are needed for data communications. Serial communications depend on the two UARTs to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits).

Serial Buffers

The modules maintain buffers to collect received serial and RF data, which is illustrated in the figure below. The serial receive buffer collects incoming serial characters and holds them until they can be processed. The serial transmit buffer collects data that is received via the RF link that will be transmitted out the UART.

Internal Data Flow Diagram
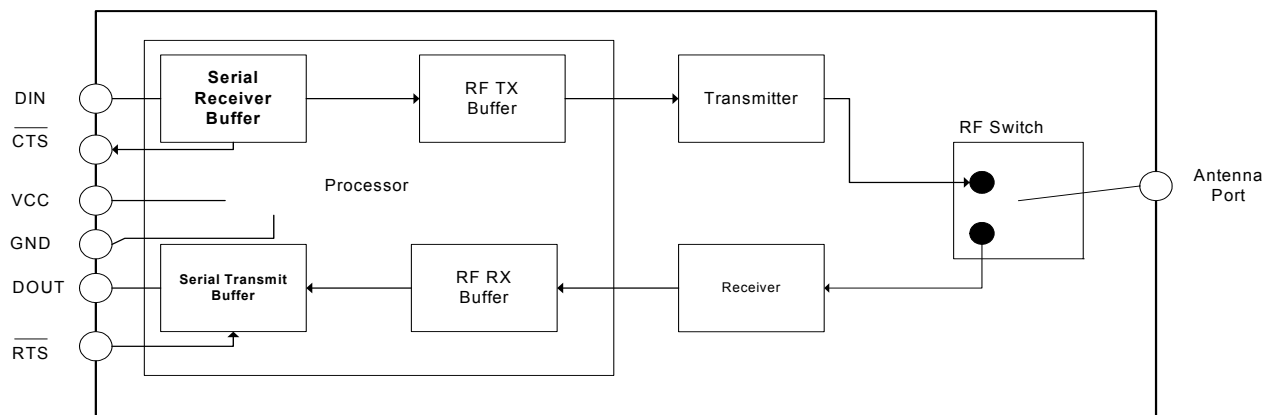
Serial Receive Buffer

When serial data enters the RF module through the DIN Pin (pin 3), the data is stored in the serial receive buffer until it can be processed. Under certain conditions, the module may not be able to process data in the serial receive buffer immediately. If large amounts of serial data are sent to the module, CTS flow control may be required to avoid overflowing the serial receive buffer.

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

1. If the module is receiving a continuous stream of RF data, the data in the serial receive buffer will not be transmitted until the module is no longer receiving RF data.

2. If the module is transmitting an RF data packet, the module may need to discover the destination address or establish a route to the destination. After transmitting the data, the module may need to retransmit the data if an acknowledgment is not received, or if the transmission is a broadcast. These issues could delay the processing of data in the serial receive buffer.

Serial Transmit Buffer

When RF data is received, the data is moved into the serial transmit buffer and is sent out the serial port. If the serial transmit buffer becomes full enough such that all data in a received RF packet won't fit in the serial transmit buffer, the entire RF data packet is dropped.

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 module, the module could receive data faster than it can send the data to the host.

2. If the host does not allow the module to transmit data out from the serial transmit buffer because of being held off by hardware flow control.

Serial Flow Control

The $\overline{RTS}$ and $\overline{CTS}$ module pins can be used to provide $\overline{RTS}$ and/or $\overline{CTS}$ flow control. $\overline{CTS}$ flow control provides an indication to the host to stop sending serial data to the module. RTS flow control allows the host to signal the module to not send data in the serial transmit buffer out the UART. $\overline{RTS}$ and $\overline{CTS}$ flow control are enabled using the D6 and D7 commands.

$\overline{CTS}$ Flow Control

If $\overline{CTS}$ flow control is enabled (D7 command), when the serial receive buffer is is filled with FT bytes, the module de-asserts $\overline{CTS}$ (sets it high) to signal to the host device to stop sending serial data. $\overline{CTS}$ is re-asserted when less than FT - 16 bytes are in the UART receive buffer.

$\overline{RTS}$ Flow Control

If flow $\overline{RTS}$ control is enabled (D6 command), data in the serial transmit buffer will not be sent out the DOUT pin as long as $\overline{RTS}$ is de-asserted (set high). The host device should not de-assert $\overline{RTS}$ for long periods of time to avoid filling the serial transmit buffer. If an RF data packet is received, and the serial transmit buffer does not have enough space for all of the data bytes, the entire RF data packet will be discarded.

Serial Interface Protocols

The XBee modules support both transparent and API (Application Programming Interface) serial interfaces.

Transparent Operation

When operating in transparent mode, the modules act as a serial line replacement. All UART data received through the DIN pin is queued up for RF transmission. When RF data is received, the data is sent out through the DOUT pin. The module configuration parameters are configured using the AT command mode interface.

Data is buffered in the serial receive buffer until one of the following causes the data to be packetized and transmitted:

- No serial characters are received for the amount of time determined by the RO (Packetization Timeout) parameter. If RO = 0, packetization begins when a character is received.
- The Command Mode Sequence (GT + CC + GT) is received. Any character buffered in the serial receive buffer before the sequence is transmitted.
- The maximum number of characters that will fit in an RF packet is received.

API Operation

API operation is an alternative to transparent operation. The frame-based API extends the level to which a host application can interact with the networking capabilities of the module. When in API mode, all data entering and leaving the module is contained in frames that define operations or events within the module.

Transmit Data Frames (received through the DIN pin (pin 3)) include:

- RF Transmit Data Frame
- Command Frame (equivalent to AT commands)

Receive Data Frames (sent out the DOUT pin (pin 2)) include:

- RF-received data frame
- Command response
- Event notifications such as reset, associate, disassociate, etc.

The API provides alternative means of configuring modules and routing data at the host application layer. A host application can send data frames to the module that contain address and payload information instead of using command mode to modify addresses. The module will send data frames to the application containing status packets; as well as source, and payload information from received data packets.

The API operation option facilitates many operations such as the examples cited below:

- Transmitting data to multiple destinations without entering Command Mode
- Receive success/failure status of each transmitted RF packet
- Identify the source address of each received packet

A Comparison of Transparent and API Operation

The following table compares the advantages of transparent and API modes of operation:

Transparent Operation Features	
Simple Interface	All received serial data is transmitted unless the module is in command mode.
Easy to support	It is easier for an application to support transparent operation and command mode.

API Operation Features	
Easy to manage data transmissions to multiple destinations	Transmitting RF data to multiple remotes only requires changing the address in the API frame. This process is much faster than in transparent operation where the application must enter AT command mode, change the address, exit command mode, and then transmit data. Each API transmission can return a transmit status frame indicating the success or reason for failure.
Received data frames indicate the sender's address	All received RF data API frames indicate the source address.
Advanced addressing support	API transmit and receive frames can expose addressing fields including source and destination endpoints, cluster ID and profile ID. This makes it easy to support ZDO commands and public profile traffic.
Advanced networking diagnostics	API frames can provide indication of IO samples from remote devices, and node identification messages.
Remote Configuration	Set / read configuration commands can be sent to remote devices to configure them as needed using the API.

As a general rule of thumb, API firmware is recommended when a device:

- sends RF data to multiple destinations
- sends remote configuration commands to manage devices in the network
- receives IO samples from remote devices
- receives RF data packets from multiple devices, and the application needs to know which device sent which packet
- must support multiple endpoints, cluster IDs, and/or profile IDs
- uses the Device Profile services.

If the above conditions do not apply (i.e. a sensor node, router, or a simple application), then AT firmware might be suitable. It is acceptable to use a mixture of devices running API and AT firmware in a network.

To implement API operations, refer to the API Operation Chapter 6, Modes of Operation.

Idle Mode

When not receiving or transmitting data, the RF module is in Idle Mode. During Idle Mode, the RF module is also checking for valid RF data. The module 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)
- Receive Mode (Valid RF data is received through the antenna)
- Command Mode (Command Mode Sequence is issued)
- Sleep Mode (Sleep-enabled devices only)

Transmit Mode

When serial data is received and is ready for packetization, the RF module will exit Idle Mode and attempt to transmit the data. The destination address determines which node(s) will receive the data. To communicate, modules must be configured to operate on the same channel and network ID.If a route is not known, route discovery will take place for the purpose of establishing a route to the destination node. If a module with a matching network address is not discovered, the packet is discarded. The data will be transmitted once a route is established. If route discovery fails to establish a route, the packet will be discarded.

Transmit Mode Sequence
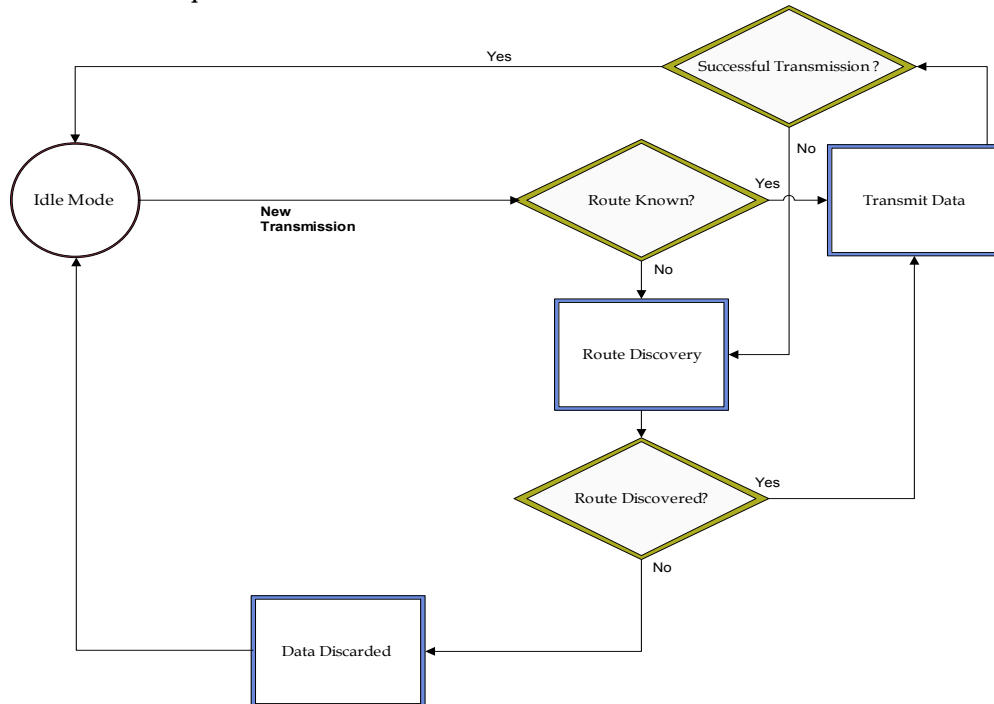
When data is transmitted from one node to another, a network-level acknowledgement is transmitted back across the established route to the source node. This acknowledgement packet indicates to the source node that the data packet was received by the destination node. If a network acknowledgement is not received, the source node will re-transmit the data. See Data Transmission and Routing in Chapter 4 for more information.

Receive Mode

If a valid RF packet is received, the data is transferred to the serial transmit buffer.

Command Mode

To modify or read RF Module parameters, the module must first enter into Command Mode - a state in which incoming serial characters are interpreted as commands. Refer to the API Mode section for an alternate means of configuring modules.

AT Command Mode

To Enter AT Command Mode:
Send the 3-character command sequence "+++" and observe guard times before and after the command characters. [Refer to the "Default AT Command Mode Sequence" below.]

Default AT Command Mode Sequence (for transition to Command Mode):

- No characters sent for one second [GT (Guard Times) parameter = 0x3E8]
- Input three plus characters ("+++") within one second [CC (Command Sequence Character) parameter = 0x2B.]
- No characters sent for one second [GT (Guard Times) parameter = 0x3E8]

Once the AT command mode sequence has been issued, the module sends an "OK\r" out the DOUT pin. The "OK\r" characters can be delayed if the module has not finished transmitting received serial data.

When command mode has been entered, the command mode timer is started (CT command), and the module is able to receive AT commands on the DIN pin.

All of the parameter values in the sequence can be modified to reflect user preferences.

NOTE: Failure to enter AT Command Mode is most commonly due to baud rate mismatch. Ensure the 'Baud' setting on the PC Settings" tab matches the interface data rate of the RF module. By default, the BD parameter = 3 (9600 bps).

To Send AT Commands:
Send AT commands and parameters using the syntax shown below.

Syntax for sending AT Commands

"AT" Prefix	+	ASCII Command	+	Space (Optional)	+	Parameter (Optional, HEX)	+	Carriage Return

Example: ATDL 1F<CR>
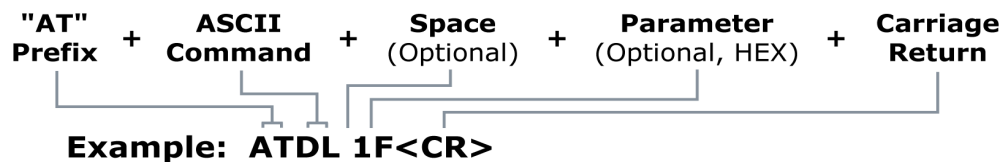
To read a parameter value stored in the RF module's register, omit the parameter field.

The preceding example would change the RF module Destination Address (Low) to "0x1F".

For modified parameter values to persist in the module's memory after a reset, changes must be saved using the WR (Write) Command. Otherwise, parameters are restored to previously saved values after the module is reset.

Command Response When a command is sent to the module, the module will parse and execute the command. Upon successful execution of a command, the module returns an "OK" message. If execution of a command results in an error, the module returns an "ERROR" message.

Applying Command Changes

Any changes made to the configuration command registers through AT commands will not take effect until the changes are applied. For example, sending the BD command to change the baud rate will not change the actual baud rate until changes are applied. Changes can be applied in one of the following ways:

- The AC (Apply Changes) command is issued.
- AT command mode is exited.

To Exit AT Command Mode

1. Send the ATCN (Exit Command Mode) command (followed by a carriage return).

    [OR]

2. If no valid AT Commands are received within the time specified by CT (Command Mode Timeout) Command, the RF module automatically returns to Idle Mode.

For an example of programming the RF module using AT Commands and descriptions of each configurable parameter, refer to the "Command Reference Tables" chapter.

Sleep Mode

Sleep mode allows the RF module to enter a low power state. The XBee DigiMesh 2.4 modules support a network synchronized sleep to conserve power. Sleep functionality is discussed in detail in Chapter 4.

3. Advanced Application Features

Remote Configuration Commands

A module in API mode has provisions to send configuration commands to remote devices using the Remote Command Request API frame (See API Operations chapter.) This API frame can be used to send commands to a remote module to read or set command parameters.

Sending a Remote Command

To send a remote command, the Remote Command Request frame should be populated with the 64-bit address of the remote device, the correct command options value, and the command and parameter data (optional). The API field for a 16 bit address should be set to 0xFFFE. If a command response is desired, the Frame ID should be set to a non-zero value. Only unicasts of remote commands are supported. Remote commands cannot be broadcast.

Applying Changes on Remote Devices

When remote commands are used to change command parameter settings on a remote device, parameter changes do not take effect until the changes are applied. For example, changing the BD parameter will not change the actual serial interface rate on the remote until the changes are applied. Changes can be applied using remote commands in one of three ways:

- Set the apply changes option bit in the API frame
- Issue an AC command to the remote device
- Issue a WR + FR command to the remote device to save changes and reset the device.

Remote Command Responses

If the remote device receives a remote command request transmission, and the API frame ID is non-zero, the remote will send a remote command response transmission back to the device that sent the remote command. When a remote command response transmission is received, a device sends a remote command response API frame out its UART. The remote command response indicates the status of the command (success, or reason for failure), and in the case of a command query, it will include the register value. The device that sends a remote command will not receive a remote command response frame if:

- The destination device could not be reached
- The frame ID in the remote command request is set to 0.

Network Commissioning and Diagnostics

Network commissioning is the process whereby devices in a mesh network are discovered and configured for operation. The modules include several features to support device discovery and configuration. In addition to configuring devices, a strategy must be developed to place devices to ensure reliable routes.

To accommodate these requirements, the modules include various features to aid in device placement, configuration, and network diagnostics.

Device Configuration

These modules can be configured locally through serial commands (AT or API), or remotely through remote API commands. API devices can send configuration commands to set or read the configuration settings of any device in the network.

Device Placement

For a mesh network installation to be successful, the installer must be able to determine where to place individual XBee devices to establish reliable links throughout the mesh network.

Link Testing

A good way to measure the performance of a mesh network is to send unicast data through the network from one device to another to determine the success rate of many transmissions. To simplify link testing, the modules support

a loopback cluster ID (0x12) on the data endpoint (0xE8). Any data sent to this cluster ID on the data endpoint will be transmitted back to the sender. This is shown in the figure below:
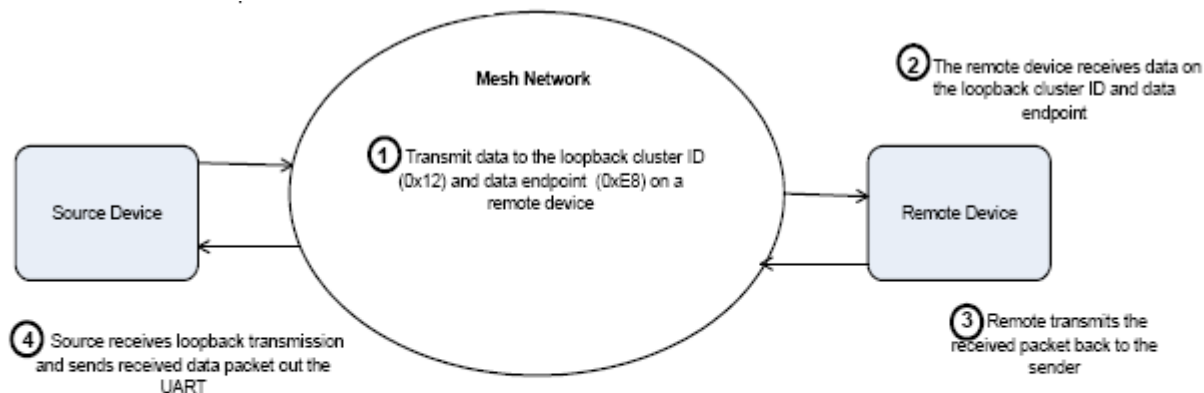
Demonstration of how the loopback cluster ID and data endpoint can be used to measure the link quality in a mesh network

The configuration steps to send data to the loopback cluster ID depend on the AP setting:

AT Configuration (AP=0)

To send data to the loopback cluster ID on the data endpoint of a remote device, set the CI command value to 0x12. The SE and DE commands should be set to 0xE8 (default value). The DH and DL commands should be set to the address of the remote (0 for the coordinator, or the 64-bit address of the remote). After exiting command mode, any received serial characters will be transmitted to the remote device, and returned to the sender.

API Configuration (AP=1 or AP=2)

Send an Explicit Addressing ZigBee Command API frame using 0x12 as the cluster ID and 0xE8 as the source and destination endpoint. Data packets received by the remote will be echoed back to the sender.

RSSI Indicators

It is possible to measure the received signal strength on a device using the DB command. DB returns the RSSI value (measured in –dBm) of the last received packet. However, this number can be misleading. 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 and should be used sparingly.

The DB value can be determined in hardware using the RSSI/PWM module pin (pin 6). If the RSSI PWM functionality is enabled (P0 command), when the module receives data, the RSSI PWM is set to a value based on the RSSI of the received packet. (Again, this value only indicates the quality of the last hop.) This pin could potentially be connected to an LED to indicate if the link is stable or not.

Node Discovery

The node discovery command can be used to discover all Digi modules that have joined a network. Issuing the ND command sends a broadcast node discovery message throughout the network. All devices that receive the command will send a response that includes the device's addressing information, node identifier string (see NI command), and other relevant information. This command is useful for generating a list of all module addresses in a network.

When a device receives the node discovery message, it waits a random time before sending its own response. The maximum time delay is set on the ND sender with the NT command. The ND originator includes its NT setting in the transmission to provide a delay window for all devices in the network. Large networks may need to increase NT to improve network discovery reliability. The default NT value is 0x82 (13 seconds).

Commissioning Pushbutton and Associate LED

The modules support a set of commissioning and LED behaviors to aid in device deployment and commissioning. These include the commissioning push button definitions and associate LED behaviors. These features can be supported in hardware as shown below.

Commissioning Pushbutton and Associate LED Functionalities
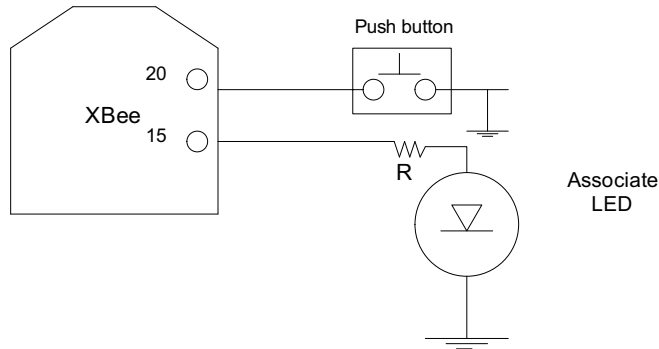
A push button and an LED can be connected to module pins 20 and 15 respectively to support the commissioning push button and associated LED functionalities.

Commissioning Push button

The commissioning push button definitions provide a variety of simple functions to aid in deploying devices in a network. The commissioning button functionality on pin 20 is enabled by setting the D0 command to 1 (enabled by default).

Push button behavior

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 will blink their Associate LED rapidly for 1 second. All API devices that receive this transmission will send a Node Identification frame out their UART (API ID 0x95)
1	Configured for sleep	Wakes the module for 30 seconds (or until the entire network goes to sleep). Queues a Node Identification broadcast transmission to be sent at the beginning of the next network wake cycle. All devices that receive this transmission will blink their Associate LED rapidly for 1 second. All API devices that receive this transmission will send a Node Identification frame out their UART (API ID 0x95).
2	Not configured for sleep	Not supported.
2	Configured for sleep	Causes a node which is configured with sleeping router nomination enabled (see description of the ATSO – sleep options command in the XBee module's Product Manual) to immediately nominate itself as the network sleep coordinator.
4	Either	Issues an ATRE to restore module parameters to default values.

Button presses may be simulated in software using the ATCB command. ATCB should be issued with a parameter set to the number of button presses to execute. (i.e. sending ATCB1 will execute the action(s) associated with a single button press.)

The node identification frame is similar to the node discovery response frame – it contains the device's address, node identifier string (NI command), and other relevant data. All API devices that receive the node identification frame send it out their UART as an API Node Identification Indicator frame (0x95).

Associate LED

The Associate pin (pin 15) can provide indication of the device's sleep status and diagnostic information. To take advantage of these indications, an LED can be connected to the Associate pin as shown in the figure above. The Associate LED functionality is enabled by setting the D5 command to 1 (enabled by default). If enabled, the Associate pin is configured as an output and will behave as described in the following sections.

The Associate pin indicates the synchronization status of a sleep compatible node. On a non-sleep compatible node the pin functions has a power indicator. The following table describes this functionality:

The LT command can be used to override the blink rate of the Associate pin. When set to 0, the device uses the default blink time (500ms for sleep coordinator, 250ms otherwise).

LED Behavior

Sleep compatible?	LED Status	Meaning
No	On, blinking	The device is powered and operating properly.
Yes	On, solid	The device has not synchronized with the network or has lost synchronization with the network.
Yes	On, slow blinking (500ms blink time)	The device is acting as the network sleep coordinator and is operating properly.
Yes	On, fast blinking (250ms blink time)	The device is properly synchronized with the network.

Diagnostics Support

The Associate pin works with the commissioning pushbutton to provide additional diagnostics behaviors to aid in deploying and testing a network. If the commissioning push button is pressed once the device transmits a broadcast node identification packet at the beginning of the next wake cycle if sleep compatible, or immediately if not sleep compatible. If the Associate LED functionality is enabled (D5 command), a device that receives this transmission will blink its Associate pin rapidly for 1 second.

I/O Line Monitoring

I/O Samples

The modules support both analog input and digital IO line modes on several configurable pins.

Queried Sampling

Parameters for the pin configuration commands typically include the following:

Pin Command Descriptions

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

Setting the configuration command that corresponds to a particular pin will configure the pin:

Pin Configuration Commands

Module Pin Names	Module Pin Number	Configuration Command
CD / DIO12	4	P2
PWM0 / RSSI / DIO10	6	P0
PWM1 / DIO11	7	P1
DTR / SLEEP_RQ / DIO8	9	D8
AD4 / DIO4	11	D4
CTS / DIO7	12	D7
ON_SLEEP / DIO9	13	D9
ASSOC / AD5 / DIO5	15	D5
RTS / DIO6	16	D6
AD3 / DIO3	17	D3
AD2 / DIO2	18	D2
AD1 / DIO1	19	D1
AD0 / DIO0 / CommissioningButton	20	D0

See the command table for more information. Pullup resistors for each digital input can be enabled using the PR command.

1	Sample Sets	Number of sample sets in the packet. (Always set to 1.)
2	Digital Channel Mask	Indicates which digital IO lines have sampling enabled. Each bit corresponds to one digital IO line on the module. • 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 IO.
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 any digital IO lines are enabled, the first two bytes of the data set indicate the state of all enabled digital IO. Only digital channels that are enabled in the Digital Channel Mask bytes have any meaning in the sample set. If no digital IO are enabled on the device, these 2 bytes will be omitted. Following the digital IO data (if any), each enabled analog channel will return 2 bytes. The data starts with AIN0 and continues sequentially for each enabled analog input channel up to AIN5.

If the IS command is issued from AT command mode then a carriage return delimited list will be returned containing the above-listed fields. If the command is issued via an API frame then the module will return an AT command response API frame with the IO data included in the command data portion of the packet.

Example	Sample AT Response
0x01\r	[1 sample set]
0x0C0C\r	[Digital Inputs: DIO 2, 3, 10, 11 enabled]
0x03\r	[Analog Inputs: A/D 0, 1 enabled]
0x0408\r	[Digital input states: DIO 3, 10 high, DIO 2, 11 low]
0x03D0\r	[Analog input ADIO 0= 0x3D0]
0x0124\r	[Analog input ADIO 1=0x120]

Periodic I/O Sampling

Periodic sampling allows a module to take an IO sample and transmit it to a remote device at a periodic rate. The periodic sample rate is set by the IR command. If IR is set to 0, periodic sampling is disabled. For all other values of IR, data will be sampled after IR milliseconds have elapsed and transmitted to a remote device. The DH and DL commands determine the destination address of the IO samples. Only devices with API mode enabled will send IO data samples out their UART. Devices not in API mode will discard received IO data samples.

A module with sleep enabled will transmit periodic IO samples at the IR rate until the ST time expires and the device can resume sleeping. See the sleep section for more information on sleep.

Digital I/O Change Detection

Modules can be configured to transmit a data sample immediately whenever a monitored digital IO pin changes state. The IC command is a bitmask that can be used to set which digital IO lines should be monitored for a state change. If one or more bits in IC is set, an IO sample will be transmitted as soon as a state change is observed in one of the monitored digital IO lines. The figure below shows how edge detection can work with periodic sampling.
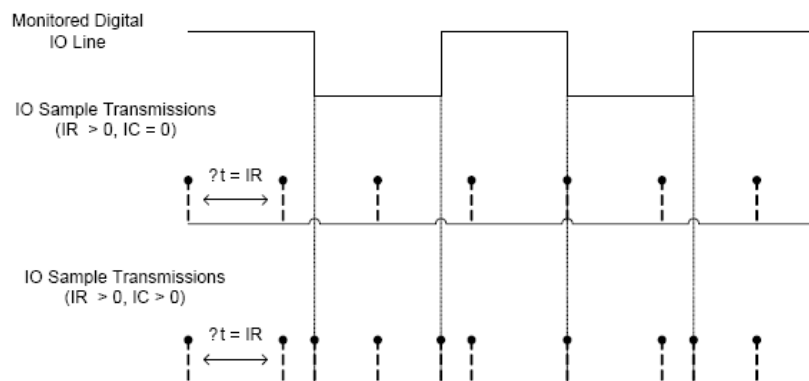
Enabling Edge Detection will force an immediate sample of all monitored digital IO lines if any digital IO lines change state.

4. XBee/XBee-PRO® DigiMesh 2.4

DigiMesh Networking

Mesh networking allows messages to be routed through several different nodes to a final destination. DigiMesh firmware allows manufacturers and system integrators to bolster their networks with the self-healing attributes of mesh networking. In the event that one RF connection between nodes is lost (due to power-loss, environmental obstructions, etc.) critical data can still reach its destination due to the mesh networking capabilities embedded inside the modules.

DigiMesh Feature Set

DigiMesh contains the following features

- **Self-healing**
  Any node may enter or leave the network at any time without causing the network as a whole to fail.
- **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 acknowledgements**
  Only the destination node will reply to route requests.
- **Reliable delivery**
  Reliable delivery of data is accomplished by means of acknowledgements.
- **Sleep Modes**
  Low power sleep modes with synchronized wake are supported with variable sleep and wake times.

Networking Concepts

Device Configuration

DigiMesh modules can be configured to act as routers or end devices with the CE command. By default all modules in a DigiMesh network act as routers. Modules configured as routers will actively relay network unicast and broadcast traffic as described below.

Network ID

DigiMesh networks are defined with a unique network identifier. This identifier is set with the ID command. For modules to communicate they must be configured with the same network identifier. The ID parameter allows multiple DigiMesh networks to co-exist on the same physical channel.

Operating Channel

DigiMesh modules utilize direct-sequence spread spectrum modulation and operate on a fixed channel. There are 16 operating channels defined in the 2.4 GHz frequency band. XBee modules support all 16 channels and XBee-PRO modules support 12 of the 16 channels. The operating channel on a module is selected using the CH command.

For modules to communicate, the channel (CH) and network identifier (ID) must be equal on all modules in the network.

Data Transmission and Routing

Unicast Addressing

When transmitting while using Unicast communications, reliable delivery of data is accomplished using retries and acknowledgements. The number of retries is determined by the NR (Network Retries) parameter. RF data packets are sent up to NR + 1 times and ACKs (acknowledgements) are transmitted by the receiving node upon receipt. If a network ACK is not received within the time it would take for a packet to traverse the network twice, a retransmission occurs.

To send Unicast messages, set the DH and DL on the transmitting module to match the corresponding SH and SL parameter values on the receiving module.

Broadcast Addressing

Broadcast transmissions will be received and repeated by all routers in the network. Because ACKs are not used the originating node will send the broadcast multiple times. By default a broadcast transmission is sent four times. Essentially the extra transmissions become automatic retries without acknowledgments. This will result in all nodes repeating the transmission four times as well. In order to avoid RF packet collisions, a random delay is inserted before each router relays the broadcast message. (See NN parameter for details on changing this random delay time.) Sending frequent broadcast transmissions can quickly reduce the available network bandwidth and as such should be used 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 and DL to 0xFFFF. In API mode the destination address would be set to 0x000000000000FFFF.

Routing

A module within a mesh network is able to determine reliable routes using a routing algorithm and table. The routing algorithm uses a reactive method derived from AODV (Ad-hoc On-demand Distance Vector). An associative routing table is used to map a destination node address with its next hop. By sending a message to the next hop address, either the message will reach its destination or be forwarded to an intermediate router which will route the message on to its destination. A message with a broadcast address is broadcast to all neighbors. All routers receiving the message will rebroadcast the message MT+1 times and eventually the message will reach all corners of the network. Packet tracking prevents a node from resending a broadcast message more than MT+1 times.

Route Discovery

If the source node doesn't have a route to the requested destination, the packet is queued to await a route discovery (RD) process. This process is also used when a route fails. A route fails when the source node uses up its network retries without ever receiving an ACK. This results in the source node initiating RD.

RD begins by the source node broadcasting a route request (RREQ). Any router that receives the RREQ that is not the ultimate destination is called 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, information from the RREQ is saved and the RREQ is updated and broadcast. When the ultimate destination receives the RREQ, it unicasts a route reply (RREP) back to the source node along the path of the RREQ. This is done regardless of route quality and regardless of how many times an RREQ has been seen 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 will use for the queued packet and for subsequent packets with the same destination address.

Throughput

Throughput in a DigiMesh network can vary by a number of variables, including: number of hops, encryption enabled/disabled, sleeping end devices, failures/route discoveries. Our empirical testing showed the following throughput performance in a robust operating environment (low interference).

Configuration	Data Throughput
1 hop, Encryption Disabled	27.0 kbps
3 hop, Encryption Disabled	10.9 kbps
6 hop, Encryption Disabled	5.78 kbps
1 hop, Encryption Enabled	20.5 kbps
3 hop, Encryption Enabled	9.81 kbps
6 hop, Encryption Enabled	4.7 kbps

Note: Data throughput measurements were made setting the serial interface rate to 115200 bps, and measuring the time to send 100,000 bytes from source to destination. During the test, no route discoveries or failures occurred.

Transmission Timeouts

When a node receives an API TX Request (API configured modules) or an RO timeout occurs (modules configured for Transparent Mode) 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, and if the route to the destination address is known. Timeouts or timing information is provided for the following transmission types:

- Transmitting a broadcast
- Transmitting a unicast with a known route
- Transmitting a unicast with an unknown route
- Transmitting a unicast with a broken route.

Note: The timeouts in this section are theoretical timeouts and not precisely accurate. The application should pad the calculated maximum timeouts by a few hundred milliseconds. When using API mode, Tx Status API packets should be the primary method of determining if a transmission has completed.

Unicast One Hop Time

A building block of many of the calculations presented below is the unicastOneHopTime. As its name indicates, it represents the amount of time it takes to send a unicast transmission between two adjacent nodes. It is largely dependent upon the mac retry setting (RR). DigiMesh networks assume that the average number of mac level retries across a multi-hop wireless link will be 3 or less. It is defined as follows:

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

Transmitting a broadcast

A broadcast transmission must be relayed by all routers in the network. The maximum delay would be when the sender and receiver are on the opposite ends of the network. The NH, NN, and MT parameters define the maximum broadcast delay as follows:

$$BroadcastTxTime=NN*NH*(MT+1)* 18ms$$

Transmitting a unicast with a known route

When a route to a destination node is known the transmission time is largely a function of the number of hops and retries. The timeout associated with a unicast assumes the maximum number of hops is necessary (as specified by NH). The timeout can be estimated in the following manner:

$$knownRouteUnicast=2*NH*MR*unicastOneHopTime$$

Transmitting a unicast with an unknown route

If the route to the destination is not known the transmitting module will begin by sending a route discovery. If the route discovery is successful and a route is found then the data is transmitted. The timeout associated with the entire operation can be estimated as follows:

$$unknownRouteUnicast=BroadcastTxTime+NH*unicastOneHopTime +knownRouteUnicast$$

Transmitting a unicast with a broken route

If the route to a destination node has changed since the last time a route discovery was completed a node will begin by attempting to send the data along the previous route. After it fails a route discovery will be initiated and, upon completion of the route discovery, the data will be transmitted along the new route. The timeout associated with the entire operation can be estimated as follows:

$$brokenRouteUnicast=BroadcastTxTime+NH*unicastOneHopTime +2*knownRouteUnicast$$

Sleeping Routers

The Sleeping Router feature of DigiMesh 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. Nodes synchronize by receiving a special RF packet called a sync message which is sent by a node acting as a sleep coordinator. A node in the network can become a sleep coordinator through a process called nomination. The sleep coordinator will send one sync message at the beginning of each wake period. The sync message is sent as a broadcast and repeated by every node in the network. The sleep and wake times for the entire network can be changed by locally changing the settings on an individual node. The network will use the most recently set sleep settings.

There are three modes of operation:

- SM0 - Normal Mode (not sleep compatible)
- SM7 - Sleep Support Mode (sleep compatible, not low power)
- SM8 - Cyclic Sleeping Mode (sleep compatible, low power).

Under most circumstances a network should consist of only nodes operating in the same sleep compatibility mode (Only SM0 nodes or only SM8 and SM7 nodes). Mesh route discovery and routing, are incompatible between normal nodes and sleep compatible nodes.

Sleep Modes

Normal Mode (SM=0)

Normal mode is the default mode for a newly powered on node. In this mode a node will not sleep, but will synchronize to a sleeping network. When synchronized, a normal node will relay sync messages generated by sleep compatible nodes but will not generate sync messages. Once a normal node has synchronized with a sleeping network it can be put into a sleep compatible sleep mode at any time.

> **Note:** Normal nodes are not compatible with nodes configured for sleep. Excepting the case of adding a new node to a sleep compatible network, a network should consist only of normal nodes or only of sleep compatible nodes.

Cyclic Sleep Mode (SM=8)

A node in 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 read commands from the UART port. Sleep and wake times are specified by the SP and ST of the network's sleep coordinator respectively. If D9 = 1 (ON_SLEEP enabled) on a cyclic sleep node the ON_SLEEP line will assert when the module is awake and de-assert when the module is asleep. CTS is also de-asserted while asleep (when D7 = 1).

An unsynchronized sleeping node, newly powered, will poll for a sync message and then sleep for the time specified by SP, repeating the cycle until it becomes synchronized by receiving a sync message. Once a sync message is received the node will synchronize itself with the network.

Sleep Support Mode (SM=7)

A node in sleep support mode will synchronize itself with a sleeping network but will not sleep. At any time the node will respond with a sync message to new nodes in range which are attempting to join the sleeping network. A sleep support node will only transmit normal data when the nodes in the sleeping network are awake.

Sleep support nodes are especially useful when used as preferred sleep coordinator nodes and as aids for adding new nodes to a sleeping network.

> **Note:** Because sleep support nodes do not sleep they should be mains powered.

Operation

Sync Messages

One node in a sleeping network acts as the sleep coordinator. The process by which a node becomes a sleep coordinator is described later in this document. At the beginning of a wake cycle the sleep coordinator will send 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 receiving a sync message will remain awake for the wake time and then sleep for the sleep time specified.

The sleep coordinator will send one sync message at the beginning of every cycle with the values specified by its SP and ST parameters for sleep time and wake time respectively. It should be noted that if SP or ST are changed the

network will not apply the new settings until the beginning of the next wake time. See the Changing Sleep Parameters section below for more information.

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 in the wake time is reduced to maintain synchronization accuracy. By default a module will also reduce its active sleep time progressively as sync messages are missed.

Synchronization Messages

A sleep coordinator will regularly send sync messages to keep the network in sync. Nodes which have not been synchronized or, in some cases, which have lost sync will also send messages requesting sync information.

Deployment mode is a mode that sleep compatible nodes employ when they are first powered up and the sync message has not been relayed. A sleep coordinator in deployment mode will rapidly send sync messages until it receives a relay of the sync message that it has sent. This allows a network to be deployed more effectively and allows a sleep coordinator which is accidently or intentionally reset to rapidly re-synchronize with the existing network. If a node which has exited deployment mode receives a sync message from a sleep coordinator which is in deployment mode the sync will be rejected and a corrective sync will be sent to the sleep coordinator. Deployment mode can be disabled using the sleep options command (SO).

A sleep coordinator which is not in deployment mode or which has had deployment mode disabled will send a sync message at the beginning of the wake cycle. The sleep coordinator will then listen for a neighboring node to relay the sync. If the relay is not heard then the sleep coordinator will send the sync one additional time.

A node which is not acting as a sleep coordinator which has never been synchronized will send a message requesting sync information at the beginning of its wake cycle. Synchronized nodes which receive one of these messages will respond with a synchronization packet. Nodes which are configured as non-sleep coordinators (using the SO command) which have gone 6 or more cycles without hearing a sync will also send a message requesting sync at the beginning of their wake period.

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

Power-up

Enter Deployment Mode

Wait Sleep Guard Time

Is Node in Deployment Mode?
— Yes
— No

Is Sleep Coordinator? — No
— Yes

Is Sleep Coordinator? — No
— Yes

Send Sync

Wait Random Holdoff

Send Sync

Listen for Relay of Sync

Ever been Sync'ed? — Yes / No

Listen for Relay of Sync

Heard Relay? — No / Yes

Is node a non-sleep coord. node which has lost sync? — Yes / No

Heard Relay? — Yes / No

Coord. Rapid Sync Disabled? — No / Yes

Exit Deployment Mode

Send Sync

Send Sync

Send Poll

Network Transmit Time

Wait Sleep Guard Time

Is Cyclic Sleep Node? — No / Yes

Wait Sleep Time

Wait Sleep Time in Low Power Mode

Becoming a Sleep Coordinator

A node can become a sleep coordinator in one of four ways:

Preferred Sleep Coordinator Option

A node can be specified to always act as a sleep coordinator. This is done by setting the preferred sleep coordinator bit (bit 0) in the sleep options parameter (ATSO) to 1. A node with the preferred sleep coordinator bit set will always send a sync message at the beginning of a wake cycle. For this reason it is imperative that no more than one node in the network has this bit set. Although it is not necessary to specify a preferred sleep coordinator, it is oftentimes advantageous to select a node for this purpose to improve network performance.   A node which is centrally located in the network can serve as a good sleep coordinator to minimize the number of hops a sync message must take to get across the network. A sleep support node and/or a node which is mains powered may also be a good candidate.

The preferred sleep coordinator bit should be used with caution. The advantages gained by using the option on an appropriate node become weaknesses to the network when used on a node which is not positioned or configured appropriately. The preferred sleep coordinator option is also used when setting up a network for the first time. When starting a network a node should be configured as a sleep coordinator so it will begin emitting sync messages. After the network is setup the preferred sleep coordinator bit can be disabled.

Nomination and Election

Nomination is an optional process that can occur on a node in the event that contact with the network sleep coordinator is lost. By default this behavior is disabled. This behavior can be enabled with the sleep options command (SO). This process will automatically occur in the event that contact with the previous sleep coordinator is lost. Any sleep compatible node which has this behavior enabled is eligible to become the sleep coordinator for the network.

If a sleep compatible node has missed three or more sync messages (presumably because the sleep coordinator has been disabled) it may become a sleep coordinator. Depending on the platform and other configured options such a node will eventually nominate itself after a number of cycles without a sync. A nominated node will begin acting as the new network sleep coordinator.

It is possible for multiple nodes to nominate themselves as the sleep coordinator. If this occurs then an election will take place to establish seniority among the multiple sleep coordinators. A node will cease being the sleep coordinator if it receives a sync message from a senior node.

Seniority is determined on the basis of four factors (in order of priority):

1. **Newer sleep parameters:** a node using newer sleep parameters (SP/ST) is considered senior to a node using older sleep parameters. (See the "Changing Sleep Parameters" section below).
2. **Preferred Sleep Coordinator:** a node acting as a preferred sleep coordinator is senior to other nodes.
3. **Sleep Support Node:** sleep support nodes are senior to cyclic sleep nodes.
4. **Serial Number:** in the event that the above factors do not resolve seniority then the node with the higher serial number is considered senior.

Commissioning Button

The commissioning button can be used to select a module to act as the sleep coordinator. If the commissioning button functionality has been enabled a node can be immediately nominated as a sleep coordinator by pressing the commissioning button twice or by issuing the CB2 command. A node nominated in this manner is still subject to the election process described previously. Nodes which are configured as a non-sleep coordinator will ignore commissioning button nomination requests.

Changing Sleep Parameters

Any sleep compatible node in the network which does not have the non-sleep coordinator sleep option set can be used to make changes to the network's sleep and wake times. If a node's SP and/or ST are changed to values different from those that the network is using then that node will become the sleep coordinator. That node will begin sending sync messages with the new sleep parameters at the beginning of the next wake cycle.

Note #1: For normal operations a module will use the sleep and wake parameters it gets from the sleep sync message, not the ones specified in its SP and ST parameters. The SP and ST parameters are not updated with the values of the sync message. It is not necessary for all nodes in the network to have the same SP and ST parameters. The current network sleep and wake time that node is currently using can be queried with the OS and OW commands.

Note #2: It should be noted that changing network parameters can cause a node to become a sleep coordinator and change the sleep settings of the network. The following commands may cause this to occur: NH, NN, NQ, and MR. In most applications these network parameters should only be configured during deployment.

Sleep Guard Times

To compensate for variations in the timekeeping hardware of the various modules in a sleeping router network sleep guard times are allocated at the beginning and end of the wake time. The size of these sleep guard times vary based on the sleep and wake times selected and the number of cycles that have elapsed since the last sync message was received. These sleep guard times guarantee that a destination radio will be awake when a transmission is initiated. As more and more consecutive sync messages are missed the sleep guard times increase in duration and decrease the available transmission time.

Auto-Early Wakeup Sleep Option

In a similar manner to the sleep guard times the auto-early wakeup option decreases the sleep period based on the number of sync messages missed. This function guarantees that the module will be awake when the sync message is sent. This option comes at the expense of battery life. This option can be disabled using the sleep options (SO) command.

Configuration

Selecting Sleep Parameters

Choosing proper sleep parameters is important to create a sleep-enabled network which will be robust and have the desired battery life. The following steps can be taken to select sleep parameters which will be good for most applications:

Choosing proper sleep parameters is important to create a sleep-enabled network which will be robust and have the desired battery life. The following steps can be taken to select sleep parameters which will be good for most applications:

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

Note: The default values of NH and NN have been optimized to work for the majority of network deployments. In most cases it is suggested that these parameters are not modified from the default values.

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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. This number can be estimated with the following formula:

   SMPT = NN * NH * 16ms

3. **Select desired duty cycle**. The ratio of sleep time to wake time is the factor that has the greatest effect on the RF module's power consumption. Battery life can be estimated based on the following factors: sleep time, wake time, sleep current, TX current, RX current, and battery capacity.

4. **Choose Sleep Time and Wake Time**. The wake time needs to be long enough to transmit the desired data as well as the sync message. The ST parameter will automatically adjust upwards to its minimum value when other AT commands are changed that will affect it (SP, NN, and NH). It is suggested that a value larger than this minimum is used. If a module misses successive sync messages it reduces its available transmit time to compensate for possible clock drift. It is wise to budget a large enough ST time to allow for a few syncs to be missed and still have time for normal data transmissions.

Starting a Sleeping Network

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

1. Enable the preferred sleep coordinator option on one of the nodes and set its SM to a 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 commands to be sent quickly through the network during commissioning.
2. Next, power on the new nodes within range of the sleep coordinator. The nodes will quickly receive a sync message and synchronize themselves to the short cycle SP and ST.
3. Configure the new nodes in their desired sleep mode as cyclic sleeping nodes or sleep support nodes.
4. Set the SP and ST values on the sleep coordinator to the desired values for the deployed network.
5. Wait a cycle for the sleeping nodes to sync themselves to the new SP and ST values.
6. Disable the preferred sleep coordinator option bit on the sleep coordinator (unless a preferred sleep coordinator is desired).
7. Deploy the nodes to their positions.

Alternatively, nodes can be configured with their sleep settings written to flash memory (using the ATWR command) prior to deployment. If this is the case, the commissioning button and associate LED can be used to aid in deployment:

1. If a preferred sleep coordinator is going to be used in the network deploy it first. If there will be no preferred sleep coordinator then select a node for deployment, power it on, and press the commissioning button twice. This will cause the node to begin emitting sync messages.

Verify that the first node is emitting sync messages by observing its associate LED. A slow blink indicates that the node is acting as a sleep coordinator.

2. Next, power on nodes in range of the sleep coordinator or other nodes which have synchronized with the network. If the synchronized node is asleep it can be woken by pressing the commissioning button once.
3. Wait a cycle for the new node to sync itself.
4. Verify that the node syncs with the network. The associate LED will blink when the module is awake and synchronized.
5. Continue this process until all nodes have been deployed.

Adding 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 in the network. On power-up a cyclic sleep node will periodically send a broadcast requesting a sync message and then sleep for its SP period. Any node in the network which receives this message will respond with a sync. Because the network can be asleep for extended periods of time, and as such cannot respond to requests for syncs, there are methods which can be used 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 will be able to respond to sync requests promptly.
2. A cyclic sleep node in the network which is asleep can be woken via the commissioning button. Place the new node in range of the existing cyclic sleep node and wake the existing node by holding the commissioning button for 2 seconds, or until the node wakes. The existing node stays awake for 30 seconds and will respond to sync requests while it is awake.

If one of these methods are not used it is necessary to wait for the network to wake up before the new node can be added. The new node should be placed in range of the network with a sleep period which is shorter than the wake period of the network. The new node will periodically send sync requests until the network wakes up and it receives a sync message.

Changing Sleep Parameters

Changes to the sleep and wake cycle of the network can be made by selecting any node in the network and changing the SP and/or ST of the node to values different than those that the network is currently using. If using a preferred sleep coordinator or if it is known which node is acting as the sleep coordinator it is suggested that this node be used to make changes to network settings. If the network sleep coordinator is not known then any node that does not have the non-sleep coordinator sleep option bit set (see the SO command) can be used.

When changes are made to a node's sleep parameters that node will become the network's sleep coordinator (unless it has the non-sleep coordinator option selected) and will send a sync message with the new sleep settings to the entire network at the beginning of the next wake cycle. The network will immediately begin using the new parameters, after this sync is sent.

Changing sleep parameters increases the chances that nodes can lose sync. If a node does not receive the sync message with the new sleep settings then it will continue operating 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 the following precautions can be taken:

1.   Whenever possible, avoid changing sleep parameters.
2.   Enable the missed sync early wakeup sleep option (SO). This command is used to tell a node to wake up progressively earlier every cycle based on the number of cycles it has gone without receiving a sync. This will increase the probability that the un-synchronized 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 which miss sync messages will have an increased wake time and decreased sleep time during the cycles in which the sync message is missed. This will reduce battery conservation.

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

   (SP1 + ST1) = N*(SP2+ST2), where SP1/ST1 and SP2/ST2 are the desired sleep settings and N is an integer.
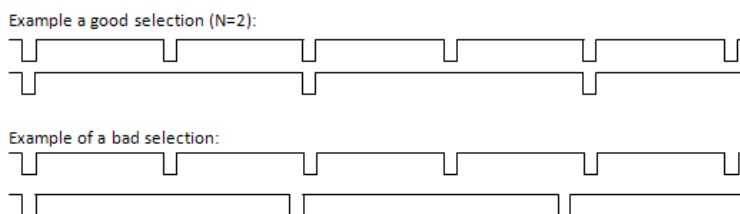
In the good example, a node which misses a sync changing the sleep parameters will get a chance to receive a sync message after 2 of the shorter cycles. In the bad example, a node which misses a sync changing the sleep parameters will have to wait many cycles before it gets another chance to hear the sync message.

Rejoining Nodes Which Have Lost Sync

 Mesh networks get their robustness from taking advantage of routing redundancies which may be available in a network. It is recommended to architect the network with redundant mesh nodes to increase robustness. If a scenario exists such that 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 (catastrophic failure condition), then multiple subnets may arise while 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 modules to fix the problem and prevent it from occurring in the future.

When the default DigiMesh sleep parameters are used separated subnets will not drift out of phase with each other. Subnets can drift out of phase with each other if the network is configured in one of the following ways:

- If multiple modules in the network have had the non-sleep coordinator sleep option bit disabled and are thus eligible to be nominated as a sleep coordinator.
- If the modules in the network are not using the auto early wakeup sleep option.

If a network has multiple subnets that have drifted out of phase with each other, then follow the following steps to get the subnets back in phase:

1. Place a sleep support node in range of both subnets.
2. Select a node in the subnet which you desire the other subnet to sync up with. Use this node to slightly change the sleep cycle settings of the network (increment ST for example).
3. Wait for the subnet's next wake cycle. During this cycle the node selected to change the sleep cycle parameters will send the new settings to the entire subnet it is in range of, including the sleep support node which is in range of the other subnet.
4. Wait for the out of sync subnet to wake up and send a sync. When the sleep support node receives this sync it will reject it and send a sync to the subnet with the new sleep settings.
5. The subnets will now be in sync. The sleep support node can be removed. If desired the sleep cycle settings can be changed back to what they were.

In the case where only a few nodes need to be replaced this method can also be used:

1. Reset the out of sync node and set its sleep mode to cyclic sleep (SM=8). Set it up to have a short sleep cycle.
2. Place the node in range of a sleep support node or wake a sleeping node with the commissioning button.
3. The out of sync node will receive a sync from the node which is synchronized to the network and sync to the network sleep settings.

Diagnostics

The following are useful in some applications when managing a sleeping router network:

Association Indication: The AI command can be used to query the synchronization status of a node in the network. The following codes are defined:

- 0x00 - synchronized. The node has been recently synchronized or is acting as the sleep coordinator.
- 0x50 - poorly synchronized. The node has been synchronized in the past, but has not received a sync for the last 3 to 6 sleep cycles.
- 0x51 - synchronization lost. The node has gone 6 or more cycles without receiving a sync message.
- 0x52 - never synchronized. The node has never received a sync message.

  Query current sleep cycle: The OS and OW command can be used to query the current operational sleep and wake time a module is currently using.

Sleep Status: The SS command can be used to query information regarding the sleep status of the module. This command can be used to query if the node is currently acting as a network sleep coordinator.

5. DigiMesh 2.4 Command Reference Tables

Special

Special Commands

AT Command	Name and Description	Parameter Range	Default
WR	**Write**. Write parameter values to non-volatile memory so that parameter modifications persist through subsequent resets. Note: Once WR is issued, no additional characters should be sent to the module until after the "OK\r" response is received.	--	--
RE	**Restore Defaults**. Restore module parameters to factory defaults.	--	--
FR	**Software Reset**. Reset module. Responds immediately with an "OK" then performs a reset 100ms later.	--	--
AC	**Apply Changes**. Immediately applies new settings without exiting command mode.	--	--
VL	**Version Long**. Shows detailed version information including application build date and time.	--	--

Addressing

Addressing Commands

AT Command	Name and Description	Parameter Range	Default
DH	**Destination Address High**. Set/Get the upper 32 bits of the 64-bit destination address. When combined with DL, it defines the destination address used for transmission.	0 to 0xFFFFFFFF	0
DL	**Destination Address Low**. Set/Get the lower 32 bits of the 64-bit destination address. When combined with DH, DL defines the destination address used for transmission.	0 to 0xFFFFFFFF	0x0000FFFF
DD	**Device Type Identifier.** Stores a device type value. This value can be used to differentiate multiple XBee-based products.	0-0xFFFFFFFF [read only]	0x40000
SH	**Serial Number High**. Read high 32 bits of the RF module's unique IEEE 64-bit address. 64-bit source address is always enabled. This value is read-only and it never changes	0-0xFFFFFFFF	Factory
SL	**Serial Number Low**. Read low 32 bits of the RF module's unique IEEE 64-bit address. 64-bit source address is always enabled. This is read only and it is also the serial number of the node..	0-0xFFFFFFFF	Factory
HP	**Hopping Channel**. Set/read the spread spectrum channel on which the module communicates. Separate channels minimize interference between multiple networks operating in the same vicinity.	0-0x7 (standard variant) 0-0x3 (International variant)	0
SE	**Source Endpoint**. Set/read the application layer source endpoint value. This value will be used as the source endpoint for all data transmissions. The default value 0xE8 (Data endpoint) is the Digi data endpoint	0-0xFF	0xE8
DE	**Destination Endpoint**. Set/read application layer destination ID value. This value will be used as the destination endpoint for all data transmissions. The default value (0xE8) is the Digi data endpoint.	0-0xFF	0xE8
CI	**Cluster Identifier**. Set/read application layer cluster ID value. This value will be used as the cluster ID for all data transmissions. The default value 0x11 (Transparent data cluster ID)	0-0xFFFF	0x11
NP	**Maximum RF Payload Bytes**. This value returns the maximum number of RF payload bytes that can be sent in a unicast transmission based on the current configurations.	0-0xFFFF	n/a

Serial Interfacing (I/O)

Serial Interfacing Commands

AT Command	Name and Description	Parameter Range	Default
AP	**API mode**. Set or read the API mode of the radio. The following settings are allowed: **0** API mode is off. All UART input and output is raw data and packets are delineated using the RO parameter. **1** API mode is on. All UART input and output data is packetized in the API format, without escape sequences. **2** API mode is on with escaped sequences inserted to allow for control characters (XON, XOFF, escape, and the 0x7e delimiter to be passed as data.	0, 1, or 2	0
AO	**API Output Format**. Enables different API output frames. Options include: **0** Standard Data Frames (0x90 for RF rx) **1** Explicit Addressing Data Frames (0x91 for RF rx)	0, 1	0

Serial Interfacing Commands

AT Command	Name and Description	Parameter Range	Default
BD	**Baud rate**. Set or read serial interface rate (speed for data transfer between radio modem and host). Values from 0-8 select preset standard rates. Values at 0x7A and above select the actual baud rate. Baud rates above 250,00 bps are not supported.The values from 0 to 8 are interpreted as follows: **0** - 1,200bps **3** - 9,600bps **6** - 57,600bps **1** - 2,400bps **4** - 19,200bps **7** - 115,200bps **2** - 4,800bps **5** - 38,400bps **8** - 230,400bps Note that exact baud rates cannot be achieved for 115,200 and 230,400 bps and are 111,111 and 250,000 respectively.	0 to 8, and 0x7a to 0x1C9C38	0x03 (9600 bps)
RO	**Packetization Timeout**. Set/Read number of character times of inter-character silence required before packetization. Set (RO=0) to transmit characters as they arrive instead of buffering them into one RF packet.	0 - 0xFF [x character times]	3
FT	**Flow Control Threshhold**. Set or read flow control threshhold. De-assert CTS and/or send XOFF when FT bytes are in the UART receive buffer. Re-assert CTS when less than FT - 16 bytes are in the UART receive buffer.	0x11 to 0xEE	0xbe = 190
NB	**Parity**. Set or read parity settings for UART communications. The values from 0 to 4 are interpreted as follows: **0** No parity **3** Forced high parity **1** Even parity **4** Forced low parity **2** Odd parity	0 to 4	0 (No parity)
D7	**DIO7 Configuration**. Configure options for the DIO7 line of the module. Options include: 0 = Input, unmonitored 1 = CTS flow control 3 = Digital input, monitored 4 = Digital output low 5 = Digital output high 6 = RS-485 Tx enable, low TX (0V on transmit, high when idle) 7 = RS-485 Tx enable, high TX (high on transmit, 0V when idle)	0-1, 3-7	0
D6	**DIO6 Configuration**. Configure options for the DIO6 line of the module. Options include: 0 = Input, unmonitored 1 = RTS flow control 3 = Digital input, monitored 4 = Digital output low 5 = Digital output high	0-1, 3-5	0

I/O Commands

I/O Commands

AT Command	Name and Description	Parameter Range	Default
P0	**PWM0/DIO10 Configuration**. Select/Read function for the DIO10 line of the RF module	0 - Disabled 1 - RSSI PWM 2 - PWM Output 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	1
P1	**PWM1/DIO11 Configuration**. Select/Read function for the DIO11 line of the RF module.	0 - Disabled 2 - PWM Output 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
P2	**DIO12 Configuration**. Select/Read function for the DIO12 line of the RF module.	0 - Disabled 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
D0	**AD0/DIO0 Configuration**. Select/Read function for the AD0/DIO0 line of the RF module.	0 - Disabled 1 -Commissioning Button Enable 2 - Analog input, single ended 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
D1	**AD1/DIO1 Configuration**. Select/Read function for the AD1/DIO1 line of the RF module.	0 - Disabled 1 - Disabled Button 2 - Analog input, single ended 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
D2	**AD2/DIO2 Configuration**. Select/Read function for the AD2/DIO2 line of the RF module.	0 - Disabled 2 - Analog input, single ended 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
D3	**AD3/DIO3 Configuration**. Select/Read function for the AD3/DIO3 line of the RF module.	0 - Disabled 2 - Analog input, single ended 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
D4	**AD4/DIO4 Configuration**. Select/Read function for the AD4/DIO4 line of the RF module.	0 - Disabled 2 - Analog input, single ended 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0

I/O Commands

AT Command	Name and Description	Parameter Range	Default
D5	**AD5/DIO5 Configuration**. Select/Read function	0 - Disabled 1 - Associated indication LED 2 - Analog input, single ended 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	1
D8	**DIO8 Configuration**. Select/Read function for the DIO8 line of the RF module.	0 – Disabled 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	0
D9	**DIO9 Configuration.** Select/Read function for the DIO9 line of the RF module.	0 – Disabled 1 – ON_SLEEP line 3 - Digital input, monitored 4 - Digital output, default low 5 - Digital output, default high	1
RP	**RSSI PWM Timer**. Time RSSI signal will be output after last transmission. When RP = 0xFF, output will always be on.	0 - 0xFF [x 100 ms]	0x28 (4 sec.)
PR	**Pullup Resistor Configuration**. Set/read the bit field that configures the internal pull-up resistor status for the I/O lines. "1" specifies the pull-up resistor is enabled. "0" specifies no pullup. Bits: 0 - DIO4/AD4 (Pin 11) 1 - AD3 / DIO3 (Pin 17) 2 - AD2 / DIO2 (Pin 18) 3 - AD1 / DIO1 (Pin 19) 4 - AD0 / DIO0 (Pin 20) 5 - RTS / DIO6 (Pin 16) 6 - DTR / SLEEP_RQ/DI08 / DIO8 (Pin 9) 7 - DIN / Config (Pin 3) 8 - Associate / DIO5 (Pin 15) 9 - On/Sleep / DIO9 (Pin 13) 10 - DIO12 (Pin 4) 11 - PWM0 / RSSI / DIO10 (Pin 6) 12 - PWM1 / DIO11 (Pin 7) 13 - DIO7/CTS (Pin 12) 14 - DOUT (Pin 2)	0 - 0x1FFF	0x1FFF
M0	**PWM0 Output Level** Set/Read the PWM0 output level.	0x3FF	0
M1	**PWM1 Output Level** Set/Read the PWM1 output level.	0x3FF	0
LT	**Assoc LED Blink Time**. Set/Read the Associate LED blink time. If the Associate LED functionality is enabled (D5 command), this value determines the on and off blink times for the LED when the module has joined a network. If LT=0, the default blink rate will be used (500ms sleep coordinator, 250ms otherwise). For all other LT values, LT is measured in 10ms.	0x14 - 0xFF (200 - 2550 ms)	0
CB	**Commissioning Pushbutton**. This command can be used to simulate commissioning button presses in software. The parameter value should be set to the number of button presses to be simulated. For example, sending the ATCB1 command will execute the action associated with 1 commissioning button press. (See D0 command).	-	-
IR	**IO Sample Rate**. Set/Read the IO sample rate to enable periodic sampling. For periodic sampling to be enabled, IR must be set to a non-zero value, and at least one module pin must have analog or digital IO functionality enabled (see D0-D9, P0-P2 commands). The sample rate is measured in milliseconds.	0 - 0xFFFF (ms)	0
IF	**Sample from Sleep Rate**. Set/read the number of sleep cycles that must elapse between periodic IO samples. This allows IO samples to be taken only during some wake cycles. During those cycles IO samples are taken at the rate specified by IR.	1-0xFF	1

I/O Commands

AT Command	Name and Description	Parameter Range	Default
RR	Mac Retries. Specifies the number of retries that can be sent for a given unicast RF packet. RR specifies the maximum number of retries, and a retry occurs whenever a unicast requesting an ACK is sent and a timeout occurs awaiting the ACK. If RR=0, an ACK is neither requested nor expected, and no retries will occur.	0 - 0x0F	0xA
MT	Multiple Transmissions. Specifies the number of additional broadcast retransmissions. All broadcast packets are transmitted (MT+1) times to ensure the receiving radio(s) receive the packet.	0 - 0x0F	0x3
IC	**IO Digital Change Detection**. Set/Read the digital IO pins to monitor for changes in the IO state. IC works with the individual pin configuration commands (D0-D9, P0-P2). If a pin is enabled as a digital input/output, the IC command can be used to force an immediate IO sample transmission when the DIO state changes. IC is a bitmask that can be used to enable or disable edge detection on individual channels. Unused bits should be set to 0. Bit (IO pin): 0 (DIO0) 1 (DIO1) 2 (DIO2) 3 (DIO3) 4 (DIO4) 5 (DIO5) 6 (DIO6) 7 (DIO7) 8 (DIO8) 9 (DIO9) 10 (DIO10) 11 (DIO11) 12 (DIO12)	0xFFFF	0
IS	**Force Sample**. Forces a read of all enabled digital and analog input lines.	-	-
1S	**XBee Sensor Sample**. Forces a sample to be taken on an XBee Sensor device. This command can only be issued to an XBee sensor device using an API remote command.	-	-
LT	Assoc LED Blink Time. Set/read the Associate LED blink time. If the Associate LED functionality is enabled (D5 command), this value determines the on and off blink times for the LED when the module has joined a network. If LT=0, the default blink rate will be used (500ms coordinator, 250ms router/end device). For all other LT values, LT is measured in increments of 10ms.	0, 0x0A - 0xFF (100 - 2550 ms)	0

Diagnostics

Diagnostics Commands

AT Command	Name and Description	Parameter Range	Default
VR	**Firmware Version**. Read firmware version of the module.	0 - 0xFFFF [read-only]	Firmware-set
HV	**Hardware Version**. Read hardware version of the module.	0 - 0xFFFF [read-only]	Factory-set
ER	**RF Errors** Read the number of times the RF receiver detected a CRC or length error. When the value reaches 0xffff, it stays there.	n/a	n/a
GD	**Good packets** Read the number of good frames with valid MAC headers that are received on the RF interface. When the value reaches 0xffff, it stays there.	n/a	n/a
RP	**RSSI PWM timer** Set or read the time that the RSSI output (indicating signal strength) will remain active after the last reception. Time units are measured in tenths of seconds	1 to 0xFF	0x20 = 3.2 seconds
TR	**Transmission Errors** Read the number of MAC frames that exhaust MAC retries without ever receiving a MAC acknowledgement message from the adjacent node. When the value reaches 0xffff, it stays there.	n/a	n/a
AI	Association Indication. Read information regarding last node join request: 0x00 - Successfully joined or formed a network. (Coordinators form a network, routers and end devices join a network.) 0x21 - Scan found no PANs 0x22 - Scan found no valid PANs based on current SC and ID settings 0x23 - Valid coordinator or router found, but is not allowing joining (ND expired) 0x27 - Node joining attempt failed (typically due to incompatible security settings) 0x2A - Coordinator start attempt failed 0x2B - Checking for an existing coordinator 0xAB - Attempted to join a device that did not respond 0xAC - Secure join error - network security key received unsecured 0xAD - Secure join error - network security key not received 0xAF - Secure join error - joining device does not have the right preconfigured link key 0xFF - Scanning for a ZigBee network (routers and end devices) Note: New non-zero AI values may be added in later firmware version. Applications should read AI until it returns 0x00, indicating a successful startup (coordinator) or join (routers and end devices).	0 - 0xFF	n/a

AT Command Options

AT Command Options Commands

AT Command	Name and Description	Parameter Range	Default
CT	**Command Mode Timeout.** Set/Read the period of inactivity (no valid commands received) after which the RF module automatically exits AT Command Mode and returns to Idle Mode.	2 - 0xFFFF [x 100 ms]	0x64 (100d)
CN	**Exit Command Mode.** Explicitly exit the module from AT Command Mode.	--	--
GT	**Guard Times**. Set required period of silence before and after the Command Sequence Characters of the AT Command Mode Sequence (GT + CC + GT). The period of silence is used to prevent inadvertent entrance into AT Command Mode.	0 to 0xFFFF	0x3E8 (1000d)
CC	**Command Character**. Set or read the character to be used between guard times of the AT Command Mode Sequence. The AT Command Mode Sequence causes the radio modem to enter Command Mode (from Idle Mode).	0 - 0xFF	0x2B

Node Identification

Node Identification Commands

AT Command	Name and Description	Parameter Range	Default
ID	**PAN ID**. Set or read the user network address. Nodes must have the same network address to communicate. Changes to ID should be written to non-volatile memory using the WR command.	0x0000 to 0x7FFF	0x7FFF
NT	**Node Discover Timeout.** Set/Read the amount of time a node will spend discovering other nodes when ND or DN is issued.	0x2EE0 [x 100 msec]	0x82 (130d)
NI	**Node Identifier**. Stores a string identifier. The string accepts only printable ASCII data In AT Command Mode, the string can not start with a space. A Carriage return ends the command. Command will automatically end when maximum bytes for the string have been entered. This string is returned as part of the ATND (Network Discover) command. This identifier is also used with the ATDN (Destination Node) command. .	up to 20 byte ASCII string	a space character
DN	**Discover Node - Destination Node**. Resolves an NI (Node Identifier) string to a physical address (casesensitive). The following events occur after the destination node is discovered: <AT Firmware> 1. DL & DH are set to the extended (64-bit) address of the module with the matching NI (Node Identifier) string. 2. OK (or ERROR)\r is returned. 3. Command Mode is exited to allow immediate communication <API Firmware> The 64-bit extended addresses is returned in an API Command Response frame. If there is no response from a module within (NT * 100) milliseconds or a parameter is not specified (left blank), the command is terminated and an "ERROR" message is returned. In the case of an ERROR, Command Mode is not exited.	20 byte ascii string	
ND	Node Discover - Node Discover. Discovers and reports all RF modules found. The following information is reported for each module discovered. 0xFFFE<CR> SH<CR> SL<CR> NI<CR> (Variable length) PARENT_NETWORK ADDRESS (2 Bytes)<CR> DEVICE_TYPE<CR> (1 Byte: 0=Coord, 1=Router, 2=End Device) STATUS<CR> (1 Byte: Reserved) PROFILE_ID<CR> (2 Bytes) MANUFACTURER_ID<CR> (2 Bytes) <CR> After (NT * 100) milliseconds, the command ends by returning a <CR>. ND also accepts a Node Identifier (NI) as a parameter (optional). In this case, only a module that matches the supplied identifier will respond. If ND is sent through the API, each response is returned as a separate AT_CMD_Response packet. The data consists of the above listed bytes without the carriage return delimiters. The NI string will end in a "0x00" null character.		
NO	**Network Discovery Options**. Set/Read the options value for the network discovery command. The options bitfield value can change the behavior of the ND (network discovery) command and/or change what optional values are returned in any received ND responses or API node identification frames. Options include: 0x01 = Append DD value (to ND responses or API node identification frames) 0x02 = Local device sends ND response frame when ND is issued.	0-0x03 [bitfield]	0

Sleep Commands

AT Command	Name and Description	Parameter Range	Default
SM	**Sleep Mode**. Set/read the sleep mode of the module.	0 (Normal) 7 (Sleep Support Node) 8 (Cyclic Sleep)	0
SO	**Sleep Options**. Options Include: bit 0 = Preferred Sleep Coordinator bit 1 = Non-Sleep Coordinator bit 2 = Enable API sleep status messages bit 3 = Disable automatic early wakeup for missed syncs bit 4 = SM7 and SM8 nodes are considered equal for purposes of election bit 5 = Disable coordinator rapid sync deployment mode.	0-0xFF (bits 0 and 1 cannot be both set at the same time)	0

Sleep Commands

AT Command	Name and Description	Parameter Range	Default
ST	**Wake Time**. Units of msec, represented in hex. Note 1: the minimum value for ST is a function of SP, SS, MT, NN, and NH. If the user attempts to set the value of ST too low it will automatically be increased to a minimum effective value. Note 2: To effectively enter command mode it is necessary that the value of ST is set greater than the value of GT.	0x45-0x36EE80	0x7D0 (2 seconds)
SP	**Sleep Period**. Units of 10 msec, represented in hex	0x01-0x15f900 (4hrs)	0xC8 (2 seconds)
MS	**Number of Missed Syncs**. Read the number of wake cycles that have elapsed since the last sync message was received.		
SQ	**Missed Sync Count**. Count of the number of syncs that have been missed. This value can be reset by setting ATSQ to 0. When the value reaches 0xFFFF it will not be incremented anymore.	n/a	n/a
SS	**Sleep Status** The SS command can be used to query a number of Boolean values describing the status of the module. Bit 0: This bit will be true when the network is in its wake state. Bit 1: This bit will be true if the node is currently acting as a network sleep coordinator. Bit 2: This bit will be true if the node has ever received a valid sync message since the time it was powered on. Bit 3: This bit will be true if the node has received a sync message in the current wake cycle. Bit 4: This bit will be true if the user has altered the sleep settings on the module so that the node will nominate itself and send a sync message with the new settings at the beginning of the next wake cycle. Bit 5: This bit will be true if the user has requested that the node nominate itself as the sleep coordinator (using the commissioning button or the CB2 command). All other bits: Reserved - All non-documented bits can be any value and should be ignored. bit 6 = This bit will be true if the node is currently in deployment mode. All other bits: Reserved - All non-documented bits can be any value and should be ignored.	n/a	n/a
OS	**Operational Sleep Period**. Read the sleep period that the node is currently using. This number will oftentimes be different from the SP parameter if the node has synchronized with a sleeping router network. Units of 10mSec	n/a	n/a
OW	**Operational Wake Period**. Read the wake time that the node is currently using. This number will oftentimes be different from the ST parameter if the node has synchronized with a sleeping router network. Units of 1 mSec	n/a	n/a
WH	**Wake Host**. Set/Read the wake host timer value. If the wake host timer is set to a non-zero value, this timer specifies a time (in millisecond units) that the device should allow after waking from sleep before sending data out the UART or transmitting an IO sample. If serial characters are received, the WH timer is stopped immediately. The device will shorten its sleep period by the value specified with the WH command to ensure that it is prepared to communicate when the network wakes up.	0-0xFFFF (x 1ms)	0

Encryption and Security

Encryption and Security

AT Command	Name and Description	Parameter Range	Default
EE	**Encryption Enable**. Set/Read the encryption enable setting.	0 - Encryption Disabled 1 - Encryption Enabled	0
KY	**Encryption Key**. Set the 128-bit AES encryption key. This command is read-only; KY cannot be read.	$0-(2^{128}-1)$	0

Networking

Networking

AT Command	Name and Description	Parameter Range	Default
CH	**Channel**. Set/Read the channel number used for transmitting and receiving data between RF modules (uses 802.15.4 protocol channel numbers).	0x0B - 0x1A (XBee) 0x0C - 0x17 (XBee-PRO)	0x0C
ID	**Network Identifier**. Set/Read the network identifier for the network. All nodes must have the same network ID to communicate.	0 - 0xFFFF	0x7FFF
CE	**Routing Type**. Set/Read the nodes routing type. Options include: 0 - Router: a node of this type will act as a router in the network. 2 - End Device: a node of this type will not route data for other nodes or relay broadcast messages.	0 - Router 2 - End Device	0

RF Interfacing

RF Interfacing

AT Command	Name and Description	Parameter Range	Default
PL	**Power Level**. Set/Read the power level at which the RF module transmits conducted power.	XBee 0 = -7dBm 1 = -1.7dBm 2 = -0.77dBm 3 = 0.62dBm 4 = 1.42dBm XBee-Pro 0 = 10dBm 1 = 12dBm 2 = 14dBm 3 = 16dBm 4 = 18dBm	4
CA	**CCA Threshold**. Set/read the CCA (Clear Channel Assessment) threshold. Prior to transmitting a packet, a CCA is performed to detect energy on the channel. If the detected energy is above the CCA Threshold, the module will not transmit the packet.	0x24 - 0x50 [-dBm]	-
DB	**Received Signal Strength.** This command reports the received signal strength of the last received RF data packet. The DB command only indicates the signal strength of the last hop. It does not provide an accurate quality measurement for a multihop link. DB can be set to 0 to clear it.	-	-

DigiMesh

Mesh Commands: Network Level Commands

AT Command	Name and Description	Parameter Range	Default
NH	**Network Hops** Set or read the maximum number of hops expected to be seen in a network route. This value doesn't limit the number of hops allowed, but it is used to calculate timeouts waiting for network acknowledgements.	1 to 0xFF	7
NN	**Network Delay Slots** Set or read the maximum random number of network delay slots before rebroadcasting a network packet. One network delay slot is approximately 66ms.	0 to 0x0A	3
NQ	**Network Route Requests** Set or read the maximum number of route discovery retries allowed to find a path to the destination node. If NQ is zero, RREQ will only be sent once.	0 to 0x0A	3
MR	**Mesh Network Retries** Set or read the maximum number of network packet delivery attempts. If MR is non-zero, packets sent will request a network acknowledgement, and can be resent up to NR+1 times if no acknowledgements are received.]	0 to 7	1

6. API Operation

As an alternative to Transparent Operation, API (Application Programming Interface) Operations are available. API operation requires that communication with the module be done through a structured interface (data is communicated in frames in a defined order). The API specifies how commands, command responses and module status messages are sent and received from the module using a UART Data Frame.

Please note that Digi may add new frame types to future versions of firmware, so please build into your software interface the ability to filter out additional API frames with unknown Frame Types.

API Frame Specifications

Two API modes are supported and both can be enabled using the AP (API Enable) command. Use the following AP parameter values to configure the module to operate in a particular mode:

- AP = 1: API Operation
- AP = 2: API Operation (with escaped characters)

API Operation (AP parameter = 1)

When this API mode is enabled (AP = 1), the UART data frame structure is defined as follows:

UART Data Frame Structure:

Start Delimiter (Byte 1)	Length (Bytes 2-3)		Frame Data (Bytes 4-*n*)	Checksum (Byte n + 1)
0x7E	MSB	LSB	API-specific Structure	1 Byte
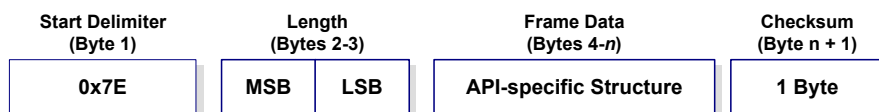
MSB = Most Significant Byte, LSB = Least Significant Byte

Any data received prior to the start delimiter is silently discarded. If the frame is not assembled correctly or if the checksum fails, the module will either discard the data or wait for further data, which can cause the preceding packet to fail also.

API Operation - with Escape Characters (AP parameter = 2)

When this API mode is enabled (AP = 2), the UART data frame structure is defined as follows:

UART Data Frame Structure - with escape control characters:

Start Delimiter (Byte 1)	Length (Bytes 2-3)		Frame Data (Bytes 4-n)	Checksum (Byte n + 1)
0x7E	MSB	LSB	API-specific Structure	1 Byte

Characters Escaped If Needed
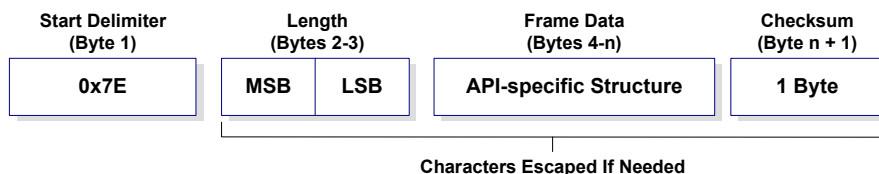
MSB = Most Significant Byte, LSB = Least Significant Byte

Escape characters. When sending or receiving a UART 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'd with 0x20.

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 above 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.

Checksum

To test data integrity, a checksum is calculated and verified on non-escaped data.

To calculate: Not including frame delimiters and length, add all bytes keeping only the lowest 8 bits of the result and subtract the result from 0xFF.

To verify: Add all bytes (include checksum, but not the delimiter and length). If the checksum is correct, the sum will equal 0xFF.

Frame Data

Frame data of the UART data frame forms an API-specific structure as follows:

UART Data Frame & API-specific Structure:

Start Delimiter (Byte 1)	Length (Bytes 2-3)		Frame Data (Bytes 4-*n*)	Checksum (Byte n + 1)
0x7E	MSB	LSB	API-specific Structure	1 Byte

API Identifier	Identifier-specific Data
cmdID	cmdData
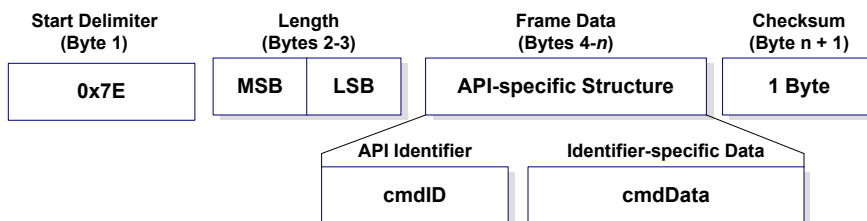
The cmdID frame (API-identifier) indicates which API messages will be contained in the cmdData frame (Identifier-specific data). Note that multi-byte values are sent big endian. The modules support the following API frames:

API Frames

API Frame Names	Values
Modem Status	0x8A
AT Command	0x08
AT Command - Queue Parameter Value	0x09
AT Command Response	0x88
Remote Command Request	0x17
Remote Command Response	0x97
Transmit Request	0x10
Explicit Addressing Command Frame	0x11
Transmit Status	0x8B
Receive Packet (AO=0)	0x90
Explicit Rx Indicator (AO=1)	0x91

Modem Status

API Identifier Value: (0x8A)

RF module status messages are sent from the module in response to specific conditions.

Modem Status Frames

Frame Fields		Offset	Example	Description
Start Delimiter		0	0x7E	
Length	MSB 1	0x00	Number of bytes between the length and the checksum
	LSB 2	0x02	
Frame-specific Data	Frame Type	3	0x8A	
	Status	4	0x00	0x00 = Hardware reset 0x01= Watchdog timer reset 0x0B = Network Woke Up 0x0C = Network Went To Sleep
Checksum		5	0x75	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

(Left spanning label: API Packet)

AT Command

API Identifier Value: (0x08)

Allows for module parameter registers to be queried or set.

AT Command Frames

Frame Fields		Offset	Example	Description
Start Delimiter		0	0x7E	
Length	MSB 1	0x00	Number of bytes between the length and the checksum
	LSB 2	0x04	
Frame-specific Data	Frame Type	3	0x08	
	Frame ID	4	0x52 (R)	Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to 0, no response is sent.
	AT Command	5	0x4E (N)	Command Name - Two ASCII characters that identify the AT Command.
		6	0x48 (H)	
	Parameter Value (optional)			If present, indicates the requested parameter value to set the given register. If no characters present, register is queried.
Checksum		8	0x0F	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

(Left spanning label: API Packet)

AT Command - Queue Parameter Value

API Identifier Value: (0x09)

This API type allows module parameters to be queried or set. In contrast to the "AT Command" API type, new parameter values are queued and not applied until either the "AT Command" (0x08) API type or the AC (Apply Changes) command is issued. Register queries (reading parameter values) are returned immediately.

(Note that frames are identical to the "AT Command" API type except for the API identifier.)

AT Command Frames

Frame Fields		Offset	Example	Description
Start Delimiter		0	0x7E	
Length	MSB 1	0x00	Number of bytes between the length and the checksum
	LSB 2	0x05	
Frame-specific Data	Frame Type	3	0x09	
	Frame ID	4	0x01	Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to 0, no response is sent.
	AT Command	5	0x42 (B)	Command Name - Two ASCII characters that identify the AT Command.
		6	0x44 (D)	
	Parameter Value (ATBD7 = 115200 baud)		0x07	If present, indicates the requested parameter value to set the given register. If no characters present, register is queried.
Checksum		8	0x68	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

(Left spanning label: API Packet)

AT Command Response

API Identifier Value: (0x88)
Response to previous command.

In response to an AT Command message, the module will send an AT Command Response message. Some commands will send back multiple frames (for example, the ND (Node Discover) command).

AT Command Response Frames.

	Frame Fields		Offset	Example	Description
A P I **P a c k e t**	**Start Delimiter**		0	0x7E	
	Length	MSB 1	0x00	Number of bytes between the length and the checksum
		LSB 2	0x05	
	Frame-specific Data	**Frame Type**	3	0x88	
		Frame ID	4	0x01	Identifies the UART data frame being reported. Note: If Frame ID = 0 in AT Command Mode, no AT Command Response will be given.
		AT Command	5	'B' = 0x42	Command Name - Two ASCII characters that identify the AT Command.
			6	'D' = 0x44	
		Command Status	7	0x00	0 = OK 1 = ERROR 2 = Invalid Command 3 = Invalid Parameter
		Command Data			Register data in binary format. If the register was set, then this field is not returned, as in this example.
	Checksum		8	0xF0	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

Remote AT Command Request

API Identifier Value: (0x17)

Allows for module parameter registers on a remote device to be queried or set

Remote AT Command Request

Frame Fields		Offset	Example	Description
Start Delimiter		0	0x7E	
Length		MSB 1	0x00	Number of bytes between the length and the checksum
		LSB 2	0x10	
Frame-specific Data	**Frame Type**	3	0x17	
	Frame ID	4	0x01	Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to 0, no response is sent.
	64-bit Destination Address	MSB 5	0x00	Set to the 64-bit address of the destination device. The following address is also supported: 0x000000000000FFFF - Broadcast address
		6	0x13	
		7	0xA2	
		8	0x00	
		9	0x40	
		10	0x40	
		11	0x11	
		LSB 12	0x22	
	Reserved	13	0xFF	Set to 0xFFFE.
		14	0xFE	
	Remote Command Options	15	0x02 (apply changes)	0x02 - Apply changes on remote. (If not set, AC command must be sent before changes will take effect.) All other bits must be set to 0.
	AT Command	16	0x42 (B)	Name of the command
		17	0x48 (H)	
	Command Parameter	18	0x01	If present, indicates the requested parameter value to set the given register. If no characters present, the register is queried.
Checksum		18	0xF5	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

The leftmost column reads vertically: **API Packet**

Remote Command Response

API Identifier Value: (0x97)

If a module receives a remote command response RF data frame in response to a Remote AT Command Request, the module will send a Remote AT Command Response message out the UART. Some commands may send back multiple frames--for example, Node Discover (ND) command.

Remote AT Command Response

Frame Fields			Offset	Example	Description
Start Delimiter			0	0x7E	
Length			MSB 1	0x00	Number of bytes between the length and the checksum
			LSB 2	0x13	
A P I **P a c k e t**	**Frame-specific Data**	**Frame Type**	3	0x97	
		Frame ID	4	0x55	This is the same value passed in to the request.
		64-bit Source (remote) Address	MSB 5	0x00	The address of the remote radio returning this response.
			6	0x13	
			7	0xA2	
			8	0x00	
			9	0x40	
			10	0x52	
			11	0x2B	
			LSB 12	0xAA	
		Reserved	13	0xFF	Reserved
			14	0xFE	
		AT Commands	15	0x53	Name of the command
			16	0x4C	
		Command Status	17	0x00	0 = OK 1 = ERROR 2 = Invalid Command 3 = Invalid Parameter
		Command Data	18	0x40	The value of the required register
			19	0x52	
			20	0x2B	
			21	0xAA	
Checksum			22	0xF4	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

Transmit Request

API Identifier Value: (0x10) A TX Request message will cause the module to send RF Data as an RF Packet.

Transmit Request

Frame Fields		Offset	Example	Description
Start Delimiter		0	0x7E	
Length		MSB 1	0x00	Number of bytes between the length and the checksum
		LSB 2	0x16	
Frame-specific Data	Frame Type	3	0x10	
	Frame ID	4	0x01	Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to 0, no response is sent.
	64-bit Destination Address	MSB 5	0x00	Set to the 64-bit address of the destination device. The following address is also supported: 0x000000000000FFFF - Broadcast address
		6	0x13	
		7	0xA2	
		8	0x00	
		9	0x40	
		10	0x0A	
		11	0x01	
		LSB 12	0x27	
	Reserved	13	0xFF	Set to 0xFFFE.
		14	0xFE	
	Broadcast Radius	15	0x00	Sets maximum number of hops a broadcast transmission can occur. If set to 0, the broadcast radius will be set to the maximum hops value.
	Transmit Options	16	0x00	Bitfield: bit 0: Disable ACK bit 1: Don't attempt route Discovery. All other bits must be set to 0.
	RF Data	17	0x54	Data that is sent to the destination device
		18	0x78	
		19	0x44	
		20	0x61	
		21	0x74	
		22	0x61	
		23	0x30	
		24	0x41	
Checksum		25	0x13	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

(Left vertical label: API Packet)

Explicit Addressing Command Frame

API Identifier Value: (0x11)

Allows application layer fields (endpoint and cluster ID) to be specified for a data transmission.

Explicit Addressing Command Frame

Frame Fields		Offset	Example	Description
Start Delimiter		0	0x7E	
Length		MSB 1	0x00	Number of bytes between the length and the checksum
		LSB 2	0x1A	
Frame-specific Data	**Frame Type**	3	0x11	
	Frame ID	4	0x01	Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to 0, no response is sent.
	64-bit Destination Address	MSB 5	0x00	Set to the 64-bit address of the destination device. The following address is also supported: 0x000000000000FFFF - Broadcast address
		6	0x13	
		7	0xA2	
		8	0x00	
		9	0x01	
		10	0x23	
		11	0x84	
		LSB 12	0x00	
	Reserved	13	0xFF	Set to 0xFFFE.
		14	0xFE	
	Source Endpoint	15	0xA0	Source endpoint for the transmission.
	Destination Endpoint	16	0xA1	Destination endpoint for the transmission.
	Cluster ID	17	0x15	Cluster ID used in the transmission
		18	0x54	
	Profile ID	19	0xC1	Profile ID used in the transmission
		20	0x05	
	Broadcast Radius	21	0x00	Sets the maximum number of hops a broadcast transmission can traverse. If set to 0, the transmission radius will be set to the network maximum hops value.
	Transmit Options	22	0x00	Bitfield: bit 0: Disable ACK bit 1: Don't attempt route Discovery. All other bits must be set to 0.
	Data Payload	23	0x54	
		24	0x78	
		25	0x44	
		26	0x61	
		27	0x74	
		28	0x61	
Checksum		29	0xDD	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

Transmit Status

API Identifier Value: 0x8B

When a TX Request is completed, the module sends a TX Status message. This message will indicate if the packet was transmitted successfully or if there was a failure.

TX Status Frames

	Frame Fields		Offset	Example	Description
A P I **P a c k e t**	Start Delimiter		0	0x7E	
	Length	MSB 1	0x00	Number of bytes between the length and the checksum
		LSB 2	0x07	
	Frame-specific Data	Frame Type	3	0x8B	
		Frame ID	4	0x47	Identifies the UART data frame being reported. Note: If Frame ID = 0 in AT Command Mode, no AT Command Response will be given.
		Reserved	5	0xFF	Reserved.
			6	0xFE	
		Transmit Retry Count	7	0x00	The number of application transmission retries that took place.
		Delivery Status	8	0x00	0x00 = Success 0x01 = MAC ACK Failure 0x15 = Invalid destination endpoint 0x21 = Network ACK Failure 0x25 = Route Not Found
		Discovery Status	9	0x02	0x00 = No Discovery Overhead 0x02 = Route Discovery
	Checksum		10	0x2E	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

Receive Packet

API Identifier Value: (0x90)

When the module receives an RF packet, it is sent out the UART using this message type.

RX Packet Frames

Frame Fields			Offset	Example	Description
Start Delimiter			0	0x7E	
Length			MSB 1	0x00	Number of bytes between the length and the checksum
			LSB 2	0x12	
Frame-specific Data	Frame Type		3	0x90	
	Frame ID		4	0x00	Identifies the UART data frame for the host to correlate with a subsequent ACK (acknowledgement). If set to 0, no response is sent.
	64-bit Source Address		MSB 5	0x13	64-bit address of sender
			6	0xA2	
			7	0x00	
			8	0x40	
			9	0x52	
			10	0x2B	
			LSB 11	0xAA	
	Reserved		12	0xFF	Reserved
			13	0xFE	
	Receive Options		14	0x01	0x01 - Packet Acknowledged 0x02 - Packet was a broadcast packet
	Received Data		15	0x52	Received RF data
			16	0x78	
			17	0x44	
			18	0x61	
			19	0x74	
			20	0x61	
Checksum			21	0x11	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

(API Packet spans the Start Delimiter through Checksum rows)

Explicit Rx Indicator

API Identifier Value:(0x91)

When the modem receives a RF packet it is sent out the UART using this message type (when AO=1).

Explicit RX Indicators

	Frame Fields		Offset	Example	Description
	Start Delimiter		0	0x7E	
	Length		MSB 1	0x00	Number of bytes between the length and the checksum
			LSB 2	0x18	
	Frame-specific Data	**Frame Type**	3	0x91	
		64-bit Source Address	MSB 4	0x00	64-bit address of sender
			5	0x13	
			6	0xA2	
A P I P a c k e t			7	0x00	
			8	0x40	
			9	0x52	
			10	0x2B	
			LSB 11	0xAA	
		Reserved	12	0xFF	Reserved.
			13	0xFE	
		Source Endpoint	14	0xE0	Endpoint of the source that initiated the transmission
		Destination Endpoint	15	0xE0	Endpoint of the destination the message is addressed to.
		Cluster ID	16	0x22	Cluster ID the packet was addressed to.
			17	0x11	
		Profile ID	18	0xC1	Profile ID the packet was addressed to.
			19	0x05	
		Receive Options	20	0x02	0x01 – Packet Acknowledged 0x02 – Packet was a broadcast packet
		Received Data	21	0x52	Received RF data
			22	0x78	
			23	0x44	
			24	0x61	
			25	0x74	
			26	0x61	
	Checksum		27	0x56	0xFF - the 8 bit sum of bytes from offset 3 to this byte.

Appendix A: Definitions

Definitions

<p align="center">**Terms and Definitions**</p>

PAN	Personal Area Network - A data communication network with a defined set of characteristics that isolates it from other like devices
Network Address	The 16-bit address is used for compatibility and has an address of 0xFFFE

<p align="center">**DigiMesh Definitions**</p>

DigiMesh Protocol	
Election	An election takes place to resolve which node will function as the network's sleep coordinator if multiple nodes nominate themselves at the same time
Hopping	One direct host-to-host connection forming part of the route between hosts
Node Identifier	A string used to identify a node, apart from its address
Nomination	Nomination is the process whereby a node becomes a sleep coordinator
Route Request	Broadcast transmission sent by a coordinator or router throughout the network in attempt to establish a route to a destination node
Route Reply	Unicast transmission sent back to the originator of the route request. It is initiated by a node when it receives a route request packet and its address matches the Destination Address in the route request packet.
Route Discovery	The process of establishing a route to a destination node when one does not exist in the Routing Table. It is based on the AODV (Ad-hoc On-demand Distance Vector routing) protocol.
Sleep coordinator	Node used to send sync messages in a cyclic sleeping network
Sync message	A transmission used in a cyclic sleeping network to maintain synchronization

Appendix B: Agency Certifications

United States (FCC)

XBee/XBee-PRO DigiMesh 2.4 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:

1. 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 [Figure A-01].
2. XBee/XBee-PRO DigiMesh 2.4 RF Modules may only be used with antennas that have been tested and approved for use with this module [refer to the antenna tables in this section].

OEM Labeling Requirements

WARNING: The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product enclosure that displays the contents shown in the figure below.

Required FCC Label for OEM products containing the XBee/XBee-PRO DigiMesh 2.4 RF Module

Contains FCC ID: OUR-XBEE/OUR-XBEEPRO*

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.

* The FCC ID for the XBee is "OUR-XBEE". The FCC ID for the XBee-PRO is "OUR-XBEEPRO".

FCC Notices

IMPORTANT: The XBee/XBee-PRO DigiMesh 2.4 OEM 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 & 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, 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: Re-orient or relocate the receiving antenna, increase the separation between the equipment and receiver, connect equipment and receiver to outlets on different circuits, or consult the dealer or an experienced radio/TV technician for help.

FCC-Approved Antennas (2.4 GHz)

XBee/XBee-PRO RF Modules can be installed using antennas and cables constructed with standard connectors (Type-N, SMA, TNC, etc.) if the installation is performed professionally and according to FCC guidelines. For installations not performed by a professional, non-standard connectors (RPSMA, RPTNC, etc) must be used.

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

XBee RF Modules (1 mW): XBee Modules have been tested and approved for use with all of the antennas listed in the tables below.

XBee-PRO RF Modules (60 mW): XBee-PRO Modules have been tested and approved for use with the antennas listed in the tables below.

The antennas in the tables below have been approved for use with the XBee/XBee-PRO DigiMesh 2.4 RF module. Digi does not carry all of these antenna variants. Contact Digi Sales for available antennas.

Antennas approved for use with the XBee/XBee-PRO DigiMesh 2.4 RF Modules (Cable-loss is not required.)

Part Number	Type (Description)	Gain	Application*	Min. Separation
A24-HASM-450	Dipole (Half-wave articulated RPSMA - 4.5")	2.1 dBi	Fixed/Mobile	20 cm
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. w/ 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

Antennas approved for use with the XBee RF Modules (Cable-loss is required)

Part Number	Type (Description)	Gain	Application*	Min. Separation	Required Cable-loss
Yagi Class Antennas					
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
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
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

XBee RF Module: High Gain Antenna Summary
The following antenna types have been tested and approved for use with the XBee Module:

Antenna Type: Yagi
RF Module was tested and approved with 15 dBi antenna gain with 7.9 dB cable loss. Any Yagi type antenna with 7.1 dBi gain or less can be used with no cable loss.

Antenna Type: Omni-directional
RF Module was tested and approved with 15 dBi antenna gain with 5.7 dB cable loss. Any Omni-directional antenna with 9.3 dBi gain or less can be used with no cable loss.

Antenna Type: Flat Panel
RF Module was tested and approved with 16 dBi antenna gain with 9.0 dB cable loss. Any Flat Panel antenna with 7.0 dBi gain or less can be used 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*	Min. 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
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
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 using the RF module in a portable application (For example - If the module is used in a handheld device and the antenna is less than 20cm from the human body when the device is operation): The integrator is responsible for passing additional SAR (Specific Absorption Rate) testing based on FCC rules 2.1091 and FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, OET Bulletin and Supplement C. 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.

RF Exposure

⚠ WARNING: 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.

The preceding statement must be included as a CAUTION statement in OEM product manuals in order to alert users of FCC RF Exposure compliance.

Europe (ETSI)

The XBee/XBee-PRO DigiMesh 2.4 RF Module has been certified for use in several European countries. For a complete list, refer to www.digi.com.

If the XBee/XBee-PRO DigiMesh 2.4 RF Modules are incorporated into a product, the manufacturer must ensure compliance of the final product to the European harmonized EMC and low-voltage/safety standards. A Declaration of Conformity must be issued for each of these standards and kept on file as described in Annex II of the R&TTE Directive.

Furthermore, the manufacturer must maintain a copy of the XBee/XBee-PRO DigiMesh 2.4 user manual 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. If any of these specifications are exceeded in the final product, a submission must be made to a notified body for compliance testing to all required standards.

OEM Labeling Requirements

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

CE Labeling Requirements
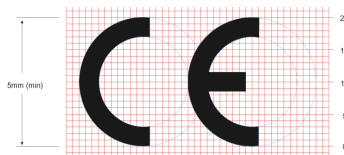
The CE mark shall consist of the initials "CE" taking the following form:

- 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 5mm 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

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

Declarations of Conformity

Digi has issued Declarations of Conformity for the XBee/XBee-PRO DigiMesh 2.4 RF Modules concerning emissions, EMC and safety.

Important Note

Digi does not list the entire set of standards that must be met for each country. Digi customers assume full responsibility for learning and meeting the required guidelines for each country in their distribution market. For more information relating to European compliance of an OEM product

incorporating the XBee/XBee-PRO DigiMesh 2.4 RF Module, contact Digi, or refer to the following web sites:

CEPT ERC 70-03E - Technical Requirements, European restrictions and general requirements: Available at www.ero.dk/.

R&TTE Directive - Equipment requirements, placement on market: Available at www.ero.dk/.

Approved Antennas

When integrating high-gain antennas, European regulations stipulate EIRP power maximums. Use the following guidelines to determine which antennas to design into an application.

XBee RF Module

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

Antenna Type: 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.

Antenna Type: 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.

Antenna Type: 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.

XBee-PRO RF Module (@ 10 dBm Transmit Power, PL parameter value must equal 0, or use International variant)

The following antennas have been tested and approved for use with the embedded XBee-PRO RF Module:

- Dipole (2.1 dBi, Omni-directional, Articulated RPSMA, Digi part number A24-HABSM)
- Chip Antenna (-1.5 dBi)
- Attached Monopole Whip (1.5 dBi)

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

Canada (IC)

Labeling Requirements

Labeling requirements for Industry Canada are similar to those of the FCC. A clearly visible label on the outside of the final product enclosure must display 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.

Japan (Telec)

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.

Labeling Requirements

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

R201WW07215214 (XBee)

R201WW08215111 (XBee-PRO)

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 have a C-Tick mark on an end product, a company must comply with (a) or (b) below:

a. Have a company presence in Australia

b. Have a company/distributor/agent in Australia that will sponsor the importing of the end product

Contact Digi for questions related to locating a contact in Australia.