BreadCrumb® LX4

USER GUIDE
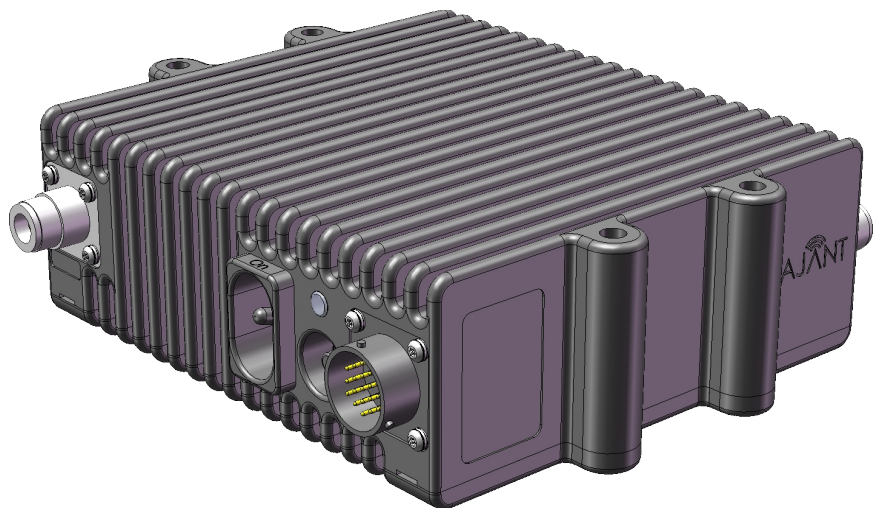
User Guide Version: 2.12
Software Version: 10.32
Date: January 17, 2013

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FCC Compliance Statements

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with this instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at their own expense.

CAUTION: Changes or modifications not expressly approved by Rajant Corp. could void the user's authority to operate the equipment.

WARNING: This equipment complies with the FCC RF radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of 30 centimeters between the radiator and all persons while the device is operating.

This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

The antennas used for this transmitter must be installed to provide a separation distance of at least 30cm from all persons and must not be located or operating in conjunction with any other antenna or transmitter.

Required Antenna Separation for LX4-2409 and LX4-2450

The FCC/IC wireless approval for the LX4-2450 and LX4-2409 is conditional on maintaining a minimum separation of 20cm between the antennas. The separation of the antenna connectors on the LX4-2450 and the LX4-2409 is 13cm, therefore at least one of the antennas must be connected to the BreadCumb with 50 ohm coaxial cable. Low loss LMR400 is recommended for this application.

IC Compliance Statements

1) This Class A digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.

2) Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

3) This radio transmitter has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Le présent émetteur radio (identifier le dispositif par son numéro de certification ou son numéro de modèle s'il fait partie du matériel de catégorie I) a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Frequency Range (MHz)	Antenna Gain (dBi)	Antenna Type	Impedance (Ohms)
912 - 917	5	Omni-directional	50
2412 - 2462	5	Omni-directional	50
4810 - 4930	6	Omni-directional	50
5745 - 5825	6	Omni-directional	50

4) This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must

accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

5) High-power radars are allocated as primary users (i.e. priority users) of the bands 5250-5350 MHz and 5650-5850 MHz and that these radars could cause interference and/or damage to LE-LAN devices.

De plus, les utilisateurs devraient aussi être avisés que les utilisateurs de radars de haute puissance sont désignés utilisateurs principaux (c.-à-d., qu'ils ont la priorité) pour les bandes 5 250-5 350 MHz et 5 650-5 850 MHz et que ces radars pourraient causer du brouillage et/ou des dommages aux dispositifs LAN-EL.

GNU General Public License Statement

Certain components of the Rajant BreadCrumb firmware are subject to the GNU General Public License Version 2, or other so-called open source licenses ("Open Source Software"). In compliance with the terms of certain Open Source Software licenses like the GNU General Public License Version 2 ("GPLv2"), Rajant makes certain modifications to Open Source Software that Rajant uses, modifies and distributes pursuant to such licenses available to customers in source code form upon request. You are free to use, modify and distribute Open Source Software so long as you comply with the terms of the relevant Open Source Software license. In particular, the GPLv2 is available in the appendix of this manual or at www.gnu.org/copyleft/gpl.html.

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BreadCrumb® LX4 User Guide

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Preface

Purpose and Scope

This manual provides information and guidance to all personnel who are involved with and use Rajant Corporation's BreadCrumb LX4.

This manual begins with an introduction to the BreadCrumb Wireless Network (BCWN). It then characterizes the features of the BreadCrumb LX4. Finally, it describes common deployment scenarios and provides concise step-by-step instructions for each scenario.

Note	Throughout this document, unless otherwise stated, the terms *LX4* and *BreadCrumb* are used to refer to *Rajant BreadCrumb LX4*.

User Information

The user of this manual is encouraged to submit comments and recommended changes to improve this manual. Please send any comments or changes to support@rajant.com. Be sure to include the version number of the manual you are using and please provide the page numbers related to your comments wherever possible

Related Documentation

For additional information, refer to these documents:

- *Rajant BC|Commander® User Guide:* This document contains information on the BC|Commander management application, which is used to configure BreadCrumbs before or during a deployment. This now includes a BreadCrumb VLAN Guide.

- *BreadCrumb® Video Guide*

- *Rajant Troubleshooting Range User Guide*

- *RF Component Installation and Verification in BreadCrumb® Networks*

1   Introduction to BreadCrumbs

Rajant Corporation's (http://www.rajant.com) BreadCrumbs utilize the 802.11 wireless networking standards to form a wireless mesh network. The network is mobile, self-integrating, self-meshing, self-healing, and secure. The focus is on flexibility, adaptability, and simplicity.

The BreadCrumb Wireless Network (BCWN) is intended for rapid deployment of a broadband wireless network into a situation or "hot zone." The network can be deployed as a stand-alone wireless network, or bridged to another network (such as the Internet) utilizing available reach-back communication links (such as a DSL, cable, or satellite modem).

BreadCrumbs provide high bandwidth for applications to stream video, audio as well as data over large distances. The network traffic can be secured by using different security features offered by the BCWN. This makes the network optimal for tactical deployments as well as emergency response situations since it offers robustness, stability and ease of setup in mission critical activities.

1.1   What is a BreadCrumb?

A BreadCrumb is an IEEE 802.11 (Wi-Fi) and Ethernet compatible networking device which has the capacity to connect to other BreadCrumbs or networking devices to form a BreadCrumb network. A BreadCrumb is specifically designed for the following scenarios:

Temporary Wireless Networks
Networks that must be established quickly and with minimal effort for short-term use (e.g., a network established to provide First Responder support at the site of a disaster).

Mobile Wireless Networks
Networks in which the network infrastructure itself is mobile, in addition to client devices (e.g., a convoy viewing a video stream from a UAV).

Wireless Network Extension
Networks in which a wireless network must be quickly extended around or through obstacles that block wireless communications (e.g., urban canyon networks, tunnels/caves, etc.)

Wired Network Extension
Networks in which two or more wired LANs at different locations must be connected wirelessly (e.g., to securely connect combat service support computers with logistics bases)

Any Combination of the Above
Most BreadCrumb deployments include elements from more than one of the above scenarios.

In many cases, BreadCrumbs will perform all of these tasks as shipped with no configuration necessary at all, providing an instant TAN (Tactical Area Network). Moreover, because BreadCrumbs use industry-standard 802.11 communications, client devices such as laptops or handheld computers require no special hardware, software, or configuration to access a BCWN.

1.2   Mobility through Meshing

The key component to a BCWN is a technique known as Meshing. While this is generally handled automatically by BreadCrumbs, complex deployment scenarios require a basic understanding of how BreadCrumbs establish and maintain a mesh.

1.2.1   Mesh – A Definition

A mesh is a collection of network devices (in our case, BreadCrumbs), each of which is linked to one or more other BreadCrumbs. Data can move between BreadCrumbs via these links, possibly passing through several intermediate BreadCrumbs before arriving at its final destination.

The intelligence of a BCWN is in how it adapts rapidly to the creation or destruction of the links in the mesh as devices are moved, switched OFF or ON, blocked by obstructions, interfered with by other devices, or otherwise affected. This adaptation takes place automatically and immediately as needed.

Note	Although all BreadCrumbs can be access points, most access points do not provide mesh capability. Traditional access points simply allow wireless devices within range to connect to a wired network; they do not extend range through other access points.

1.2.2   BreadCrumb Mesh Connections

In order for two BreadCrumbs to establish a mesh link to each other, they must be set to the same radio channel, and the same ESSID, and have the same InstaMesh key settings. An ESSID is essentially a name for a wireless network. By default, BreadCrumbs use the ESSID "breadcrumb54-v10" if programmed with version 10 firmware. InstaMesh key settings include the Network Authentication Key (NAK) and the Network Encryption Key (NEK).

Assuming that the security settings are the same, the following examples illustrate how the use of channels and ESSIDs can establish or break mesh links:

Example 1:

Suppose you have three BreadCrumbs, called A, B, and C. Each has two radios. BreadCrumb A's radios are on channels 1 and 8, B's are on 8 and 11, and C's are on 1 and 11. All three BreadCrumbs are using the default ESSID of "breadcrumb54-v10." Assuming that all three BreadCrumbs are within radio range of one another, the network will be connected, as shown below:
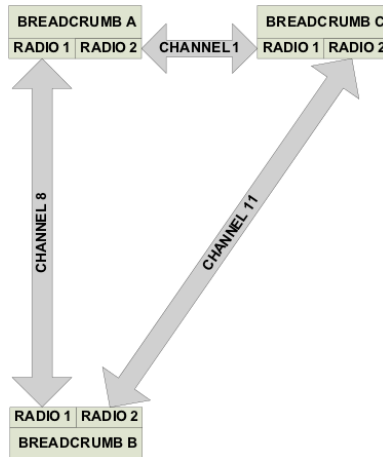
Figure 1: All BreadCrumbs use the same ESSID.

Example 2:

Now suppose that you change the ESSID of BreadCrumb C to "lonely". The network will adjust to this change, resulting in the following configuration:
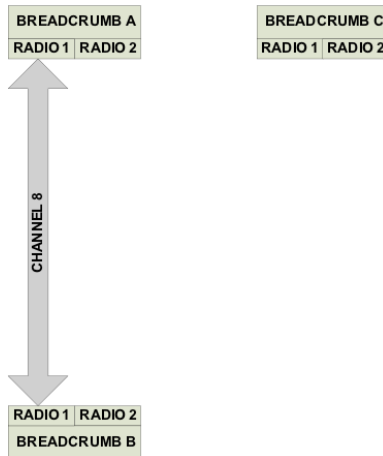
Figure 2: ESSID of BreadCrumb C changes to "lonely."

Note that BreadCrumb C can no longer communicate with A or B, and vice versa.

2 Description of a BreadCrumb LX4

BreadCrumb LX4 is a portable, wireless device deployable in almost any environment. It is light in weight, offers up to 4 external antennas and is designed to be completely mobile as worn by an individual. The BreadCrumb LX4 must be powered by an external source.

2.1 Radios

The BreadCrumb LX4 contains between two and four radios. 802.11g radios are used in the 900 MHz and 2.4 GHz bands, and 802.11a radios are used in the 4.9 GHz and 5 GHz bands. The radios support the channels and frequencies listed in Tables 1, 2, 3, 4, and 5 in the United States and Canada.

| Note | Not all channels are allowed for use everywhere around the world. Check with the corresponding wireless spectrum regulatory body to determine the subset of channels authorized for use in your country. |

Table 1: 2.4 GHz Radio Channel and Frequencies.

Channel Number	Center Frequency (MHz)
1	2412
2	2417
3	2422
4	2427
5	2432
6	2437
7	2442
8	2447
9	2452
10	2457
11	**2462**

The default channel for a 2.4 GHz BreadCrumb radio is 11 (2462 MHz).

Table 2: 900 MHz Radio Channel and Frequencies.

Channel Number	Center Frequency (MHz)	Channel Bandwidth
4	907	Half (10 Mhz)
5	**912**	**Full (20 Mhz)**
6	917	Full (20 Mhz)
7	922	Half (10 Mhz)

The default channel for a 900 MHz BreadCrumb radio is 5 (912 MHz). Half (10 MHz) and Quarter (5 MHz) bandwidth support is available on all 900MHz channels.

Note	Channels 4 and 7, as well as Half (10 MHz) and Quarter (5 MHz) bandwidth may not be supported on some BreadCrumbs with 900MHz radios.

Table 3: 5 GHz Radio Channel and Frequencies.

Band	Channel	Center Frequency (MHz)	Turbo Capability
U-NII Upper Band (5725 - 5825 MHz / ISM Band (5725 - 5875 MHz	149	5745	No
	152	**5760**	**Static Turbo**
	153	5765	No
	157	5785	No
	160	5800	Static Turbo
	161	5805	No
	165	5825	No

The default channel for a 5 GHz BreadCrumb radio is 152 (5760 MHz). Some 5 GHz channels support a feature called *Static Turbo* mode. In this mode, the radio binds two standard 20 MHz channels to obtain a wider bandwidth 40 MHz channel. The end result is improved throughput and/or communication range for the radio. Users should refer to the applicable compliance regulations in the intended region of deployment for use of these frequencies.

| Caution | Most 5 GHz antennas only support a subset of the 802.11a 5 GHz frequency channels the Rajant radio is capable of operating at. Before changing the channel of a 5 GHz radio, verify that the channel is supported by the connected antenna. |

| Caution | Since the radios operate at different frequencies, you must be careful to use the correct type of antenna with each radio. As an example, a 2.4 GHz antenna will not work with a 5 GHz radio and vice versa. |

Table 4: 4.8 GHz Radio Channel and Frequencies.

Channel Number	Center Frequency (MHz)	Channel Number	Center Frequency (MHz)
162	4810	175	4875
163	4815	176	4880
164	**4820**	177	4885
165	4825	178	4890
166	4830	179	4895
167	4835	180	4900
168	4840	181	4905
169	4845	182	4910
170	4850	183	4915
171	4855	**184**	**4920**
172	4860	185	4925
173	4865	186	4930
174	**4870**		

The default channel for a 4.8 GHz BreadCrumb radio is 164 (4820 MHz). If a second 4.8 GHz radio is present, it's default channel is 184 (4920 MHz). If a third 4.8 GHz radio is present, it's default chanel is 174 (4870 MHz)

Table 5: 4.9 GHz Radio Channel and Frequencies.

Channel Number	Center Frequency (MHz)	Channel Bandwidth
5	4942.5	Quarter (5 Mhz)
10	4945.0	Half (10 Mhz)
15	4947.5	Quarter (5 Mhz)
20	**4950.0**	**Full (20 Mhz)**
25	4952.5	Quarter (5 Mhz)
30	4955.0	Full (20 Mhz)
35	4957.5	Quarter (5 Mhz)
40	4960.0	Full (20 Mhz)
45	4962.5	Quarter (5 Mhz)
50	4965.0	Full (20 Mhz)
55	4967.5	Quarter (5 Mhz)
60	4970.0	Full (20 Mhz)
65	4972.5	Quarter (5 Mhz)
70	4975.0	Full (20 Mhz)
75	4977.5	Quarter (5 Mhz)
80	4980.0	Full (20 Mhz)
85	4982.5	Quarter (5 Mhz)
90	4985.0	Half (10 Mhz)
95	4987.5	Quarter (5 Mhz)

The default channel for a 4.9 GHz BreadCrumb radio is 20 (4960.0 MHz).

2.2　Enclosure

The LX4 enclosure has been designed to operate in extreme conditions, with protection against ingress of dust as well as protection against immersion in water. The enclosure dimensions are 195 mm x 187 mm x 61 mm (7.683" x 7.352" x 2.400"). The external features of the enclosure are shown in Figure 6 and Figure 4.
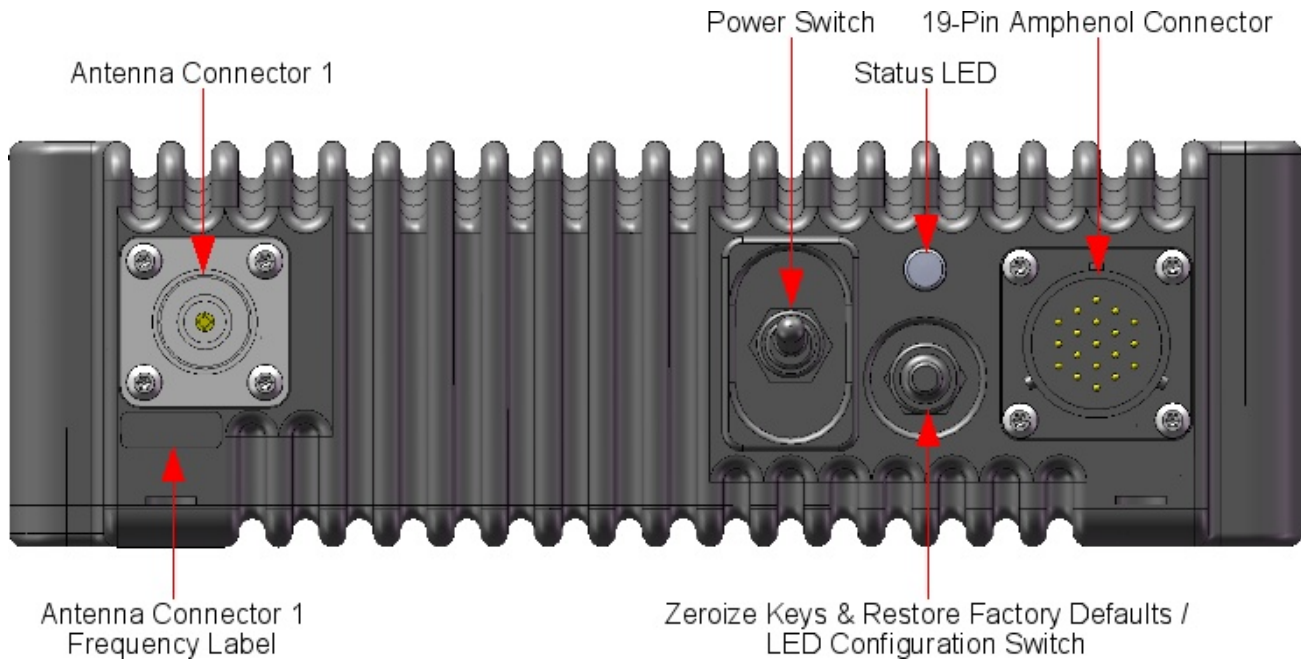

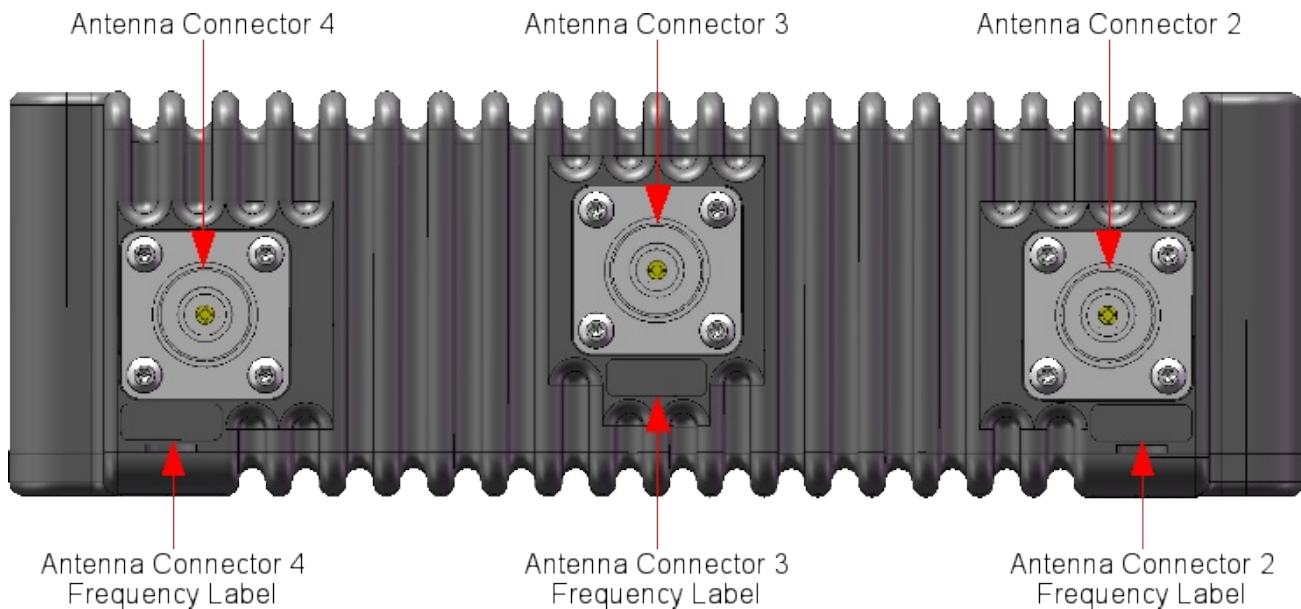**Figure 3: BreadCrumb LX4 Enclosure Features (Front)**

Figure 4: BreadCrumb LX4 Enclosure Features (Rear)

2.3   Antenna Connectors

The BreadCrumb LX4 provides up to four Type N female antenna connectors. One connector is located on the front side of the enclosure (see Figure 6), the other three connectors are located on the rear side of the enclosure (see Figure 4). In general, only one antenna port per radio is utilized. Some BreadCrumb models offer the 900 MHz antenna diversity feature, in which case two antenna ports on the 900 MHz radio are utilized. There are many different LX4 Models available, each with a different configuration of radios and antennas. Each antenna connector will be labeled with the frequency of its corresponding radio.

Because the antennas are mounted top and bottom and on opposite sides of the unit, the only viable means of using the LX4 with all antennas directly attached to the device is by using the pole mount option. Care should be taken to make sure the antennas, and therefore the pole is mounted plumb. This is because most of Rajant's standard antennas are characterized by high-gain and therefore small vertical beamwidth. The small vertical beamwidth necessitates the antennas to be plumb, so that units using these antennas will see each other without a significant loss of signal strength.

Warning ⚠	To avoid possible damage to the BreadCrumb radio(s), always connect or disconnect external antennas with the power to the BreadCrumb LX4 off.

2.4   19-Pin Amphenol Connector

The majority of the signals and features of BreadCrumb LX4 can be accessed through the 19-pin Amphenol connector on the enclosure (see Figure 6 and Figure 5). The most important of these interfaces are external power, Ethernet, and USB, which are described in more detail in the following sections. The 19-pin Amphenol connector interfaces to the LX4 cable assembly that provides access to input power, Ethernet and USB ports of the device.

Connector from Rear
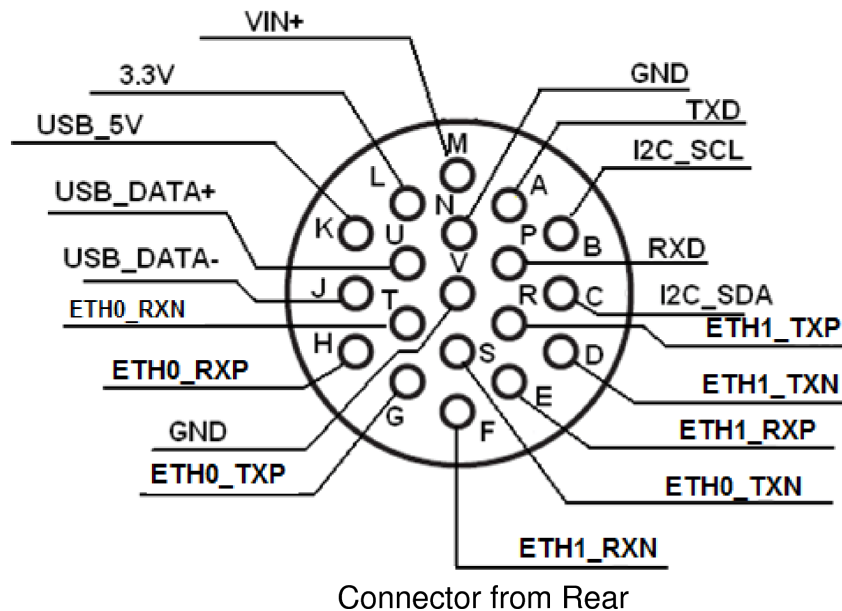
Figure 5: 19-Pin Amphenol Connector

2.4.1 Power

The input power interface to the BreadCrumb LX4 resides on the 19-pin Amphenol connector (see see Figure 6 and Figure 5). The device accepts external power in the range of 24 VDC to 48 VDC. The peak power consumption of BreadCrumb LX4 is 23 W with two radios, 30 W with three radios, and 37 W with 4 radios at 24 VDC.

2.4.2 Ethernet

BreadCrumb LX4 contains two 10/100 Base-TX Ethernet ports, which can be accessed through the 19-pin Amphenol connector on the enclosure (see Figure 6 and Figure 5). Both ports support Auto MDI/MDIX allowing the use of either straight-through or crossover data cables for connections. The data interface includes electrostatic discharge, and electrical fast transient/burst immunity compliant to the IEC 61000-4-2 ESD, and IEC 61000-4-4 EFT standards, respectively.

The ETH0 port, when accessed through the standard LX4 Cable Assembly (see section 2.5), also supports Passive Power over Ethernet (Passive PoE), and therefore acts as a dual function Ethernet and DC power input port for the BreadCrumb LX4. An external inline injector is used to merge DC power for the BreadCrumb LX4 with data from a LAN port or a wired client (see Figure 3).

To ensure proper operation of the BreadCrumb LX4, the inline injector must output a DC voltage between 24 VDC to 48 VDC @ 23 W (two radio operation), 30 W (three radio operation) or 37 W (four radio operation) minimum. Using a higher output voltage facilitates longer cable runs between the inline injector and the ETH0 port on the BreadCrumb LX4.

The BreadCrumb LX4 ships with a standard 48 V AC/DC Passive PoE injector. The Rajant VHDC-24 is an optional accessory, and supports powering the Breadcrumb LX4 from an unregulated DC supply.
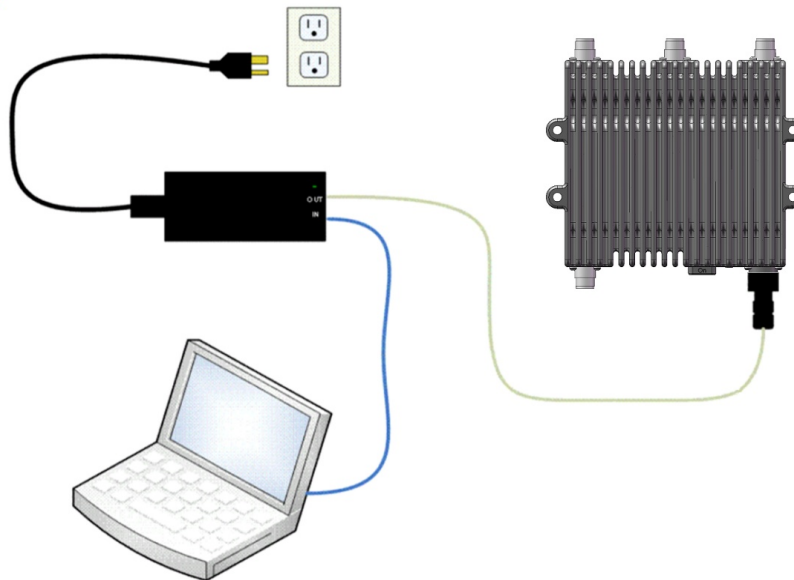
Figure 6: BreadCrumb LX4 Ethernet and Passive PoE Connections

Warning

⚠️

In order to avoid sparking and possible damage to the unit, be sure to connect the powered Ethernet cable to the BreadCrumb LX4 before applying power to the power supply.

2.4.3   USB

The signals that interface to the BreadCrumb LX4 device's USB port are located on the 19-pin Amphenol connector on the enclosure (see Figure 6 and Figure 5). The port is compliant to the Enhanced Host Controller Interface (EHCI) and USB Transceiver 2.0 Macrocell Interface (UTMI+) Level 2 specifications. The port supports all three standard data transfer rates of low speed (1.5Mbps), full speed (12Mbps), and high speed (480Mbps). The power switch for the port includes over current protection, thermal protection, in-rush current limiting, and hot-plug noise filtering.

The USB port can be used to perform BreadCrumb firmware upgrades and USB-based zeroize. It can also interface to an optional GPS receiver accessory available from Rajant.

2.5   LX4 Cable Assembly

The LX4 comes with a standard cable assembly(part number 06-100044-001) that connects to the BreadCrumb's 19-pin Amphenol connector (see Figure 7). The cable assembly includes two Ethernet ports and one USB port. The ETH0 port of the cable assembly supports Passive Power over Ethernet (Passive PoE), and therefore acts as a dual function Ethernet and DC power input port for the BreadCrumb LX4.
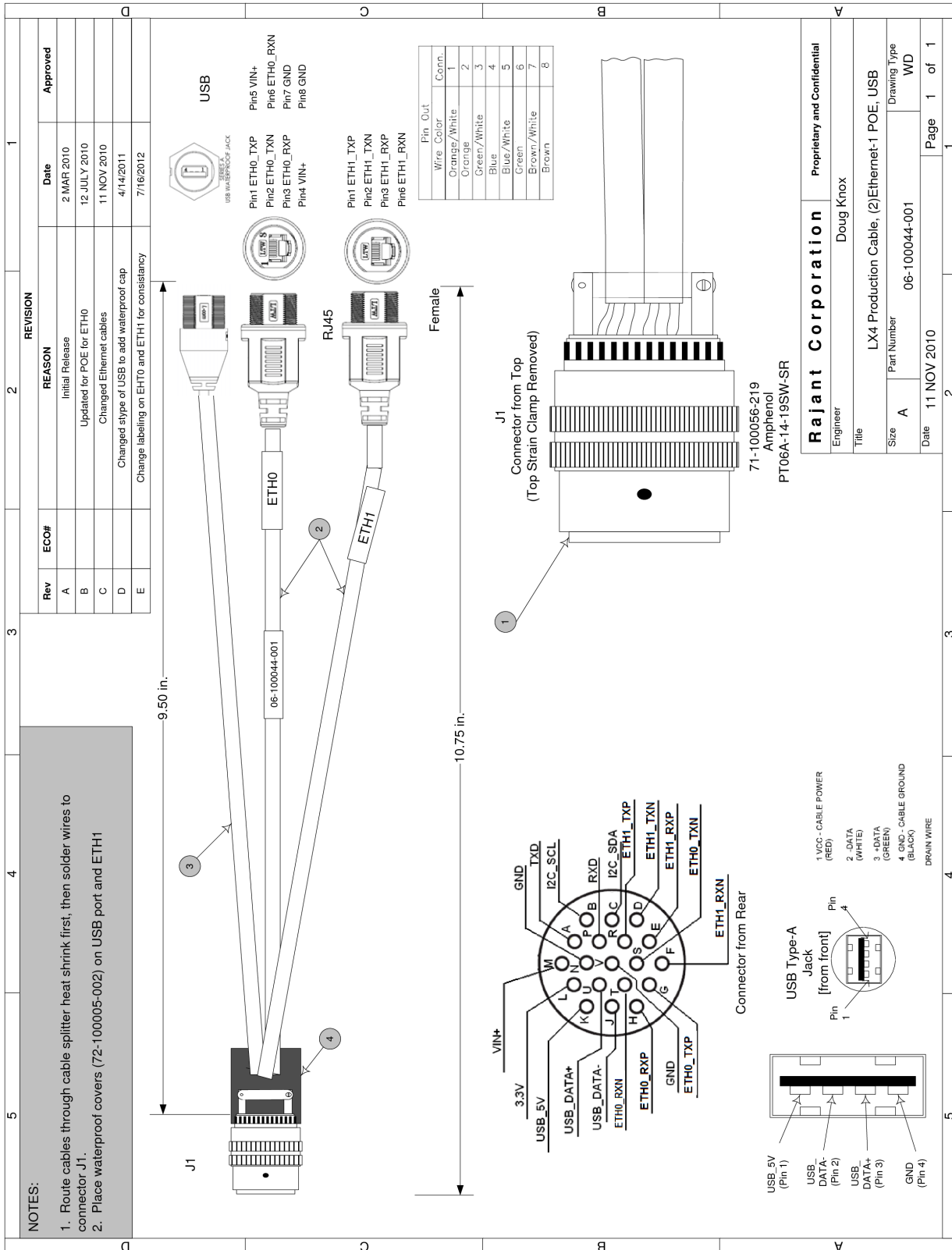
Figure 7: LX4 Cable Assembly Drawing.

2.6 Status LED

The Status LED (see Figure 6) is capable of displaying warning and error codes, and link states. The LED Mode can be configured in BC|Commander to be ON (switchable), ALERTS ONLY (switchable), OFF (non-switchable), or OFF (switchable). When the LED Mode is ON, the BreadCrumb LED alternates between displaying the link state and any warnings or errors. When the LED Mode is OFF, the BreadCrumb LED does not display any warnings, errors, or the link state. When the LED Mode is set for ALERTS ONLY, the BreadCrumb LED alternates between displaying the link state and any warnings or errors only if there are warnings or errors to report. If there are no warnings or errors, the LED displays nothing.

The Status LED combines the three base colors of red, green and blue to display a broader spectrum of colors which indicate the current status of a BreadCrumb. The meanings of the color code indicators are given in Table 6.

Table 6: Status LED Color Codes.

Color	Status
White (red, green and blue LEDs together; may appear pale blue or pale green)	Powered, prior to Booting
Solid Red	Booting
Blinking Red[1]	Error
Solid Blue	Ready, but no peers
Solid Green	At least one 24 Mbps or higher peer
Blinking Green	At least one peer
Blinking Yellow (at a constant rate)	Progress
Blinking Yellow[1] (with short and long pauses between blinks)	Warning
All Status LED colors scrolling in succession	Success/Completion

2.7 LED Configuration / Zeroize Keys and Restore Factory Defaults Switch

The LED Configuration / Zeroize Keys and Restore Factory Defaults Switch (see Figure 6) has two modes of operation. The modes are set by the length of time the switch is asserted. The modes are:

- LED Configuration

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1 For a list of error and warning codes refer to Appendix A at the end of this document.

- Zeroize Keys and Restore Factory Defaults

2.7.1 LED Configuration

This mode is used to control the display states of the Status LED. The LED Configuration function is accessed by pressing the switch and releasing it after a two second hold. The configured display state of the Status LED is dictated by the LED Mode setting that is configured from BC|Commander (please refer to the BC|Commander User Guide for a more detailed description of the LED Mode setting). The user can toggle between the configured state and an alternate state of the Status LED by pressing the switch and activating the LED Configuration function.

Table 7 lists the possible configured and corresponding alternate display states of the Status LED.

Table 7: Setting and alternate display states of the Status LED.

Configured State	Alternate State
ON (SWITCHABLE)	OFF
ALERTS ONLY (SWITCHABLE)	ON
OFF (NON-SWITCHABLE)	OFF
OFF (SWITCHABLE)	ON

Note that state changes can occur only between options in the same rows of the table above. For example, it is possible to toggle the state back and forth between ALERTS ONLY and ON, but not between ALERTS ONLY and OFF. Transitioning from ALERTS ONLY to OFF would require changing the LED mode setting in BC|Commander.

The default LED Mode for the LX4 is OFF (switchable).

Note	As of firmware release 10.16, there are two different configurable OFF states: OFF (switchable), which toggles to ON, and OFF (non-switchable), which has no alternate state. If the LED Mode is set to OFF (non-switchable) in BC|Commander, the Configuration Switch will NOT turn it on.

2.7.2 Zeroize Keys and Restore Factory Defaults

This mode is is used to erase the security protocol keys of a BreadCrumb LX4 and to restore its software configuration to the factory default state. To operate this switch follow these procedures:

- Ensure that the BreadCrumb is powered on, has fully booted-up and its Status LED color is green or blue (see Table 6).

- Press and hold the switch for approximately 10 seconds until the Status LED changes to blinking yellow (see Table 6). This indicates that the Zeroize Keys and Restore Factory Defaults operation has been initiated and is in progress.

● Release the switch. The Status LED should change to display the blinking red error code 32. See Appendix A for a description of the blinking red color sequence. The BreadCrumb will then reboot using the factory default configuration.

Warning	Do NOT turn off power or reboot a BreadCrumb that is being zeroized. An interruption to power during the zeroization process may result in the BreadCrumb being unable to boot properly.

Tip	The process of zeroizing keys and restoring factory defaults can also be performed remotely from within the BC|Commander management software. For details on this alternative method, refer to the BC|Commander User Guide.

3   Using BC|Commander

BC|Commander is Rajant's software package used for monitoring the status of BreadCrumbs with **version 10 firmware** on a BreadCrumb Wireless Network (BCWN). BC|Commander is also used for configuring version 10 BreadCrumbs and to graphically portray the network topology.

Note	BC|Commander includes an option called *v10 Transitional Mode*. This allows a user to run a mixture of BreadCrumbs with firmware version 9 and firmware version 10 within the same mesh network. This is very useful when BreadCrumbs in a very large network are being upgraded from version 9 to version 10 firmware.

BC|Commander typically runs on a laptop PC, but can be run on any PC that has access to the entire BCWN. Versions of the software package are available for Microsoft Windows® or Linux.

Note	Some portions of the BC|Commander User Guide assume a working knowledge of TCP/IP networking, including DHCP, NAT and DNS. While the network lay person may be able to perform some BCWN management tasks, it is recommended that network configuration be performed by experienced network administrators.

Note	**The BC|Commander version used must be equal to or greater than the firmware version running on any administered BreadCrumbs** in order to administer all BreadCrumb firmware features overed in Rajant's BC|Commander User Guide.

Rajant periodically releases updated BC|Commander software. The updated software must be obtained from Rajant. Refer to Rajant's most recent BC|Commander User Guide for instructions on how to install the latest version of BC|Commander on your computer and how to use BC|Commander with Rajant's BreadCrumbs.

4 Deploying the BreadCrumb Wireless Network

There are many factors which need to be taken into account when deploying the BreadCrumb Wireless Network (BCWN). Section 4.1 describes the addressing scheme of the BCWN. Section 4.2 discusses channel assignments. Section 4.3 details some of the most commonly occurring environmental factors that will have a major impact on the performance of the BCWN. Finally, section 4.4 details guidelines and methodology needed to follow when deploying the BCWN.

4.1 Addressing

When in gateway mode or when using its own embedded DHCP servers, the BreadCrumb Wireless Network requires that wireless devices use IPv4 addresses in the Class A network 10.0.0.0/8 (that is, any address that begins with '10.'). If you are not connected to another network, or if you are bridging to one rather than routing to it, your wireless client devices may have any address whatsoever.

Note	Any computers running the BC|Commander management application must have an address in the same range as the BreadCrumbs they manage. Refer to the BC|Commander User Guide document for the details of the BreadCrumb IP address configuration.

4.1.1 BreadCrumb Device Addresses

Each BreadCrumb radio has one IPv4 address in the Class A network 10.0.0.0/8. These addresses are assigned during manufacturing and cannot be changed in the field. Rajant ensures during manufacturing that these addresses are not duplicated between any two BreadCrumb devices. Addresses assigned to BreadCrumb devices can be viewed using BC|Commander.

4.1.2 DHCP

Each BreadCrumb device includes an embedded DHCP server. You may safely enable the DHCP servers of multiple BreadCrumb devices simultaneously, and it is in fact the most common case that all BreadCrumb devices in a BCWN run DHCP servers. Address conflicts among DHCP clients are prevented by using the unique BreadCrumb device addresses assigned at the factory as a base.

A BreadCrumb device determines its DHCP range as follows:

- Start with the first three bytes of the first radio's IPv4 address.
- Add a low-byte range of 10 to 210.

4.2 Channel Assignments

BreadCrumb radios have default channels assigned, based on the frequency of the radio. See Table 8 for a list of available radios and their default channel assignments.

Table 8: Default Channel Assignments

Radio Card Frequency	Default Channel
900 MHz	5
2.4 GHz	11
4.9 GHz	20
5 GHz	152

In some cases, it may be necessary to manually set the radios to specific channels to provide critical links within a mesh. This can be especially important when using single-radio BreadCrumb devices. Refer to the BC|Commander User Guide for the details of BreadCrumb channel configuration.

4.3   Physical Placement and other Considerations

Commonly occurring environmental factors have a significant impact on performance and behavior of the BreadCrumb Wireless Network. LOS (Line of Sight) obstructions, distance, weather, and device placement should all be considered when deploying a wireless network.

IEEE 802.11 wireless operation degrades gradually as distance increases between nodes or as interference becomes prominent. This manifests as a data rate reduction between nodes.

The goal in planning and deploying a BreadCrumb Wireless Network is to maximize both coverage and the data transfer rate between devices. These can be maximized by taking into consideration all of the contributing factors described in this section.

4.3.1   Line-of-Sight

Unobstructed LOS (Line-of-Sight) is critical for optimal performance of the BCWN. Partial LOS obstruction results in noticeable network performance degradation. Total LOS obstruction can result in complete loss of network connectivity.

Elevating the device and external antenna will assist in providing better LOS. This can allow the radio waves to propagate over some possible obstructions.

Unobstructed LOS is not necessary from every BreadCrumb device and wireless client to every other BreadCrumb device and wireless client. However, each device must have unobstructed LOS to the previous and subsequent device.

Client connectivity will degrade and drop if LOS to a BreadCrumb device can not be maintained.

4.3.2   Distance

Many factors determine acceptable distances between BreadCrumb devices when deploying a BCWN:

- If many devices are placed too closely together, it is possible that interference will degrade

the performance of the system.

- Devices placed too far away or in RF "shadows" may experience total loss of connection.

- RF transmit power and receive sensitivity are important in determining the distances over which the device will be effective.

- When placing a BreadCrumb device, check the connection status to the nearest available device using either the BreadCrumb device's status LED (described in section 2.6 Status LED), or the BC|Commander management application. If the connection is poor or non-existent, attempt to relocate the BreadCrumb device closer to another device until an acceptable connection is obtained. If a poor connection or no connection is made at even relatively close distances, you should refer to Chapter 6 Troubleshooting.

- When the connection quality is found to be acceptable from BC|Commander, the distance of the BreadCrumb device from the network can be increased until an optimal balance between distance, connectivity and tactical placement is achieved.

4.3.3   Weather

Precipitation and fog also act as obstructions blocking the propagation of the wireless network's radio waves.

Light fog or precipitation may result in noticeable degradation of wireless network performance. Heavy precipitation or fog may result in severe performance degradation and possible loss of network connectivity.

If the performance of a well functioning network is degraded by worsening weather conditions, it may be advisable to add BreadCrumb devices into the network to act as short haul repeaters to counteract the effects of the weather. An alternative is to move the devices closer together.

4.3.4   Interference

RF interference can degrade network performance and can come from many different sources, including:

- Other BreadCrumb devices that are placed too closely together.

- Other RF devices such as microwave devices, cordless phone base stations, radio transmitters, other wireless networks, jamming devices, etc.

- Metal surfaces such as fences and building can cause radio waves to be reflected, causing multipath interference.

Caution

Plan the BreadCrumb Wireless Network to minimize the effects of RF interference.

4.3.5   Placement of BCWN Components

The placement of BreadCrumb devices has a major impact on maximum effective range, and therefore network performance. The components must be elevated above the surrounding terrain to allow for adequate wave propagation. A device placed directly on the ground has a significantly reduced effective range. Elevating a device above the ground dramatically increased the maximum effective range. Rajant recommends elevating the components a minimum of 6 ft. above the surrounding surface.

4.4   Deployment Guidelines and Methodology

This section addresses the actual on-site deployment of the BCWN. While by no means an exhaustive treatise, it is intended as a good source of guidelines and methodology for the successful deployment of the BCWN in the field.

4.4.1   Deployment Guidelines

Follow these guidelines when deploying the BCWN:

1. Placement of BCWN components

    (a) Elevate the BCWN components whenever possible.

        i. Directly on the ground, the maximum distance between any two BCWN components is approximately 300 ft. Also, the maximum distance between a wireless client and the nearest BCWN component is approximately 300 ft.

        ii. Rajant recommends elevating each BCWN component a minimum of 6 ft. above the surrounding terrain for maximum range. Elevating the BCWN components, as little as 14 inches, has proven to increase the range out to approximately 600 ft.

2. Distance

    (a) If you cannot elevate the BCWN components, they can only be approximately 300 ft. apart. Also, any wireless clients can be no farther than approximately 300 ft. from a BCWN component.

3. Line of sight

    (a) Obstructions to line of sight block/absorb/deflect the wireless network's radio waves, resulting in poor network performance or total loss of network connectivity.

    (b) When placing the BCWN components, scan the area for LOS obstructions. Envision the BCWN's radio waves as a light beam. Look for obstructions that would result in shadows in the light beam, they will most likely weaken or block the BCWN's radio waves.

4. Weather

    (a) Light precipitation will reduce the range and performance of the BCWN components and wireless clients.

    (b) Heavy precipitation or fog will most likely result in extremely reduced range and frequent or total loss of network connectivity.

4.4.2   Deployment Methodology

The steps detailed in this section should assist you in successfully deploying the BCWN.

1. Scan the terrain on which the BCWN will be deployed.

   (a) Determine the initial distances between BreadCrumb devices.

      Refer to *Rajant Troubleshooting Range User Guide* for more information.

   (b) Note any LOS obstructions, and plan BreadCrumb placement to work around them.

2. Identify the PC on which BC|Commander will be run.

   (a) This PC should have a wireless NIC, as you will need to carry it with you as you deploy the BCWN.

      i. Alternatively, the BC|Commander PC can be stationary with one person monitoring BC|Commander while another deploys the BreadCrumbs. This method requires some form of communication (radio, cell phone, etc.) between the two persons.

3. Determine the location for the first BreadCrumb.

4. Power ON the device.

5. Wait approximately 90 seconds for the device to boot.

6. Power ON the BC|Commander PC.

7. Start BC|Commander.

8. The BC|Commander console should display the first BreadCrumb.

9. Determine the approximate location for the next BreadCrumb.

10. Proceed to the location for this BreadCrumb, observing the network in BC|Commander as you progress.

   (a) If the BreadCrumb loses network connectivity before you reach its destination, backtrack until network connectivity is restored. The point at which network connectivity for this BreadCrumb is restored is most likely the farthest point in this direction at which you will be able to place this BreadCrumb.

   (b) If you reach the destination without losing connectivity you can place it there.

      i. At this point, you may choose to proceed farther in an attempt to make optimal use of the available BreadCrumbs.

      ii. If so, proceed until network connectivity is lost and then backtrack until network connectivity is restored for this BreadCrumb. The point at which network connectivity is restored for this BreadCrumb is most likely the farthest point in this direction at which you will be able to place this BreadCrumb.

11. Repeat steps 9 and 10 for any remaining BreadCrumbs.

5   BreadCrumb LX4 Firmware Upgrade

Each BreadCrumb relies on low-level software known as *firmware* for proper execution. For a BreadCrumb to communicate with other BreadCrumb devices or a BC|Commander client, the firmware version of the device must be compatible with the firmware versions of all other devices within the network, and with the version of BC|Commander running on the client computer.

Note   For procedures to install and upgrade the BC|Commander management application, refer to the latest BC|Commander User Guide.

The firmware is routinely updated by Rajant Corporation to add new product features, support new applications, and to fix reported problems. To upgrade the firmware on a BreadCrumb, you must obtain the appropriate firmware file for your BreadCrumb model from Rajant. Save the file on a computer on which the BC|Commander management application has been installed.

5.1   Over The Air Firmware Upgrade

One method of upgrading the firmware is a process called "Over-the-Air (OTA) firmware upgrade". This is a remote process, controlled and initiated by a system administrator using BC|Commander. Follow the instructions in the *BC|Commander User Guide* (Administrative Tasks – Over-the-Air (OTA) firmware upgrade) to perform the firmware upgrade process.

5.2   USB Firmware Upgrade

Another method is the USB firmware upgrade. This process takes place at the BreadCrumb's location and requires a properly prepared USB storage device. To perform the firmware upgrade process, follow these procedures:

1. Prepare a USB storage device with the appropriate firmware file using BC|Commander. Follow the instructions in the *BC|Commander User Guide* (Administrative Tasks – USB Firmware Upgrade).

2. Turn power to the BreadCrumb OFF.

3. Connect the USB storage device to the BreadCrumb's USB port.

4. Turn power to the BreadCrumb ON.

5. The firmware upgrade process will take several minutes. Observe the BreadCrumb's Status LED to monitor progress.

   (a) When the USB firmware upgrade begins, the Status LED will start blinking yellow, which indicates progress. When the process nears completion, the blink rate will increase from once per second to several times per second.

   (b) If the firmware upgrade completes successfully, the Status LED will rapidly rotate between red, green, blue, cyan, magenta, yellow and white colors.

   (c) If an error condition is encountered, the Status LED will start repeating a particular sequence of long and short blinks in red, indicating the error code. Take note of the error

code (see Appendix A for an explanation of error codes). Leaving the USB storage device connected, turn power to the BreadCrumb OFF and then ON again. Observe the Status LED to monitor progress. If, during this second firmware upgrade attempt, another error occurs, take note of the new error code and then apply for technical support.

6. When complete, turn power to the BreadCrumb OFF, disconnect the USB storage device, then turn power to the BreadCrumb back ON.

5.3   USB-Based Zerioze

As of firmware version 10.27, there is a USB-based Zeroize feature. This feature does not upgrade or in any other way affect the firmware version running on the BreadCrumb. This process takes place at the BreadCrumb's location and requires a properly prepared USB storage device. To perform the firmware upgrade process, follow these procedures:

1. Prepare a USB storage device using BC|Commander by selceting the "Zeroize (Do Not Upgrade)" option in the USB Flash Manager. Please see the *BC|Commander User Guide* (Administrative Tasks – USB-Based Zeroize) for more detailed instructions on how to properly prepare the USB storage device.

2. Turn power to the BreadCrumb OFF.

3. Connect the USB storage device to the BreadCrumb's USB port.

4. Turn power to the BreadCrumb ON.

5. The USB-based Zeroize process will take less than a minute. Observe the BreadCrumb's Status LED to monitor progress. Wait for the LED to flash error code 32 "BreadCrumb has been zeroized."

6. Turn power to the BreadCrumb OFF, disconnect the USB storage device, then turn power to the BreadCrumb back ON.

6   Troubleshooting

6.1   Sporadic Network Connectivity

Table 9: Sporadic Network Connectivity Issues.

Problem	Resolution
As a BreadCrumb device's battery approaches exhaustion, network connectivity will become sporadic for the BreadCrumb device and its associated wireless clients.	Monitory battery usage and charge/replace batteries as necessary.
Light precipitation or fog beginning after initial deployment of the BCWN can result in sudden sporadic network connectivity for BreadCrumb devices and their associated wireless clients.	Increase the density of the network by adding more BreadCrumb devices or by moving existing BreadCrumbs closer together.
As a wireless client moves around through the coverage area, LOS to the BreadCrumb device can become obstructed resulting in sporadic network connectivity for this wireless client.	Train users to maintain LOS to known BreadCrumb device locations. Place BreadCrumb devices strategically to ensure coverage of areas through which users are expected to move.
A wireless client that moves beyond the range of the BCWN will experience sporadic, and eventually complete, loss of network connectivity.	Drop more BreadCrumb devices as necessary to increase range.
A wireless client cannot join the network.	- Ensure that BreadCrumb devices are powered on. - Ensure that the wireless card in the client device (laptop) is enabled. This is usually indicated with a blinking light on the card. - Ensure that the wireless card is in "Infrastructure" or "Access Point" mode, and not in "Ad Hoc" mode. Scan for the default ESSID "breadcrumb54-v10" (or the ESSID that you set for the network) using the software accompanying your

Problem	Resolution
	wireless card. ● Ensure that the wireless client's IP address settings are configured properly. ● Ensure that the security settings on the client device and BreadCrumb devices match. ● Ensure that the client device is not prevented from connecting by an ACL. ● Ensure that the VLAN settings for the BreadCrumb allow clients of the ESSID being used to communicate to the Local Port of the BreadCrumb. See the VLAN section of the BC|Commander manual for more information.

6.2   BreadCrumb Device Cannot Connect to BCWN

Table 10: BreadCrumb to BCWN Connectivity Issues.

Problem	Resolution
Discharged batteries can cause the BreadCrumb device to appear to power up, but not be able to establish connectivity to the BCWN.	When deploying the BCWN, ensure that the batteries are fully charged.
When using external antennas, faulty cable connections or crimped cables can result in difficulty establishing and maintaining network connectivity.	Check antenna cables and their connections to the BreadCrumb device.

6.3   BreadCrumb Power and Start-Up Issues

Table 11: BreadCrumb Power and Start-Up Issues.

Problem	Resolution
Discharged external batteries can cause a BreadCrumb to appear to power up("PWR" LED is lit), but fail to start-up.	Monitory battery usage and charge/replace batteries as necessary.
Electrostatic Discharge can cause a BreadCrumb to appear to power up (Status LED indicates power is on with a white light, which can sometimes appear pale blue or pale green), but fail to start-up.	Manually reboot the device by turning off or disconnecting power to the device and turning power back on. For BreadCrumbs powered by PoE, in order to avoid sparking and possible damage to the device, be sure to connect the powered Ethernet cable to the BreadCrumb **before** applying power to the power supply.
Rapid power cycling can cause a BreadCrumb JR to appear to power up ("PWR" LED is lit) but fail to start-up.	Turn off power to the device, wait at least 10 seconds and turn power back on. The BreadCrumb should start-up normally.
Connecting a cable assembly which has an active power source (like a battery pack) to a BreadCrumb JR can cause the power to fluctuate at startup if it is connected with an unsteady hand. This can cause the BreadCrumb to appear to power up ("PWR" LED is lit), but fail to start-up.	• Disconnect the cable assembly, wait 10 seconds, and try to make the connection again more smoothly. • Try connecting the cable assembly to the BreadCrumb **before** connecting or applying power to the power supply.

Appendix A: Error and Warning Codes

All possible BreadCrumb error and warning codes are listed below:

JR/LX/LX3/ME3/UX2400 Firmware Upgrade Codes (1*).

> 11 – Flash image file does not exist.
>
> 12 – Current flash image version is greater than versions of files found on USB drive.
>
> 13 – No flash image files found.
>
> 14 – Unable to mount USB drive.
>
> 15 – Unlocking of /dev/mtd0 failed.
>
> 16 – fconfig for SetFailsafeBoot failed.
>
> 17 – Unlocking of /dev/mtd0 failed.
>
> 18 – fconfig for SetMainBoot failed.
>
> 19 – Copying of zImage failed.
>
> 111 – Copying of ramdisk failed.
>
> 112 – FIS directory update of ramdisk failed.
>
> 113 – Copying of etc failed.
>
> 114 – FIS directory update of /etc failed.
>
> 115 – Copying failed.
>
> 116 – flashunbundle failed.
>
> 117 – Version information in flash file name and breadcrumb-buildinfo.conf do not match.
>
> 1171 – Platform information in flash file name and breadcrumb-buildinfo.conf do not match.
>
> 118 – Untar failed.
>
> 119 – FIS directory update of kernel failed.
>
> 121 – Failed to unmount /etc.
>
> 122 – In Failsafe mode, but no USB drive detected.
>
> 123 – BreadCrumb will be in failsafe mode and unable to communicate with other BreadCrumbs after next reboot.
>
> 124 – Failed to suspend bcconfigd.
>
> 125 – Failed to set boot path to next image.
>
> 126 – Failed to erase end of next file system image.
>
> 127 – Failed to copy file system image.
>
> 128 – Failed to checksum file system image.

129 – Failed to create directory for next file system image.

131 – Failed to mount next file system image.

132 – Failed to create directory for settings.

133 – Failed to copy current settings to next file system image.

134 – Failed to unmount next file system image.

135 – Failed to mount /etc.

141 – Error retrieving flash file.

ME2 Firmware Upgrade Codes (2*)

21 – Flash image file does not exist.

22 – Current flash image version is greater than or equal to versions of files found on the USB drive.

23 – No flash image files found.

24 – Unable to mount USB drive.

25 – Kernel corrupted.

26 – FS corrupted.

27 – Unmounting of old root file system failed.

28 – Mounting of USB drive failed.

29 – flashunbundle failed.

211 – Version information in flash file name and breadcrumb-build info.conf do not match.

212 – In Failsafe mode, but no USB drive detected.

Self-Test Codes (3*)

31 – Hardware configuration not set. Factory initialization required.

311 – InstaMesh license update required.

32 – BreadCrumb has been zeroized.

321 – BreadCrumb is being zeroized.

33 – Radio not detected. Turn the unit off, and then back on. If the problem persist, contact technical support.

333 – Low Battery.

334 – Gas gauge not initialized. Please fully charge unit turned off to initialize.

34 – Cannot read /dev/nand6 information, or cannot resize or format /dev/nand6.

36 – Hardware monitor missing.

37 – Failed to add ethernet port to bridge.

38 – Resetting radio due to error.

FIPS Codes (4*)

41 – FIPS self-tests failed.

411 – OpenSSL FIPS vector test programs not found.

412 – OpenSSL FIPS vector test hash mismatch.

413 – 802.11i AES-CCMP test vectors failed.

414 – Unable to use FIPS CCMP encryption.

415 – Kernel integrity check failed.

416 – Filesystem integrity check failed.

42 – Mixed SecNet/Non-SecNet configuration.

43 – Rekeying error.

44 – Rekeying error.

45 – Rekeying error.

46 – Rekeying error.

47 – Rekeying error.

48 – Rekeying error.

49 – Rekeying error.

431 – Rekeying error.

432 – Rekeying error.

433 – Rekeying error.

434 – Rekeying error.

435 – Rekeying error.

436 – Rekeying error.

441 – Status override CPLD feature not available (wrong CPLD version).

Fatal Codes (5*)

51 – instamesh fatal error.

52 – hostapd fatal error.

53 – cvm fatal error.

54 – fatal error.

55 – Low memory - automatic reboot scheduled.

UX Battery Fault Codes (51*)

See BC|Commander System Alerts for more detailed information.

511 – Pack 1: does not exist|charge fault|charge gauge fault|discharge fault.

512 – Pack 2: does not exist|charge fault|charge gauge fault|discharge fault.

513 – Pack 3: does not exist|charge fault|charge gauge fault|discharge fault.

514 – Pack 4: does not exist|charge fault|charge gauge fault|discharge fault.

515 – Pack 5: does not exist|charge fault|charge gauge fault|discharge fault.

516 – Pack 6: does not exist|charge fault|charge gauge fault|discharge fault.

Battery Gas Gauge Codes (6*)

61 – Battery gas gauge i2c device could not be found.

62 – Incorrect gas gauge revision 1 EEPROM settings.

63 – Incorrect gas gauge revision 2 EEPROM settings.

64 – Incorrect gas gauge revision 3 EEPROM settings.

65 – Unknown gas gauge revision.

66 – Incorrect ME3 gas gauge revision 0 EEPROM settings.

67 – Internal battery charger disabled.

Other Codes (7*)

71 – Host flapping detected.

72 – Critical I2C failure.

81 – <Username>@<IP address> issued reboot on <date> <time>

Appendix B: GNU General Public License

Version 2, June 1991

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Appendix C: Using Pole Mount Bracket

1. Use the supplied four bolts to attach the mounting bracket to the LX4.

2. Use the U-Bolts to attach LX4 Pole Mount Bracket to a pole.

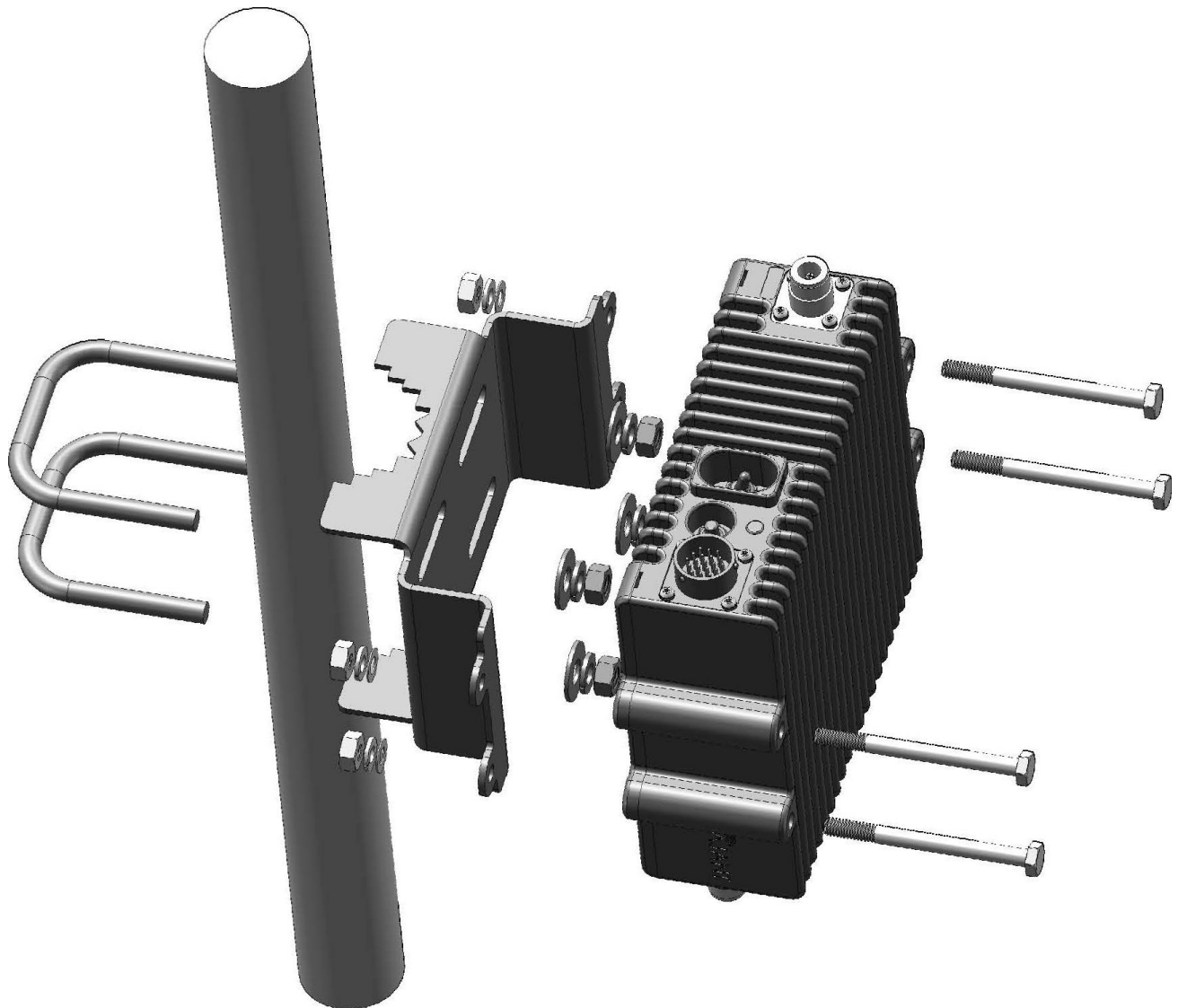3. Tighten the four (4) nuts on the two (2) U-Bolts to secure the LX4 assembly to the pole.

Figure 8: LX4 Pole Mount Bracket with U-Bolts.