WaveRider®
The World's Wireless Web Company

LMS4000

900 MHz Radio Network

User Guide

APCD-LM043-4.0

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This equipment has been tested and found to comply with the limits for a Class B Intentional Radiator, pursuant to Part 15 of the FCC Regulations and RSS-210 of the IC Regulations. These limits are intended to provide protection against harmful interference when the equipment is operated in a residential environment.

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

Notice to User

Any changes or modifications to equipment that are not expressly approved by the manufacturer may void the user’s authority to operate the equipment.

Contents

Figures

Tables

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Preface

About this Manual

WaveRider recommends that you read the following sections before proceeding with the instructions in this guide:

- *Software License Agreement* on page ii
- *Warranty* on page iv
- *Warnings and Advisories* on page xvii
- *Conventions* on page xv

> **NOTE:** The information contained in this manual is subject to change without notice. The reader should consult the WaveRider web site for updates.

The procedures in this document are centered around the command-line interface (CLI). For information about configuring and operating the CCU and EUM using the WaveRider Configuration Utility refer to the *CCU/EUM Configuration Utility User Guide* (APCD-LM030).

Conventions

The following conventions are used throughout this document:

WARNING!

Whenever you see this icon and heading, the associated text addresses or discusses a critical safety or regulatory issue.

CAUTION: Whenever you see this icon and heading, the associated text discusses an issue, which, if not followed, could result in damage to, or improper use of, the equipment or software.

TIP: Whenever you see this icon and heading, the associated text provides a tip for facilitating the installation, testing, or operation of the equipment or software

Regulatory Notices

This device has been designed to operate with several different antenna types. The gain of each antenna type shall not exceed the maximum antenna system gain as given in Appendix D on page 181. Antennas having a higher gain are strictly prohibited by Industry Canada and FCC regulations. The required antenna impedance is 50 ohms.

Industry Canada

CCU and EUM

The IC Certification Number for the CCU and EUM is 3225104140A.

Operators must be familiar with IC RSS-210 and RSS-102. The CCU and EUM have been designed and manufactured to comply with IC RSS-210 and RSS-102.

Federal Communications Commission

CCU and EUM

The CCU and EUM have been designed and manufactured to comply with FCC Part 15.

Operators must be familiar with the requirements of the FCC Part 15 Regulations prior to operating any link using this equipment. For installations outside the United States, contact local authorities for applicable regulations.

The FCC ID for the CCU and EUM equipment is OOX-LMS3000.

The transmitter of this device complies with Part 15.247 of the FCC Rules.

The CCU and EUM (with outdoor antenna only) must be professionally installed.

Interference Environment

Operation is subject to the following conditions:

- This device may not cause harmful interference and,
- This device must accept any interference received, including interference that might cause undesired operation.

Operational Requirements

CCU and EUM

In accordance with the FCC Part 15 regulations:

1. The maximum peak power output of the intentional radiator shall not exceed one (1) watt for all spread spectrum systems operating in the 902 to 928 MHz band. This power is measured at the antenna port of the CCU or the EUM.
2. Stations operating in the 902 to 928 MHz band may use transmitting antennas of directional gain greater than 6 dBi, provided the peak output power from the intentional radiator is reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

NOTE: The gains referred to in point 2 are with respect to the total antenna system gain.

3. The operator of a spread spectrum system and the user of the radio device are each responsible for ensuring that the system is operated in the manner outlined in *Interference Environment* on page xvi.

Warnings and Advisories

General Advisory

Operator and maintenance personnel must be familiar with the related safety requirements before they attempt to install or operate the LMS4000 equipment.

It is the responsibility of the operator to ensure that the public is not exposed to excessive Radio Frequency (RF) levels. The applicable regulations can be obtained from local authorities.

Do not operate the CCU or EUM without connecting a 50-ohm termination to the antenna port. This termination can be a 50-ohm antenna or a 50-ohm resistive load capable of absorbing the full RF output power of the transceiver.

WARNING!

The LMS4000 external antennas must be professionally installed and properly grounded. Antennas and associated transmission cable must be installed by qualified personnel. WaveRider assumes no liability for failure to adhere to this recommendation or to recognized general safety precautions.

WARNING!

To comply with FCC RF exposure limits, the antennas for the CCU must be fix-mounted on outdoor permanent structures to provide a separation distance of 2 m or more from all persons to satisfy RF exposure requirements. The distance is measured from the front of the antenna to the human body. It is recommended that the antenna be installed in a location with minimal pathway disruption by nearby personnel.

The antennas for the EUM must be fix-mounted, indoors or outdoors, to provide a separation distance of 20 cm or more from all persons to satisfy RF exposure requirements. The distance is measured from the front of the antenna to the human body. Again, it is recommended that the antenna be installed in a location with minimal pathway disruption by nearby personnel.

CAUTION: There is a DC signal of 5-7.5 V (current limited to 5 mA) on the Antenna Output of the EUM. Antennas or RF test equipment must be able to accept this DC signal or have a device to block the DC signal. Otherwise, the antenna, test equipment, and/or the EUM may be damaged.

Customer Support

If you have any problems with the instructions in this manual, please contact WaveRider Communications Inc.

Telephone: +1 416–502–3161

Fax: +1 416–502–2968

Email: **Customer Services Group:**
techsupport@waverider.com

Customer Documentation Feedback and Comments:
customerdocs@waverider.com

URL: www.waverider.com

WaveRider offers a complete training program. Please contact your sales representative for training information.

1 Introduction

The LMS4000 system provides 900MHz and 2.4GHz wireless. high-speed Internet connectivity to business and residential subscribers. This manual, which is specific to the LMS4000 900MHz Radio Network, provides the following information:

- A detailed description of the operation of the hardware and software
- Guidelines for planning and designing your network
- Instructions for configuring, installing the 900MHz radio modem, monitoring, maintaining and troubleshooting
- Support information that you may find useful for operating your network

TIP: The installation of other LMS4000 network equipment is described in *LMS4000 Installation Guide*, which can be obtained from WaveRider.

The LMS4000 900MHz Radio Network, which operates in the 900MHz ISM band, offers the following features and benefits:

- **Excellent Propagation Characteristics:** LMS4000 900MHz radio networks provide excellent coverage to non-line of sight installations using WaveRider's proprietary indoor diversity antenna and extended coverage to installations using external high-gain antennas.The 900MHz ISM band is more suited to NLOS (non-line of sight) wireless Internet applications than other ISM bands because it has superior propagation performance, demonstrating the following benefits:
    - Lower free-space, cable and foliage loss
    - Better wall and glass penetration
    - More signal recovery from diffraction and reflection
- **High-speed Channel:** The LMS4000 900MHz Radio Network provides a raw channel bit rate of 2.75Mbps, which translates to peak FTP rates of 2Mbps.
- **High-performance Polling MAC:** WaveRider's patented Polling MAC algorithm takes advantage of typical usage patterns found in Internet transactions, such as Web browsing and email, to provide an operating capacity of up to 300 end users per RF

channel. Even with large numbers of subscribers, end users generally perceive that they have the entire channel to themselves.

- **Grade of Service Support:** The Polling MAC supports up to four end-user grades of service, which allows the system operator to segment service offerings for those users that demand and are willing to pay for higher grades of service, and those that are only willing to pay for a more basic grade of service.
- **License-free Radio Bands:** The main advantage of using the ISM band is that you need not apply to the FCC or Industry Canada for an operating license. This freedom reduces your time to market and the effort and high cost associated with obtaining a license.
- **Robust Hardware and Software:** LMS4000 hardware and software have been rigorously tested in lab and field environments. The hardware, which is mechanically robust, works over a broad range of temperatures and operating conditions. The software is equally robust and has been designed to recover automatically from unplanned events and abnormal operating conditions.
- **Simple End-user Modem Configuration:** The end-user modem is very easy to configure. Normally, operators pre-configure the EUM prior to field deployment, so they can maintain control over their network.
- **Simple End-user Modem Installation and Operation:** It is very easy to install and operate the EUM. So easy, in fact, that when the installation is based on the WaveRider indoor diversity antenna, the end user should be able to install and operate the modem with no involvement from the network operator. This simplicity saves the network operator the cost and inconvenience of having to visit the end-user's premises. The EUM uses a standard Ethernet interface which means the EUM and the antenna can be located up to 100 m from the end-user's PC.
- **Flexible Network Topology:** The LMS4000 900 MHz Radio Network has a flexible topology, allowing it to line up with the operator's existing Internet points of presence and site facilities. As well, LMS4000 supports the following connections:
    - Connection between the end-user modem and the Internet through the network operator's gateway router
    - Direct connection between end-user modems through the LMS4000 900 MHz channel units (CCUs), if the CCU is configured to support this routing
    - Connection between end-user modems on different, but colocated, CCUs if these routes are configured in the CCU routing tables
- **DHCP Relay:** CCUs support DHCP relay, which, once enabled, allows end-user PCs to automatically obtain their IP and DNS server addresses from the network operator's DHCP servers. DHCP relay simplifies the EUM installation even further and makes it even easier for the modem to be installed by the end user.
- **End-user Registration:** All end user modems automatically transmit a registration request to the LMS4000 system so they can access the wireless network. They can only register if the network operator has authorized them in the CCU. This registration guarantees that only approved subscribers can gain access to LMS4000 wireless services.
- **Remote System Configuration and Diagnostics:** The network operator can configure and monitor CCUs and EUMs from anywhere. This remote access allows the operator to make configuration changes, download new features, and diagnose problems remotely without having to visit distant network sites or end-user premises.

- **SNMP Support:** Using WaveRider-supplied SNMP MIBs, network operators can integrate the LMS4000 with their existing network management system to allow monitoring of CCUs and EUMs from an existing and/or centralized SNMP manager. Once SNMP is configured, the operator can monitor system events, parameters, and statistics in real time. Statistics can be processed in the SNMP manager to provide alarms, trend data, graphical outputs, and derived performance data.
- **Channel Redundancy (optional):** Optional CCU redundancy, which can be ordered from WaveRider, improves LMS4000 system reliability, and reduces or eliminates down time if a CCU fails. This redundancy eliminates interruption of service to the end users and reduces the urgency for getting to the CCU site to replace the failed CCU.
- **Accurate Time Stamping (SNTP):** The CCUs and EUMs can be programmed to synchronize their internal clocks with one or more NTP servers. Time stamping enables all logged events in the CCUs and EUMs to be correlated with events that have taken place at other locations in the network or with events logged by equipment installed outside the network, if this equipment is equipped with accurate time-stamping. Accurate time-stamping facilitates diagnosis of complex network problems.
- **Field-replaceable Equipment:** In the event of an equipment failure, LMS4000 components are easily replaced with minimal or no disruption to the operation of other components.
- **System Upgradability:** The LMS4000 network architecture supports orderly growth from simple installations, through single-CCU CAP (Communication Access Point) sites and multi-CCU CAP sites, to multi-CAP networks.
- **Port Filtering:** The LMS4000 network operator can configure CCUs and EUMs to filter IP packets on specific TCP and UDP ports to improve network performance, security, and privacy.
- **Low Maintenance:** CCUs and EUMs require no routine maintenance, other than maintenance of their operating environments within the specified temperature and humidity range.
- **Extensive Installation, Maintenance and Diagnostic Support:** The CCU and EUM are equipped with a wide range of features and utilities to facilitate unit installation, operation, maintenance, monitoring, and diagnostics:
    - Visual status indicators on all units
    - Simple-to-use command-line interface, offering full unit configuration capability
    - Windows-based EUM configuration and installation utilities
    - RSSI (receive signal strength indication) output, to simplify antenna pointing and performance measurement
    - Ability to remotely FTP files to and from CCUs and EUMs
    - Wide range of operating and performance statistics
    - SNMP support
    - Simple and reliable field-upgrade process
    - Remote download of equipment configuration files to CCUs and EUMs

Your decision to implement an LMS4000 900MHz Radio Network enables you to deliver high-quality, high-speed wireless Internet service to the business and residential subscribers in your serving area.

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2 Quick Startup

This section outlines the procedure for setting up a very simple LMS4000 900 MHz radio network consisting of one CCU and one EUM. This simple network, which can be set up in a lab environment, helps you become familiar with basic LMS4000 configuration and operation. As you become more confident and are ready to progress to customer installations, WaveRider recommends you read the other sections in the manual.

Quick Startup uses static IP addresses for the purpose of simplicity, even though the CCU and EUM support DHCP relay.

2.1 Equipment

As a minimum, the Quick Startup requires the following equipment:

one CCU kit, consisting of

- CCU
- CCU power supply and cable
- CCU setup antenna

one EUM kit, consisting of

- EUM
- EUM power supply and cable
- 3 m CAT5 crossover Ethernet cable

one PC, equipped with terminal emulation software such as HyperTerminal and an Ethernet network interface card

one WaveRider indoor antenna, complete with mounting bracket and RF cable

one Straight-through RS-232 serial cable, DB-9 male to DB-9 female

2.2 Equipment Setup

1. Remove the equipment from the boxes and set up the physical configuration shown in Figure 1. Use this setup procedure to configure the CCU, while keeping the following points in mind:
   - Maintain the order of installation shown in Figure 1.
   - Maintain at least 3 to 5 meters of physical separation between CCUs and EUMs.
   - Ensure the paths between the CCU and EUMs are relatively free from obstruction.

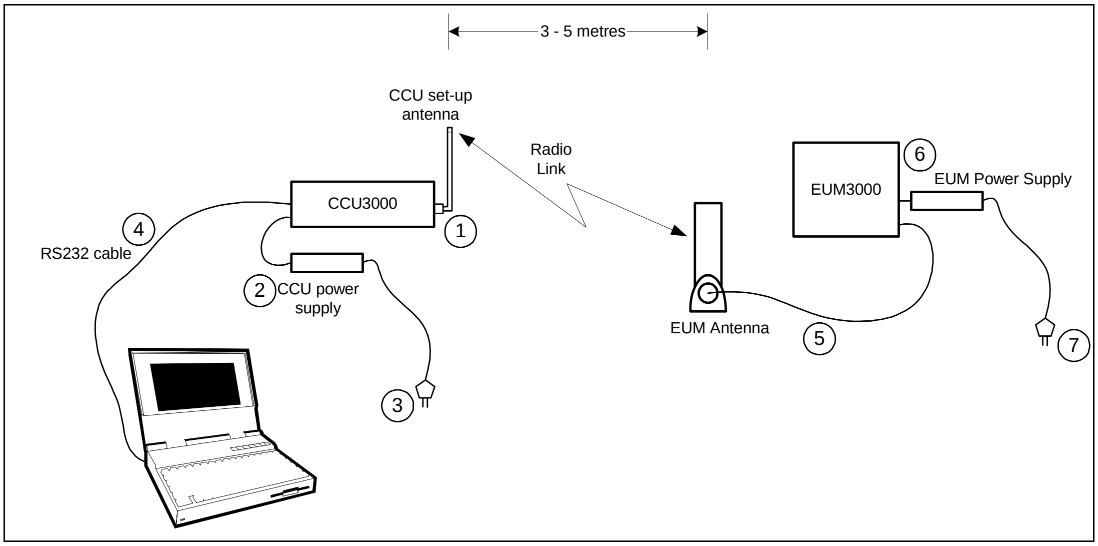


Figure 1 Quick Startup — CCU Configuration

CAUTION: Always make sure that you connect the antenna to the CCU or EUM before you apply power to the unit.

2. Configure your PC terminal emulation software as shown in Table 1.

Table 1 Console Settings

Bits per second	9600
Data bits	8
Parity	None
Stop bits	1
Flow Control	None

2.3 CCU Configuration

1. Start the PC terminal emulation software. You will receive the following prompt:

```
WaveRider Communications, Inc. LMS3000
Password:
```

   The default password is a carriage return.

```
Console>
```

   The default prompt on your CCU is the CCU Ethernet MAC address.

2. Type the following commands to configure the CCU:

```
Console> ip ethernet 192.168.10.10 24
Console> ip radio 10.0.0.1 22
Console> ip gateway 192.168.10.1
Console> radio frequency 9150
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved
```

3. Reboot the CCU for the changes to take effect.

```
Console> reset
rebooting CCU ...

(... Power On Self Test ...)

WaveRider Communications, Inc. LMS3000
Password:
```

TIP: If you want to connect the Quick Setup to the Internet as outlined in *Connecting the Quick Startup to the Internet* on page 11, obtain the CCU gateway IP address from your network administrator. You can then set the CCU Ethernet IP address to any IP address in the subnet.

4. Confirm the CCU has been properly configured, as follows:

```
Console> ip
Ethernet IP Address: 192.168.10.10
Ethernet Net Mask  : ffffff00
Gateway IP Address: 192.168.10.1
Radio IP Address: 10.0.0.1
Radio Net Mask  : fffffc00
Console> radio
RF Power: HIGH
Radio Frequency: 9150
Console>
```

2.4 EUM Configuration

1. Connect the PC to the console port of the EUM, as shown in Figure 2.

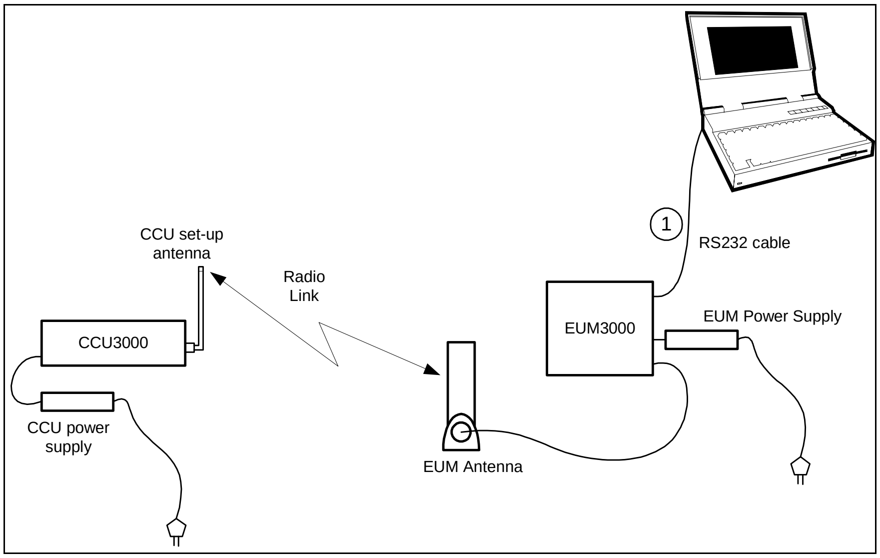


Figure 2 Quick Startup — EUM Configuration

2. Start the terminal emulation software.
3. Type the following commands to configure the EUM:

```
WaveRider Communications, Inc. LMS3000
Password:
Console> ip ethernet 10.0.0.2 22
Console> ip gateway 10.0.0.1
Console>
Console> radio frequency 9150
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Console>
```

4. Reboot the EUM for the settings to take effect.

```
Console> reset
rebooting EUM ...

(... Power On Self Test ...)

WaveRider Communications, Inc. LMS3000
Password:
```

5. Confirm that the EUM has been properly configured, as follows:

```
Console> ip
Ethernet/USB IP Address: 10.0.0.2
Ethernet/USB Net Mask  : fffffc00
Gateway IP Address: 10.0.0.1
Console> radio
RF Power: HIGH
Radio Frequency: 9150
Console>
```

2.5 Testing CCU–EUM Communications

Once you have completed the configuration of the Quick Startup, you can test communications between the CCU and the EUM by pinging the CCU through the EUM console port.

To Run a Ping Test Through the EUM Console Port

1. Connect the PC to the EUM console port, as shown in Figure 3.

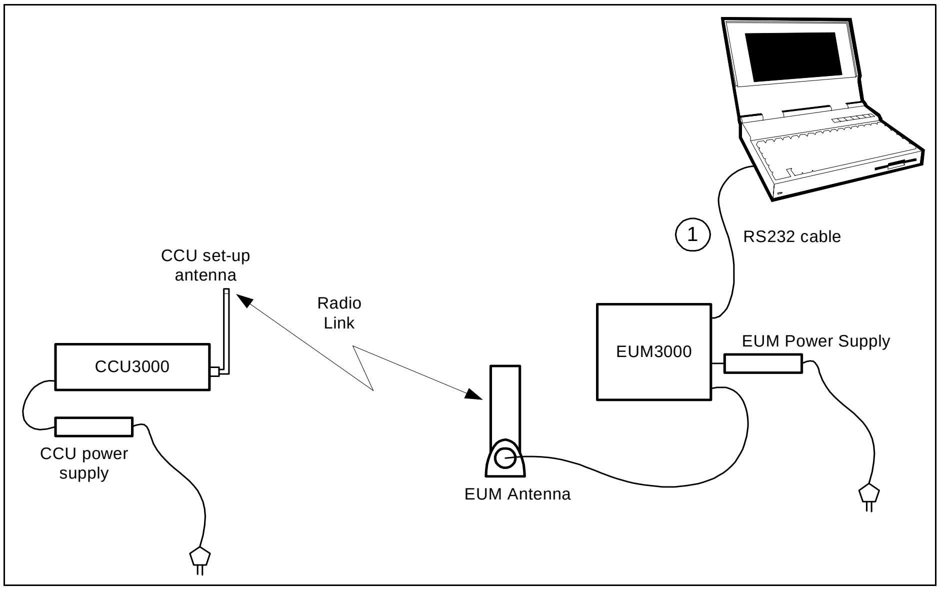


Figure 3 Quick Startup — Ping Test (from console port)

2. From the EUM, ping the CCU radio port (IP address 10.0.0.1), as follows. Press any key to stop.

```
console>
console> ping 10.0.0.1
Press any key to stop
PING 10.0.0.1: 56 data bytes
64 bytes from 10.0.0.1: icmp_seq=1. time=112. ms
64 bytes from 10.0.0.1: icmp_seq=2. time=48. ms
64 bytes from 10.0.0.1: icmp_seq=3. time=48. ms
64 bytes from 10.0.0.1: icmp_seq=4. time=32. ms
64 bytes from 10.0.0.1: icmp_seq=5. time=32. ms
```

```
64 bytes from 10.0.0.1: icmp_seq=6. time=16. ms
64 bytes from 10.0.0.1: icmp_seq=7. time=64. ms
64 bytes from 10.0.0.1: icmp_seq=8. time=64. ms
----10.0.0.1 PING Statistics----
8 packets transmitted, 8 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 16/52/112

console>
```

This test verifies the radio link between the EUM and the CCU.

To Run a Ping Test Through the EUM Ethernet Port

1. Connect the PC to the EUM Ethernet port, as shown in Figure 4.

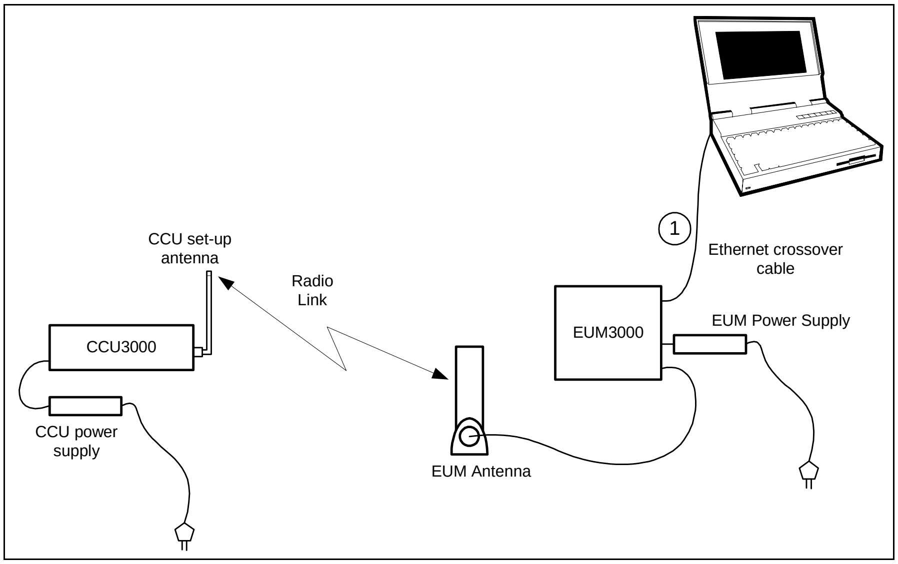


Figure 4 Quick Startup — Ping Test (from EUM Ethernet port)

2. Open the **TCP/IP Properties** window in the PC. If you are not sure how, consult your operating system manual.
3. Select *Use the following IP address* (or *Specify an IP address*—the exact wording depends on your operating system). Enter the following:
    - IP Address 10.0.1.2
    - Subnet Mask 255.255.252.0
    - Default Gateway10.0.0.1
4. From the PC, progressively ping the PC Ethernet port (10.0.1.2), the EUM (10.0.0.2), and the CCU radio (10.0.0.1) and Ethernet (192.168.10.10) ports.

2.6 Connecting the Quick Startup to the Internet

Once you have verified that the CCU and EUM are communicating properly, you may want to to connect the Quick Startup system to the Internet.

To Connect to the Internet

1. Connect the PC to the Ethernet port of the EUM as shown in Figure 5.

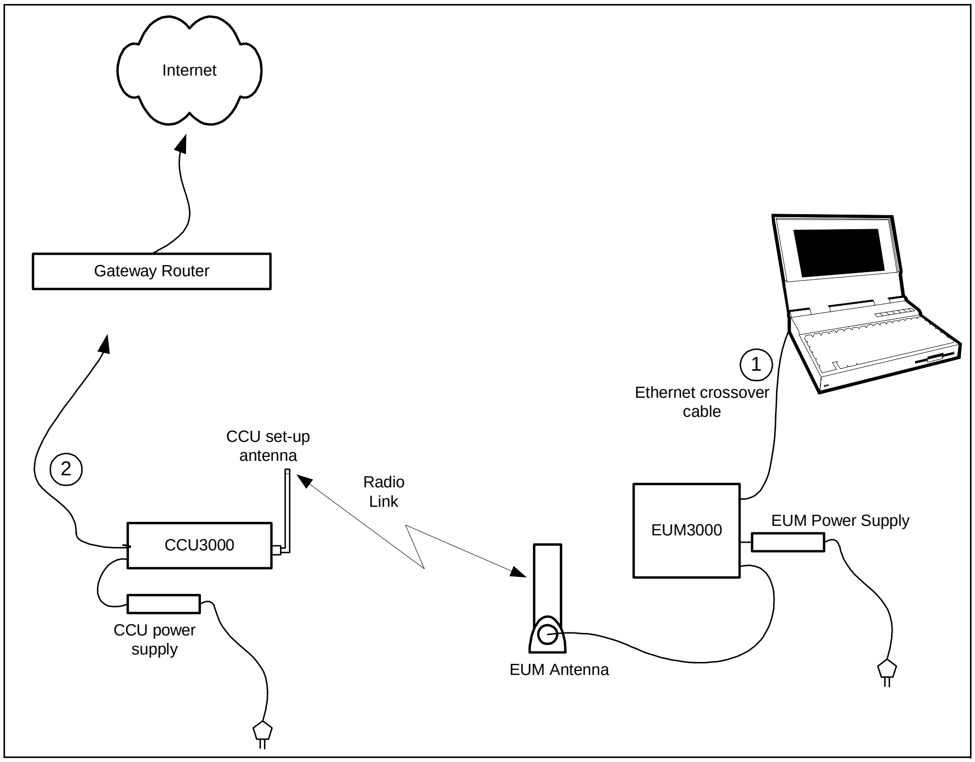


Figure 5 Quick Startup — Connecting to the Internet

TIP: If you want to connect the Quick Setup to the Internet, you must obtain the CCU gateway IP address from your network administrator. The CCU Ethernet IP address can then be set to any IP address in the subnet.

2. If you have not already configured the PC IP address as outlined in *Testing CCU–EUM Communications* on page 9, open the **TCP/IP Properties** window in the PC. If you are not sure how, consult your operating system manual.

3. Select *Use the following IP address* (or *Specify an IP address*; the exact wording depends on the operating system), and enter the following:
   - IP Address 10.0.1.2
   - Subnet Mask 255.255.252.0
   - Default Gateway10.0.0.1

4. Select *Use the following DNS server address* (the exact wording depends on your operating system), and enter the IP address for the *Preferred DNS Server,* which is available from your Network Administrator.
5. Connect the CCU Ethernet port to the appropriate network switch or hub, or directly to the gateway router of your network.
6. From the PC, you should now be able to open your browser and surf the Web.

2.7 Adding more EUMs to the Quick Startup

You can add other EUMs and PCs to the Quick Startup system. At all times, try to maintain at least 3 to 5 m (10 to 15 ft.) separation between the EUMs, and between the EUMs and the CCU.

Other EUMs are added in the same way as the first EUM, using the same gateway IP address (10.0.0.1), subnet masks (255.255.252.0), and the following EUM and PC IP addresses:

Table 2 Quick Startup — EUM Addresses

EUM Number	EUM IP Address	PC IP Address
2	10.0.0.3	10.0.1.3
3	10.0.0.4	10.0.1.4
4	10.0.0.5	10.0.1.5
5	10.0.0.6	10.0.1.6
6	10.0.0.7	10.0.1.7

3 Detailed Description

This section describes the technologies and features used in the LMS4000 900 MHz Radio Network.

3.1 LMS4000 Overview

Figure 6 is a high-level schematic of the LMS4000 system, showing the key system components and interfaces.

As shown, each LMS4000 component is associated with one of three major system entities:

- End-user Modem (EUM)
- Communications Access Point (CAP)
- Network Access Point (NAP)

End-user Modem or Customer-premises Equipment

The EUM equipment is installed at the end-user's premises. It provides an interface to the customer's computer or local area network on one side and wireless access to the LMS4000 network on the other.

Communications Access Point (CAP)

The CAP is the collection and distribution point for data travelling to and from the EUMs. In the EUM-to-network direction, the CAP aggregates the data from the radio channels into a single data stream, which is passed either directly or over a backhaul facility to the Network Access Point.

In the Internet-to-EUM direction, the CAP receives data from the Network Access Point and distributes this data to the appropriate radio channels for transmission to the EUMs over the 900 MHz radio link.

Network Access Point (NAP)

The NAP provides the Internet connection point for one or more CAPs. An LMS4000 system can have more than one NAP. The number of NAPs depends on the geographical layout of the LMS4000 system and the location of available Internet access points. A single NAP can provide Internet connection for one CAP, or several CAPs, each either colocated with the NAP or connected to the NAP over backhaul facilities.

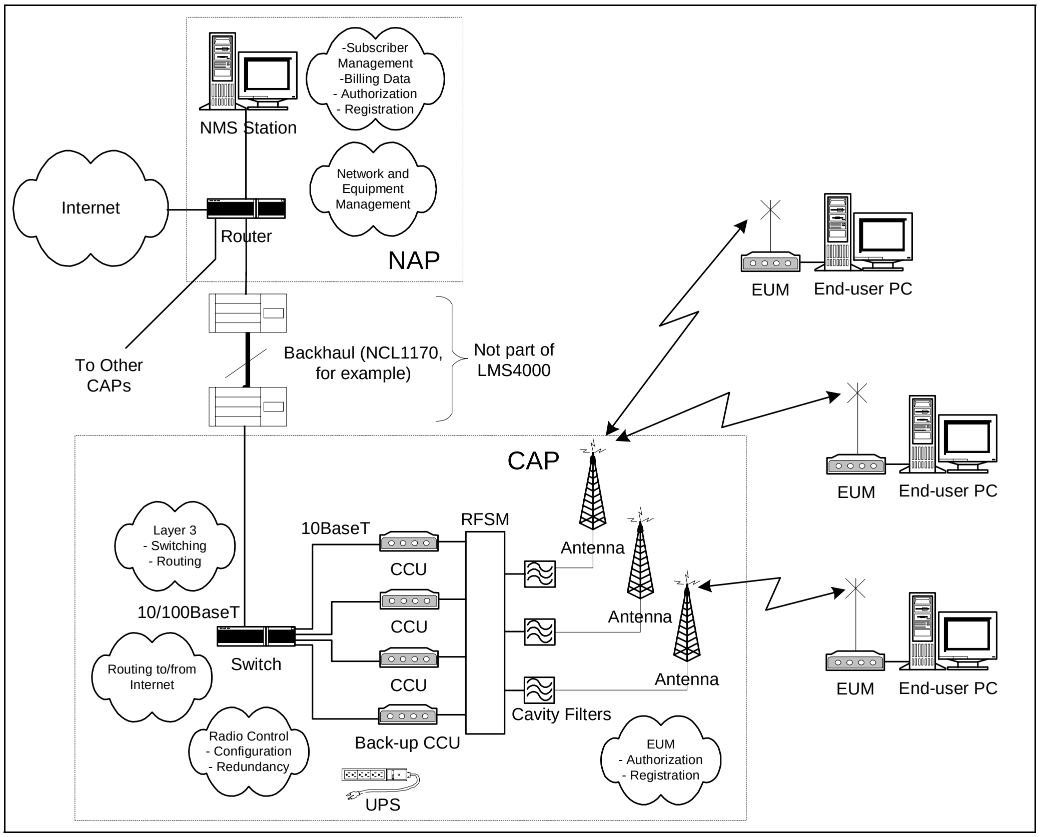


Figure 6 LMS4000 System

The following sections discuss the operation of the LMS4000 900 MHz Radio Network, of which the CCU and EUM are the key components.

3.2 Communications Access Point

3.2.1 Key Components

The following are key components of the Communication Access Point:

- CCU
- Cavity filters
- Lightning arrestors

- Transmission line
- Antenna
- Ethernet switch

Each of the above components is discussed in the following sections.

CCU

The CCU, shown in Figure 7, is the wireless access point for up to 300 end-user modems. The functional blocks of the CCU are illustrated in Figure 8.

Figure 7 CCU

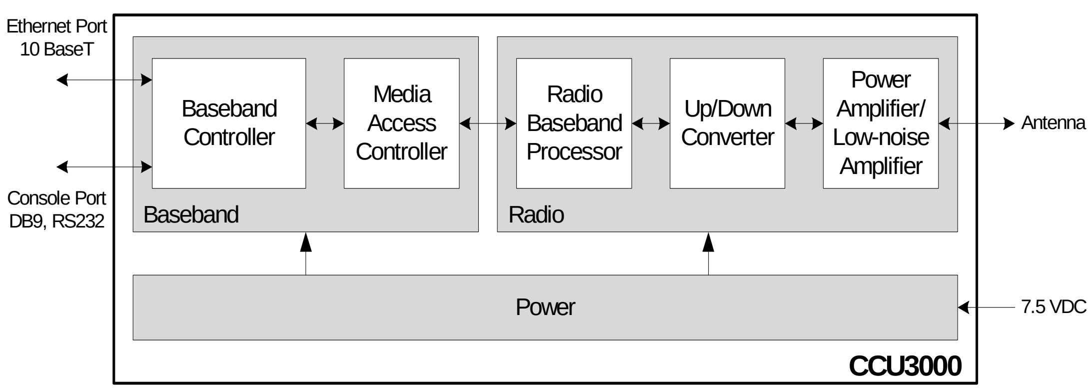


Figure 8 CCU Functional Blocks

The CCU routes IP packets received from the CCU radio port

- to internal CCU processes,
- through the CCU Ethernet port to any router on the Ethernet network, such as the Network Access Point, or
- back out the radio port to other EUMs (EUM-to-EUM packets).

The CCU routes IP packets that are received from the Network Access Point through the Ethernet port

- to internal CCU processes, or
- through the radio port to the destination EUM.

The CCU can be installed in a standalone configuration, or in a CCU shelf, as shown in Figure 9, with other operating and backup CCUs. The CCU is powered by an AC/DC power supply, which can also stand alone or be installed in the CCU shelf. The CCU operates independently of other CCUs and can be swapped out without interrupting the operation of other CCUs.

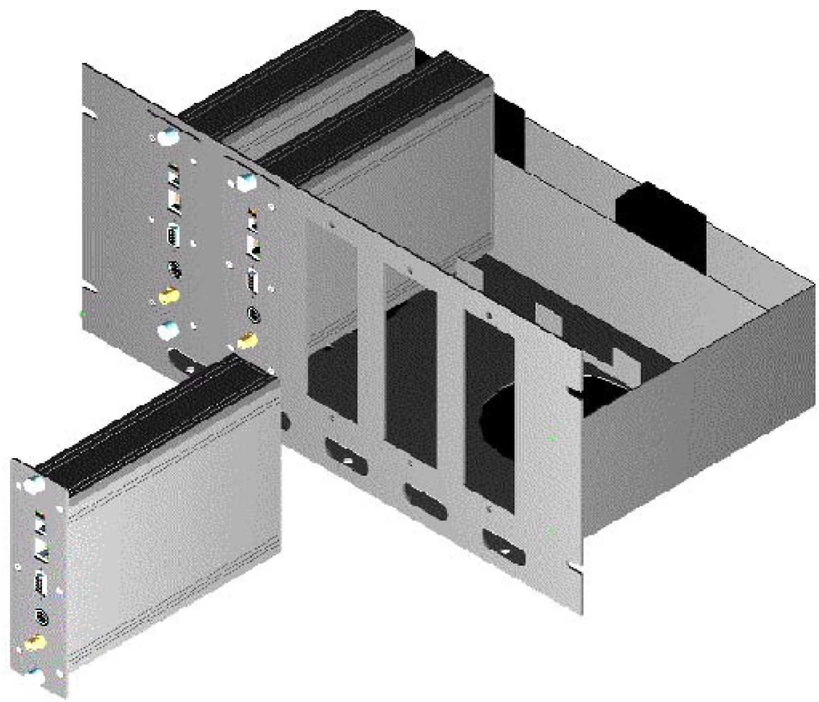


Figure 9 CCU Shelf

Up to four CCUs can be installed at the same CAP, as follows:

- Up to three operating CCUs, each with its own cavity filter, lightning protector, transmission line, and antenna.
- One backup CCU, if CCU redundancy is provisioned. Since the backup CCU is “switched” into the RF circuit of the failed CCU, by the RFSM, it does not require its own cavity filter, lightning protector, transmission line or antenna.

The CCU comes with a setup antenna, which can be used during CCU configuration and test, prior to deployment.

Cavity Filters

WaveRider recommends the use of cavity filters with all CCUs and is mandatory if colocated with other CCUs. Cavity filters help to isolate the CCU from inband interferers, such as colocated CCUs or non-WaveRider ISM band equipment, as well as out-of-band interferers, such as cellular base stations and paging transmitters.

Lightning Arrestors

Since the CCU antenna is mounted outdoors, lightning arrestors are required with all CCU installations. Lightning arrestors divert most of the energy from a lightning strike away from the RF transmission line and equipment, to a bonded ground point. The lightning arrestor is installed in series with the RF transmission line, as close as possible to the point where the transmission line enters the building.

Transmission Line

A good quality RF transmission line should always be used to connect the CCU to the antenna. “Good quality RF transmission line” means one that is weather resistant and UV-protected, and that has low attenuation characteristics. All connectors in the transmission line should be wrapped to prevent water penetration. Connecting the CCU to the transmission line requires RF jumper cables, available from WaveRider.

Antenna

Each active CCU requires its own antenna. Antennas can be omnidirectional or have a sectored beam pattern (for example, 180, 120, or 90 degrees). The choice of antenna is be based on site and RF engineering considerations, and FCC and Industry Canada guidelines, which are summarized in Appendix D on page 185.

Ethernet Switch

An Ethernet switch is required at the CAP if it is provisioned with more than one CCU, or to interface with certain types of backhaul equipment.

3.2.2 Optional Components

The following Communications Access Point components are optional:

- RFSM
- RF Distribution Panel

RFSM

The optional RFSM (RF Switch Matrix), shown in Figure 10, is required if CCU redundancy is provisioned. The RFSM monitors the health of the operating CCUs. If a CCU fails, the RFSM switches to a provisioned backup CCU, which is automatically programmed with the same settings as the failed CCU. In this way, the CAP can be provisioned for N+1 redundancy, meaning there is one backup CCU for ‘N’ operating CCUs, up to a maximum of N=3.

Figure 10 RFSM

RF Distribution Panel

The optional RF Distribution Panel provides

- external interface to the antenna subsystem and site ground,
- common surge protector mounting point for each external RF interface, and
- common ground point for all CAP components.

Other Optional CAP Equipment

Depending on your configuration and operational requirements, you may require other components in your LMS4000 CAP, such as a UPS system, CCU Shelf, or free-standing 19–inch rack.

The CCU Shelf is a standard 19-inch mounting rack with an integrated power supply fan and cooling fans. It contains five CCU slots, for up to three operating CCUs, a backup CCU, and backhaul CCU.

These optional components can be ordered through WaveRider.

3.3 Customer-premises Equipment

3.3.1 Key Components

The following Customer-premises Equipment components are key:

- EUM
- EUM antenna
- Transmission line
- Lightning arrestor

3.3.2 EUM

The EUM, shown in Figure 11, is a wireless modem that connects to the end-user's computer through an Ethernet connection. The EUM, which acts as a network bridge, receives data from the CCU over the 900 MHz radio link, and then forwards this data to EUM internal processes or to the end-user's computer through the Ethernet port. In the other direction, the EUM forwards data received from the end-user's computer over the radio link to the CCU.

Figure 11 EUM

The EUM functional blocks are the same as those of the CCU and are illustrated in Figure 8.

EUM Antenna

For many EUM installations, you can use an indoor antenna. WaveRider recommends the WaveRider directional antenna with switched-beam diversity. This antenna, shown in Figure 12, performs very well in cases where the radio path to the CCU is obstructed and/or where there is significant multipath. The diversity antenna accepts a DC signal on the antenna cable from the EUM, for beam pattern selection. The antenna comes with a mounting bracket and is designed to mount vertically on walls or windows (using drywall screws for wall mounting or suction cups for window mounting), or horizontally (on desks, for example, using the suction cups).

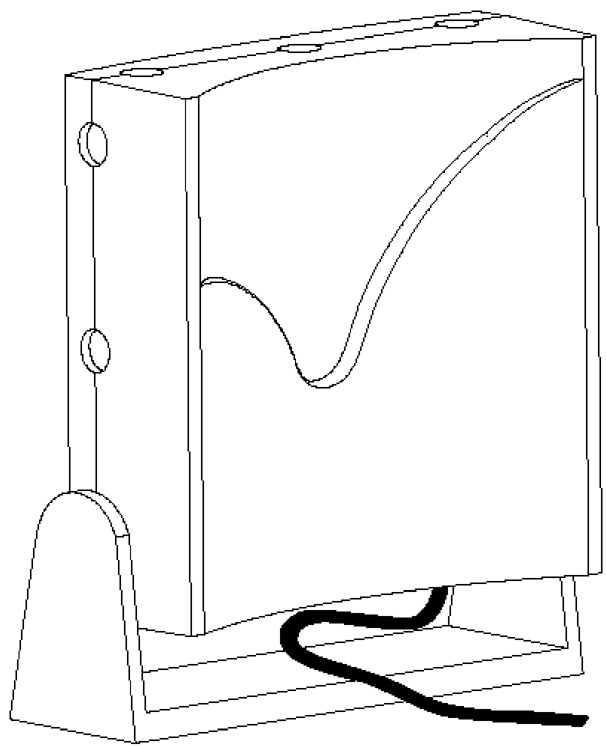


Figure 12 WaveRider Indoor Directional Antenna with Switched-beam Diversity

The WaveRider diversity antenna contains two vertical antenna elements mounted inside and on either side of the antenna housing. The phasing between these elements, which modifies the antenna pattern, is controlled by a DC voltage from the EUM. It produces two patterns, one perpendicular to the face of the antenna, which has a gain of about 6 dBi, and the other, a dual-beam pattern off both sides, offering about 3 dBi gain for each beam. These beam patterns are illustrated in Figure 13.

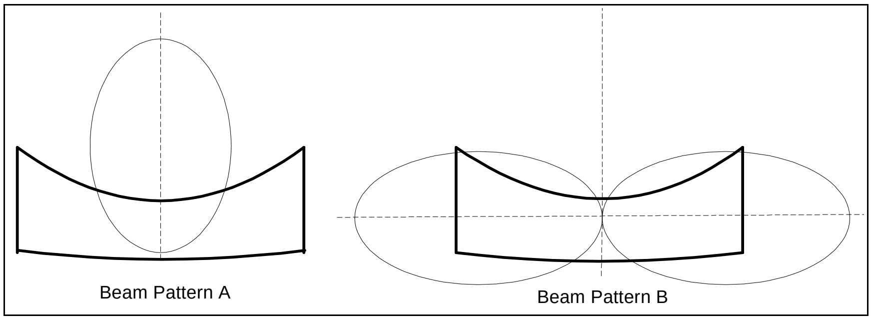


Figure 13   WaveRider Switched-beam Diversity Antenna — Beam Patterns

The EUM samples the signal strength from both antenna patterns during the preamble of every received packet and automatically selects the best signal. When the EUM transmits, it sends on the antenna pattern that was last used to receive a signal. Since most of the traffic comes from the CCU, the EUM samples the signal strength often—typically faster than once every 5 ms.

The end user must position the switched-beam diversity antenna correctly to receive an adequate signal level. The Radio LED on the EUM, described in *Indicators and Connectors* on page 74, can be used to help with the alignment. Since the switched-beam diversity antenna has a good front-to-back ratio, it can be positioned to suppress interference from other wireless devices at the end-user’s premises.

WaveRider also offers a simple dipole antenna, which can often be used where the path to the CCU is very short or relatively unobstructed; i.e., where there is a short line of sight path from the EUM to the CCU with no more than a wall or window obstructing the path.

Other WaveRider-approved antennas can be used at EUM locations that require outdoor antennas. A professional installer is required to install outdoor EUM antennas to ensure the antenna system is properly installed with lightning protection and consistent with FCC and Industry Canada guidelines, which are outlined in Appendix D on page 185.

Transmission Line

If the WaveRider diversity or dipole antenna is used, it comes equipped with RF cables and connectors. The connector is a proprietary WaveRider connector, which is mandated by the FCC requirement that the connectors used in ISM band products that are not professionally installed must be unique, or at least not readily available. If an alternate indoor or outdoor antenna is used, the installer must obtain an RF jumper cable to connect the antenna cable to the EUM. These jumper cables can be obtained from WaveRider.

Lightning Arrestor

A lightning arrestor is required at the EUM only if an outdoor antenna is used.

3.4 Basic Operation

3.4.1 LMS4000 Transmission Concept

Conceptually, the LMS4000 900 MHz Radio Network can be thought of as an Ethernet switch with a built-in router, as shown in Figure 14.

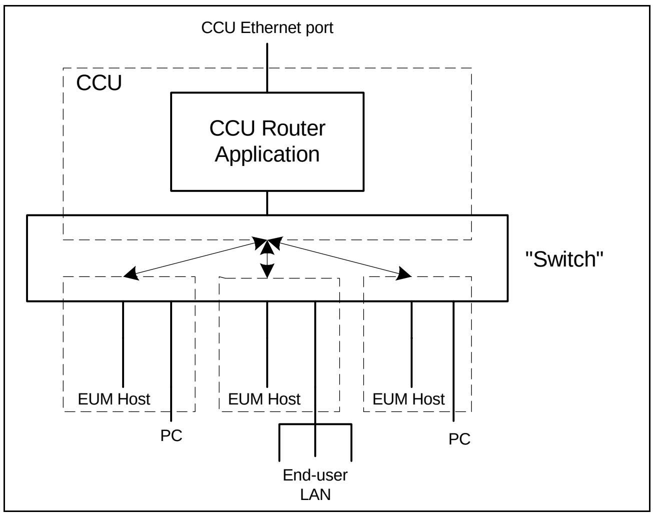


Figure 14 LMS4000 Transmission Concept

In the above diagram, the “switch” consists of the CCU and EUM physical, MAC, and IP bridging layers, and the 900 MHz link between them. IP packets originating from any host in the radio subnet (EUM or PC, for example), which are destined for a host that is also in the radio subnet, are “switched” by the CCU directly to that host. IP packets originating from any host in the radio subnet, which are destined for a host outside the radio subnet, are “switched” to the CCU router for routing to the destination host.

IP packets coming into the CCU Ethernet port, which are destined to a host in the radio subnet, are routed to the “switch” and “switched” to the host.

3.4.2 CCU and EUM Configuration

When CCUs and EUMs are shipped from the factory, they are pre-programmed with a set of factory default settings. Some of these default settings must be modified before the system can pass traffic. These basic settings are listed Table 3 and Table 4. Once your system is carrying traffic, you can configure the more advanced CCU and EUM features and functions, which are also listed in these tables.

Table 3 CCU Configuration

<table>
<tr><th>Basic CCU Settings</th><th>Advanced CCU Settings</th></tr>
<tr><td>Before the system can pass traffic, input or modify the following CCU parameters:
• CCU Ethernet IP address
• CCU radio IP address
• Gateway router IP address
• Radio frequency

For instructions on how to set these parameters, read the following sections:
• Quick Startup on page 5
• IP Network Planning on page 53
• Radio Network Planning on page 59</td><td>Once the system is passing traffic, you can start to configure and fine tune the following CCU features and functions:
• Grade of Service
• DHCP relay
• Port filtering
• SNTP time clock
• SNMP communities

You can find a technical description of these features in CCU–EUM Interface — Detailed Technical Description on page 28. You can find procedures for configuring these features in Configuring the CCU on page 83.</td></tr>
</table>

Table 4 EUM Configuration

<table>
<tr><th>Basic EUM Settings</th><th>Advanced EUM Settings</th></tr>
<tr><td>Before the system can is implemented, input or modify the following EUM parameters:
• EUM Ethernet IP address
• Gateway (CCU Radio) IP address
• Radio frequency

For instructions on how to set these parameters, read the following section:
• Configuring the EUM on page 97

Note: Since the EUM is a wireless bridge, it passes data without having a unit or gateway IP address assigned. However, to support system management (SNMP, for example) of an EUM, a unique IP address must be assigned. The EUMs all ship with the same default unit and gateway IP addresses, so if these are not changed you will experience network IP conflicts.</td><td>Once the system is passing traffic, you can start to configure and fine tune the following EUM features and functions:
• Port filtering
• SNMP communities
• Customer list

For instructions on how to set these parameters, read the following section:
• Configuring the EUM on page 97</td></tr>
</table>

Table 5 End-user PC Configuration

Basic End-user PC Settings	Advanced End-user PC Settings
In addition to the above CCU and EUM settings, the end-user's PC must be assigned an IP address and subnet, and a static gateway address. These IP addresses can be statically assigned to the PC, as described in *Configuring EUM IP Parameters* on page 99, or dynamically assigned from a DHCP server by configuring the CCU for DHCP Relay, described in *DHCP Relay* on page 48, and *Configuring DHCP Relay* on page 88.	DHCP

3.4.3 LMS4000 Protocol Stacks

The LMS4000 900 MHz Radio Network is an IP (layer 3) network that provides connectivity from the end-user's computer to the Internet.

Figure 15 shows the protocol stacks through which an IP packet traverses as it travels between the end-user's computer, shown on the left, and the Internet, shown on the right.

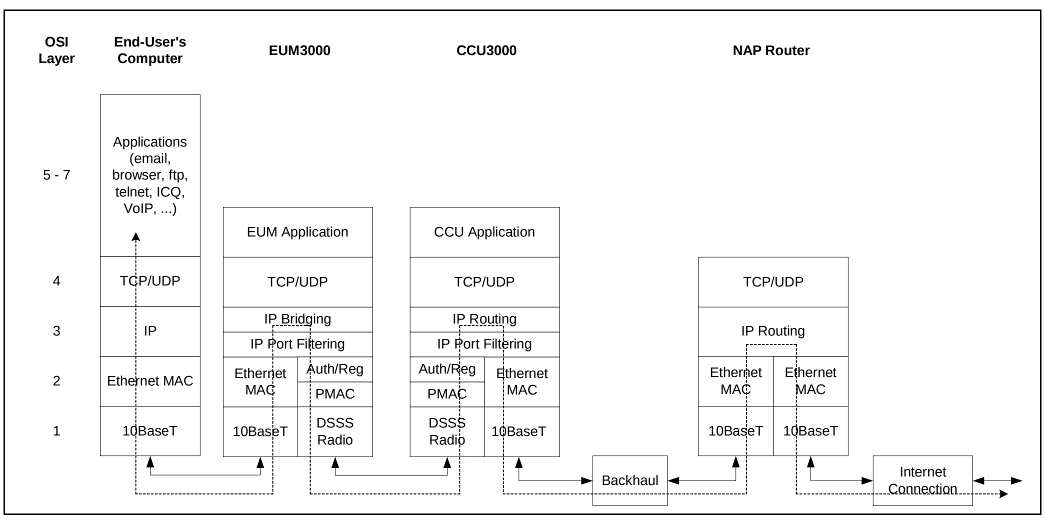


Figure 15 LMS4000 Protocol Stacks

3.4.4 Basic Data Transmission

This section describes how an EUM registers, and once it is registered, how data traffic flows from the Internet to the end-user PC and from the end-user PC to the Internet. The process in both directions involves CCU and EUM data tables, which are described in more detail in Appendix E on page 183.

EUM Registration

EUMs need to register with the CCU before user traffic can pass between the LMS4000 900 MHz Radio Network and the end user. The heart of EUM registration is the Authorization Table, discussed in *Authorization Table (CCU only)* on page 189.

The EUM registration process is as follows:

1. The system operator enters the EUM's grade of service in the CCU Authorization Table, described in *Authorization Table (CCU only)* on page 189.
2. On power up, the EUM sends a *registration_request* to the CCU.
3. The CCU obtains the EUM's grade of service from the Authorization Table. If the EUM grade of service is DENIED, the CCU sends a *de-registration_response* to the EUM and data communications are enabled. The EUM continues to send *registration_requests* to the CCU approximately every 10 minutes.
4. If the EUM grade of service is not DENIED, the CCU sends a *registration_response* to the EUM, and data communications are enabled. At this point, the CCU adds the EUM to the Registration Table, described in *Registration Table (CCU only)* on page 190.
5. If at some later time, the EUM does not respond to messages from the CCU, the CCU sends a *de-registration_request* to the EUM and removes the EUM from the Registration Table. If there has been no traffic to or from the EUM for more than 12 hours, the CCU removes the EUM from the Registration Table without sending it a *de-registration_request*.

Addressing of IP Packets

Figure 16 shows how the source and destination MAC and IP addresses are sent in IP packets travelling between the end-user's PC and the Internet network servers.

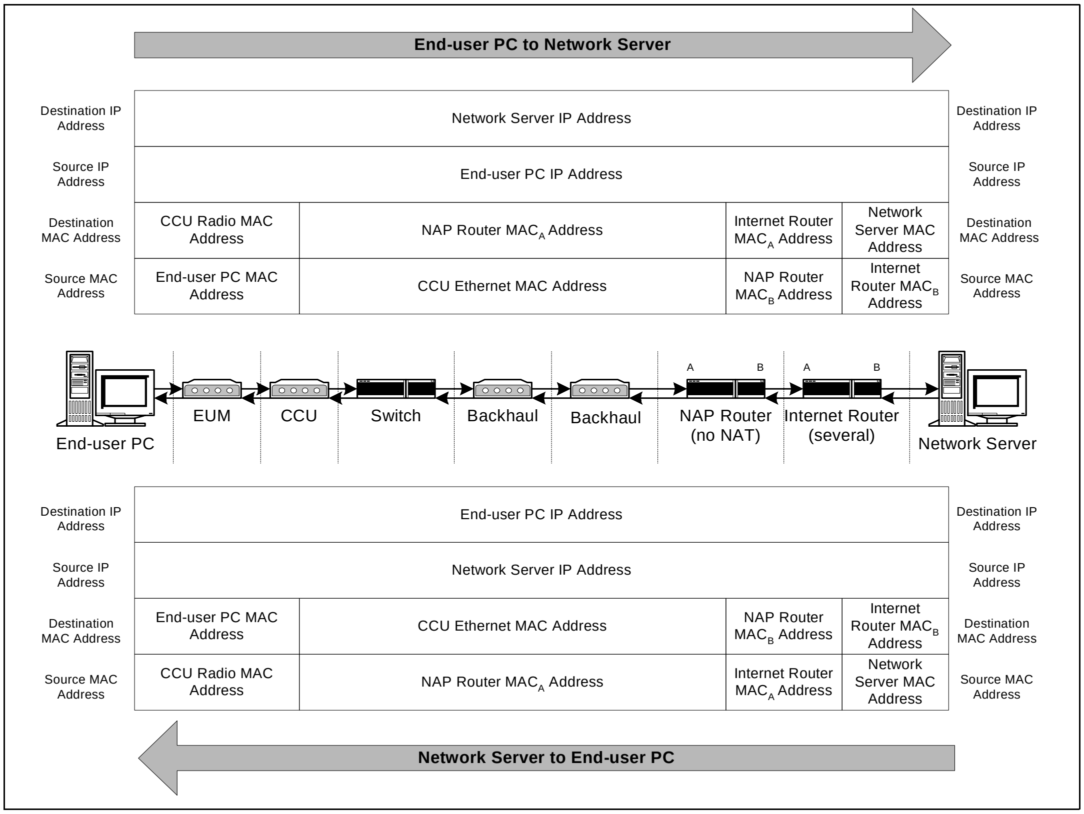


Figure 16 Addressing of IP Packets

As shown in Figure 16, if NAT is not enabled in the NAP Router, then the source and destination IP addresses are maintained throughout the route between the end-user PC and network servers. The source and destination MAC addresses, however, change whenever the packet is passed through a router. This change of MAC addresses also takes place in the CCU router application.

Internet to End-user Computer Data Transmission

1. Internet traffic comes through the gateway router, and possibly through backhaul and Ethernet switches, to the CCU Ethernet port.
2. The CCU receives an IP packet through the CCU Ethernet port and checks the TCP or UDP port number. If the port number appears in the CCU Port Filter Table, described in *Port Filter Table (CCU and EUM)* on page 183, the packet is discarded.
3. The CCU reads the destination IP address. If the destination IP address is the same as either the CCU Radio or Ethernet IP address, the packet is sent to the CCU application.
4. The CCU checks the Routing Table, described in *Routing Table (CCU and EUM)* on page 184. If the route to the destination is through the CCU Ethernet port, then the packet is discarded, since it is not destined for a host in the CCU's radio subnet.

5. If the route to the destination is through the CCU Radio Port, then the CCU obtains the destination Ethernet MAC address from the ARP Table, described in *ARP Table (CCU and EUM)* on page 187. If the destination is not listed in the ARP Table, the CCU obtains its MAC address by issuing an ARP query. Once it gets the MAC address, it adds the entry to the ARP Table.
6. Using the destination Ethernet MAC address, the CCU obtains the EUM ID from the Address Translation Table, described in *Address Translation Table (CCU only)* on page 188.
7. Using the EUM ID, the CCU obtains the EUM grade of service from the Registration Table, described in *Registration Table (CCU only)* on page 190.
8. The IP packet is then transmitted through the Polling MAC and radio interface to the EUM.
9. The EUM receives the packet through the EUM radio port and checks the port number. If the port number appears in the EUM Port Filter Table, the packet is discarded.
10. If the port number does not appear in the EUM Port Filter Table, the EUM checks the destination MAC address. If the MAC address is the EUM MAC address, then the packet is forwarded to the EUM application; otherwise, the IP packet is sent out through the Ethernet port to the end user’s equipment.

End-user Computer to Internet Data Transmission

1. The EUM receives IP packets from the end-user’s equipment through the Ethernet port.
2. The EUM checks the port number. If the port is listed in the EUM Port Filter Table, the packet is discarded.
3. If it is not already in the list, the EUM adds the source Ethernet address to the Customer Table, described in *Customer Table (EUM only)* on page 192. The EUM determines whether or not the source is entitled to air access, based on the Customer Table.
4. If the source is not entitled to air access, the packet is discarded.
5. The EUM checks the destination MAC address. If the destination MAC address appears in the Customer Table, meaning the destination is on the Ethernet side, the packet is discarded.
6. If the destination MAC address is the same as the EUM MAC address, then the packet is forwarded to the EUM application; otherwise, it is forwarded through the polling MAC and radio link to the CCU.
7. The CCU receives the packet through the CCU radio port. The CCU either updates or adds the Ethernet address to the Address Table.
8. The CCU checks the port number. If the port number appears in the CCU Port Filter Table, the packet is discarded.
9. The CCU checks the destination MAC address. If the destination MAC address is not in the Address Table, the packet is sent to the CCU router application.

10. If the IP address is the same as either the CCU radio or Ethernet IP address, the packet is forwarded to the CCU application; otherwise, the CCU gets the appropriate gateway IP address from the Routing Table and the gateway MAC address from the ARP Table, and then sends the packet to the gateway (most likely the NAP router) through the Ethernet port.

NOTE: The CCU and EUM pass only IP or ARP packets. All other packets are discarded so non-IP packets, such as IPX/SPX, are not passed over the radio link.

3.5 CCU–EUM Interface — Detailed Technical Description

This section provides a detailed description of the physical and MAC layers of the interface between the CCU and EUM, depicted in Figure 15 on page 24.

3.5.1 Physical Layer (DSSS Radio)

Frequency Band

The LMS4000 900 MHz Radio Network operates in the 902-928 MHz Industry, Scientific, and Medical (ISM) frequency band.

Channel Bandwidth

The channel bandwidth is 6 MHz. This channel bandwidth is used to determine the lowest and highest allowable channel in the band. As illustrated in Figure 17, the center frequency of the lowest and highest channels have to be set such that the signal power that falls in the bands adjacent to the ISM band does not exceed FCC and Industry Canada limits.

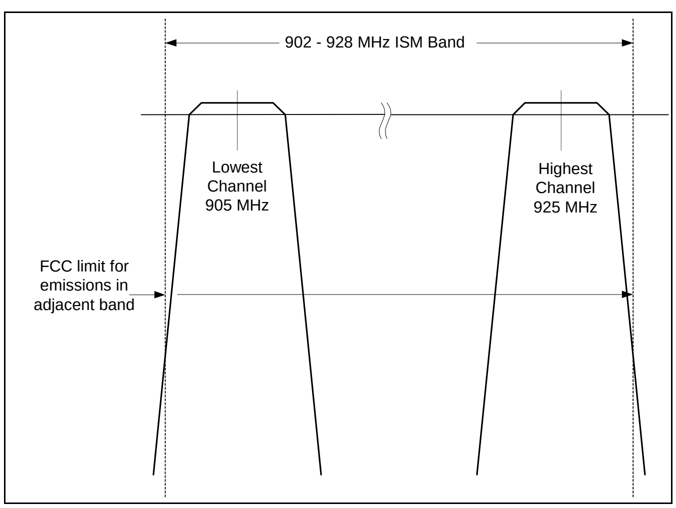


Figure 17 Determination of Lowest and Highest Channel

The channel bandwidth also determines the minimum adjacent channel spacing for colocated CCUs.

Channels

There are 101 channels in the band, set in 0.2 MHz increments:

Table 6 LMS4000 900 MHz Radio Network Channelization

Channel	Center Frequency
Lowest channel	905.0 MHz
...	905.2 MHz
...	905.4 MHz
...	...
...	924.8 MHz
Highest channel	925.0 MHz

Modulation

The CCU-EUM radio channel is based on DSSS (Direct-Sequence Spread Spectrum) signals, modulated with CCK and Barker-coded BPSK and QPSK, similar to that defined in IEEE 802.11 for the 2.4 GHz ISM band.

DSSS offers the following advantages:

- **Reduced power spectral density:** Spreading over a wider bandwidth reduces the spectral density (power per Hz of bandwidth) of the transmitted signal, allowing simultaneous operation of many spread-spectrum systems in the same frequency band and geographic area. The reduced spectral density also allows you to meet the regulatory emissions requirements in the ISM frequency bands.
- **Transmission security:** It is technologically more difficult to recover (or jam, in the case of military communications systems) spread-spectrum signals than it is to recover conventional narrowband signals.

- **Interference suppression:** The same mechanism that de-spreads the desired signal in the receiver, spreads undesired signals, which then appear to the receiver as lower levels of RF noise. This effect is illustrated in Figure 18.

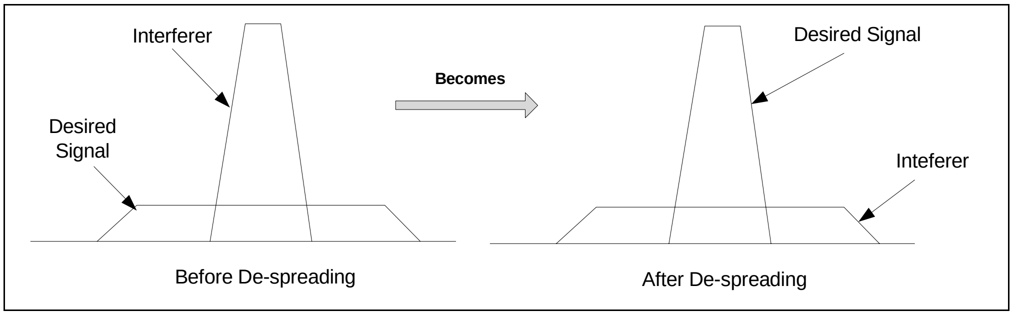


Figure 18 Effect of Despreading

Data Rate

The raw channel bit rate is 2.75 Mbps. The maximum data rate presented to the MAC layer is 2.4 Mbps, which translates to a peak FTP rate of about 2 Mbps.

Colocated Channels

A maximum of four orthogonal (nonoverlapping) channels can be provisioned at a single CAP but WaveRider recommends a maximum of three. To ensure adequate isolation between channels, a minimum co-channel spacing of 6.6 MHz is recommended, as is the use of channel filters and a properly engineered antenna system. A possible frequency set for a three-channel CAP is

- 905.0 MHz
- 915.0 MHz
- 925.0 MHz

A separate CCU, channel filter, transmission line, lightning protector, and antenna are required for each of the orthogonal channels.

Duplexing

The radio channel uses Time Division Duplexing (TDD), which means that the CCU or EUM is in either receive or transmit mode, but does not transmit and receive at the same time.

Transmit Power

The maximum transmit power (HIGH power setting) of the CCU and EUM is +26 dBm, measured at the unit's RF connector. It does not include gains and losses from antennas, transmission lines, and lightning arrestors, all of which affect the ERP (Effective Radiated Power) from the CAP or customer's premise. Refer to Appendix D on page 185 for a discussion of related FCC and Industry Canada guidelines.

The CCU and EUM transmit power can each be set to +15 dBm (LOW power setting) to address special or regional applications of the LMS4000, or for bench testing.

Receive Sensitivity

The receive sensitivity (received signal required to attain a raw data BER of 10^{-5} or better using 1000-byte packets) of the CCU and EUM is $\leq$ -86 dBm, measured at the unit's RF connector.

Antenna Connector

The RF connector used on the CCU and EUM is a WaveRider-proprietary connector. As noted above, the use of a proprietary antenna connector is mandated by FCC requirements for a unique RF connector on ISM products.

Antenna Control (EUM)

A DC voltage (5 VDC or 7.5 VDC) is applied to the EUM RF connector for powering and controlling the WaveRider diversity antenna. One beam pattern is selected if the voltage is 5 VDC. A second beam pattern is selected if the voltage is 7.5 VDC.

CAUTION: The EUM sends DC power and control voltages through the RF connector to the switched-beam diversity antenna. You must use WaveRider-approved indoor or outdoor antennas; otherwise, you could inadvertently short out the DC voltage and damage the EUM. Contact WaveRider Technical Support for a list of approved antennas.

Propagation Path

CCU and EUM radios and antennas provide the basis for excellent radio propagation in both line of sight (LOS) and non line of sight (NLOS) EUM installations. Radio propagation in the 902 – 928 MHz ISM band is superior to propagation in higher ISM bands for several reasons:

- Lower free space loss
- Lower cable loss
- Lower vegetation loss
- Better wall and glass penetration
- More signal recovery from diffraction
- More signal recovery from reflections

Radio line of sight exists when there is a clear optical path between the CCU and EUM antennas, as well as adequate clearance of the path over terrain, foliage, and buildings. This clearance requirement is called the Fresnel clearance. The required clearance varies along the path and reaches a maximum at the path midpoint. If you have a path with Fresnel clearance, the loss between the antennas is generally equivalent to free-space loss and can be readily calculated.

NLOS exists when the path between the CCU and EUM is obstructed, or partially obstructed, by terrain, buildings, or foliage. NLOS is illustrated in Figure 19. Since radio waves reflect, refract, and diffract, a non line of sight path does not necessarily mean the EUM-CCU radio link does not have enough signal margin. It simply means that the path loss is be greater than the LOS path loss. Within the engineered NLOS coverage range of the CCU, the NLOS path, using an indoor antenna, is acceptable for most EUM installations.

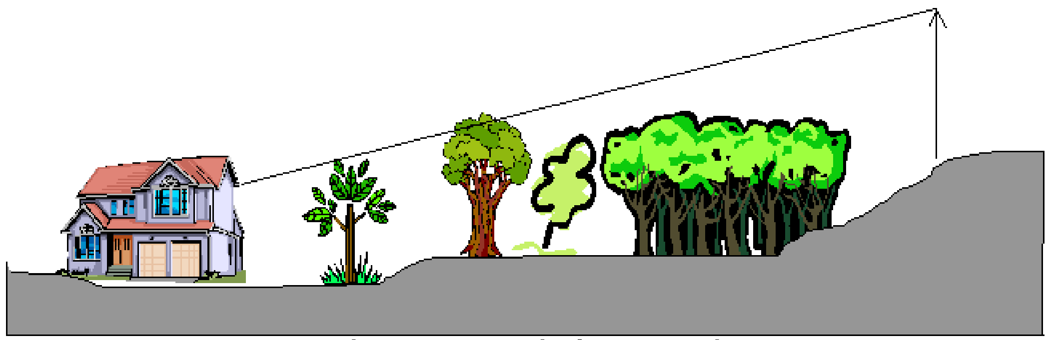


Figure 19 Typical NLOS Path

It is difficult to accurately predict NLOS path loss; however, a lot of field data has been collected and factored into commercially available path-prediction software.

LMS4000 900 MHz radio coverage prediction depends on the following:

- CCU radio output power, transmission-line losses, and antenna height and gain
- Length of the path between the CCU and EUM
- Height of terrain, foliage, and buildings along the path between the CCU and EUM, which determines the percentage of the path that is obstructed.
- EUM antenna height and gain, transmission-line losses, and receiver sensitivity
- If the EUM antenna is installed indoors, location of the EUM antenna within the end-user premises, and the premises building type and wall construction

The EUM has been designed to work with the WaveRider indoor switched-beam diversity antenna. Where greater range is required, outdoor EUM antennas are also available.

Generally, the higher the CCU antenna, the better the range, especially for LOS performance. Ideally, the CCU antenna should be installed well above the average height of trees in the vicinity of the CCU.

To illustrate the impact that proper siting of the CCU has on the LM4000 radio coverage, consider the three cases shown in Figure 20.

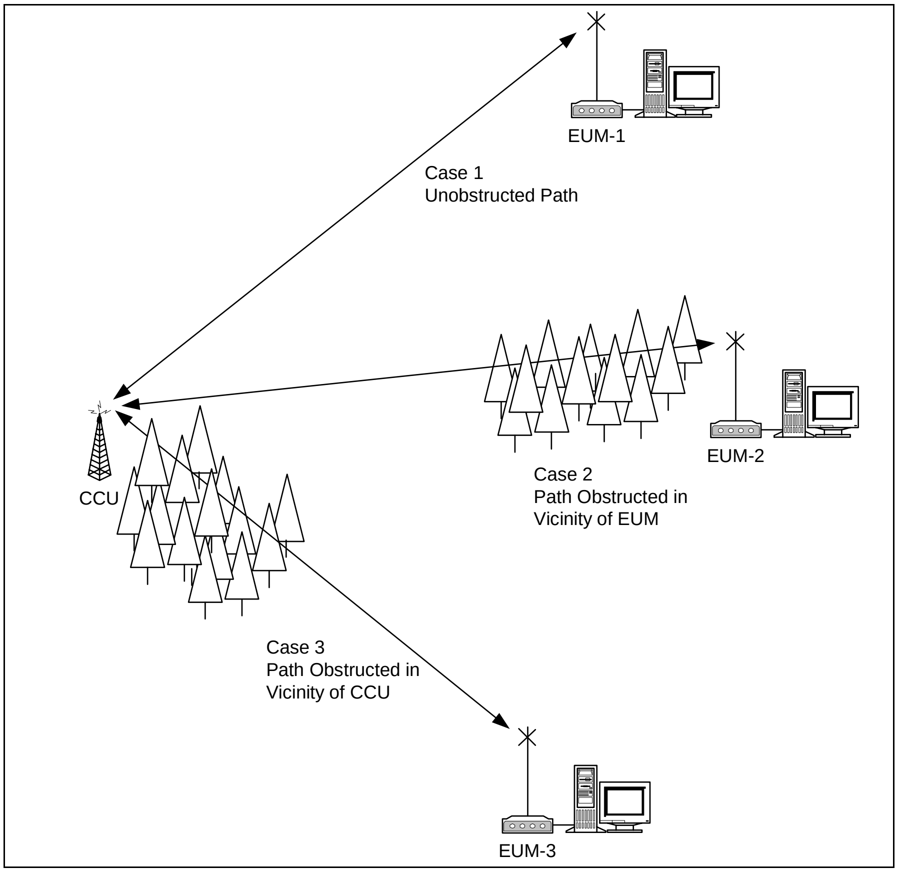


Figure 20 Examples of Radio Paths

- Case 1 is a clear, unobstructed path between the CCU and the EUM, with full Fresnel clearance.
- Case 2 is a clear, unobstructed path, except for the last few hundred meters, which is obstructed by foliage and terrain.
- Case 3 is obstructed in the vicinity of the CCU for the first few hundred meters, and then clear and unobstructed to the EUM.

You can predict the amount of path loss for each of these cases, as illustrated in Figure 21.

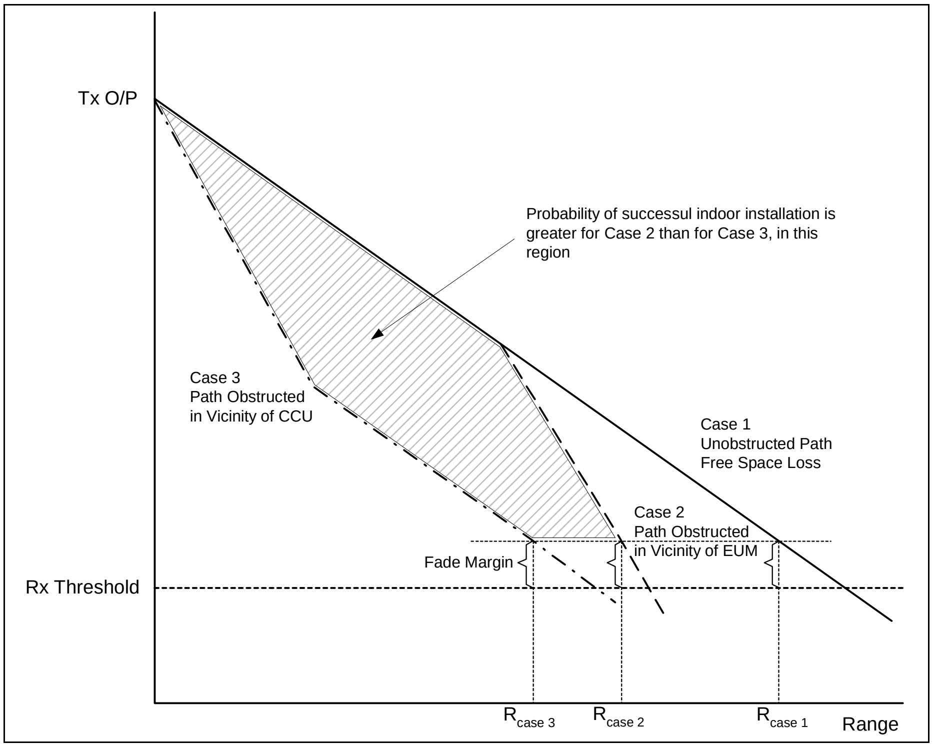


Figure 21 Path Loss Calculation

As shown in Figure 21, the path loss for each case is quite different:

- **Case 1 (Unobstructed Path):** Over the length of the path, the signal drops as $1/R^2$, where R is the distance from the CCU. The range, R_{case1}, is determined by the distance at which the signal reaches threshold plus the desired fade margin.
- **Case 2 (Path Obstructed in Vicinity of EUM):** From the CCU, the signal initially drops as $1/R^2$ until it reaches the obstructions in the vicinity of the EUM. Through these obstructions, the signal drops more steeply than it does in the unobstructed case, more like $1/R^4$. Once again, the range, R_{case2}, is determined by the distance at which the signal reaches threshold plus the desired fade margin. As shown above, $R_{case2} < R_{case1}$, which intuitively makes sense. If the path to the EUM is unobstructed, you would expect to be able to serve EUMs that are farther from the CCU, and to provide better fade margin to those that are in closer.
- **Case 3 (Path Obstructed in Vicinity of CCU):** From the CCU, the signal initially drops as $1/R^4$ until it leaves the obstructing clutter and terrain in the vicinity of the CCU. Once the signal leaves these obstructions, it drops as $1/R^2$ since the remainder of the path is clear. Once again, the range R_{case3}, is determined by the distance at which the signal reaches threshold plus the desired fade margin. As shown above, $R_{case3} < R_{case1}$. Although it shows $R_{case3} < R_{case2}$, this may or may not always be the case; however, it is always true that the margin is greater for Case 2 than Case 3, in the coverage area indicated by the shading in Figure 21. In this area, the probability of successful indoor installs is likewise higher for Case 2 than Case 3.

The following key conclusions that can be drawn from the simple example and analysis shown above:

- Coverage range and fade margins are maximum when paths are clear and unobstructed.
- Coverage range and fade margins are reduced for specific EUMs if there is obstructing clutter and terrain in the vicinity of these specific EUMs.
- Coverage range and fade margins are reduced for all EUMs if there is obstructing clutter or terrain in the vicinity of the CCU. For this reason, it is critical that the CCU location be chosen and the antenna height be sufficient to eliminate local obstructions for all possible radio links from the CCU. By local, it is recommended that the radio paths be obstruction-free between the CCU and halfway to the limit of the coverage range.

Table 7 shows the typical radio coverage (distance from the CCU) that the LMS4000 900 MHz Radio Networks can achieve. Table 7 should be used as a planning guideline only, due to the difficulty of accurately predicting radio coverage.

Table 7 Typical Radio Coverage

EUM Installation	Typical LOS Range	Typical NLOS Range
Indoor Antenna (path to CCU is through a window)	3 mi (5 km)	1 mi (1.6 km)
Outdoor Antenna	5 mi (8 km)	2 mi (3.2 km)

The following assumptions have been made in calculating the above ranges:

- For practical purposes, assume that typically 80% of the subscribers in the predicted coverage area will be able to receive service. Higher coverage is possible but often requires more extensive RF engineering.
- LOS (line of sight) means optical view and radio Fresnel clearance between the EUM premise and the CCU antenna.
- Typical CCU antenna height of 130 ft. (40 m), at least 10 ft. (3 m) above the trees.
- Typical EUM antenna height (for outdoor antennas) of at least 13 ft. (4 m).
- The CCU EIRP has been maximized to +36 dBm in all cases. Refer to Appendix D on page 181 for further guidelines.
- The EUM outdoor antenna (Yagi antenna, for example) has a gain of 9 dBi, and the indoor antenna (WaveRider switched-beam diversity antenna) has a gain of 6.6 dBi.
- Coverage with the WaveRider indoor switched-beam diversity antenna depends on the composition of the exterior walls and structure of the end-user's premises. For best results, the EUM antenna should be installed behind a window.

Actual results vary significantly due to local conditions. Coverage-area prediction that takes into account local terrain and clutter factors provides a better estimate of coverage.

3.5.2 MAC Layer (Polling MAC)

EUM States

The LMS4000 900 MHz Radio Network data transmission is based on a WaveRider's patented polling algorithm, which takes advantage of patterns found in typical Internet usage. Based on the EUM's subscribed grade of service and current traffic level, the Polling MAC continuously adjusts the rate at which the EUM is polled. This process is illustrated in the EUM State Diagram in Figure 22.

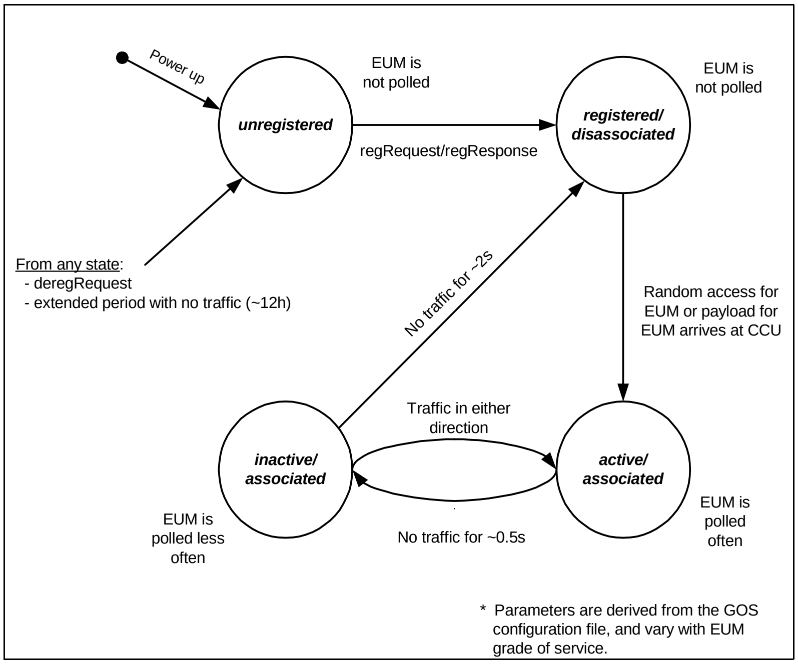


Figure 22 EUM State Diagram

When an EUM first powers up, it is in an *unregistered* state.

In the *unregistered* state, the EUM is not being polled and is therefore not passing traffic. As outlined in *EUM Registration* on page 25, an *unregistered* EUM sends a *registration_request* to the CCU. If the EUM is authorized in the CCU Authorization Table, it becomes *registered/ disassociated*.

In the *registered/disassociated* state, the EUM is still not being polled. But if the EUM has traffic to send, it tries to associate with the CCU through the random access channel. The EUM may also become *associated* if the CCU has a payload to send to the EUM. Once *associated*, the state of the EUM changes to *active/associated*.

In the *active/associated* state, the EUM is polled often, at a rate consistent with its subscribed grade of service. If there is no traffic to or from an *active/associated* EUM for a defined interval (typically set around 0.5 seconds), the state of the EUM changes to *inactive/associated*.

An *inactive/associated* EUM is polled less frequently than an *active/associated* EUM. If traffic is resumed, the state of the EUM changes back to *active/associated*. If there is no traffic for a longer defined interval (typically set around 2 seconds), the state of the EUM changes back to *registered/associated*.

If an EUM is issued a deregistration request, for any reason, or if it has no traffic for an extended period of time, 12 hours or so, its state changes back to *unregistered*.

Basic Operation of the Polling MAC

The Media Access Control (MAC) layer determines which unit (CCU or EUM) gets to transmit and when it gets to transmit. Through the MAC layer, the CCU determines which associated EUM gets to transmit next and indicates to the EUM that it can transmit by polling it. The frequency with which an EUM is polled is based on its assigned Grade of Service (GOS). The CCU transmits a directed poll to the EUM, which immediately transmits a response to the CCU. After the response is received from the EUM, the CCU transmits the next poll. In this way, the inbound (EUM-to-CCU) and outbound (CCU-to-EUM) channels are maintained collision free.

If the CCU has data to send to an EUM, then that data is sent with the directed poll. If the EUM has data to send to the CCU, then that data is sent with the EUM response to the poll.

EUMs that are not *authorized* are not polled.

To optimize polling efficiency, EUMs that no longer have traffic to send are not polled. EUMs that are not being polled can submit a request to be polled by responding to a special random access poll transmitted regularly by the CCU. Collisions may sometimes occur on this random access channel; however, since only a small number of users are vying for service through the random access channel at any one time, the effect on channel performance is negligible. Recovery from these collisions is made possible by random back-off and retry.

Once again, if the EUM requesting service through the random access channel has data to send to the CCU, it will be included with the request message. If the CCU has outstanding broadcast messages to send, they will be sent to all EUMs with the random access poll.

An automatic repeat request (ARQ) scheme, using acknowledgements and retransmissions to recover from message losses due to collisions or radio link errors, provides reliable transport. Each transmitted data payload is numbered in the packet header. Each packet header also contains an acknowledgement for the last correctly received payload, by number. If a CCU or EUM does not receive an acknowledgement for a payload that it has transmitted, it retransmits that payload with the following poll of, or response from, that EUM. A payload is transmitted a maximum of four times, after which it is discarded. Note that contrary to the 802.11b system, MAC-layer acknowledgements are not transmitted as separate packets, reducing overhead by 33%, on average.

Network Usage

The design of the Polling MAC has been optimized to allow maximized user capacity for typical patterns found in Internet usage, which include browsing the world wide web, accessing email, transferring files, and streaming audio and video. The common characteristic of these uses is that they are bursty—data is transferred in bursts, with time in between the bursts when no data is transferred. As a result, not all users will be transferring data at the same time. In fact, the number of users that are actually transferring data at any one time is generally much smaller than the number sitting in front of their computers which, in turn, is much smaller than the total number of end users. As a result, many users can share the radio link and, for the short time they need it, use a significant portion of the link bandwidth. In other words, many users share the limited bandwidth of the channel, yet each perceives that they have most of the channel bandwidth to themselves. This over-subscription model is the basis of Ethernet, DOCSIS cable networks, 802.11 radio networks, Bluetooth, and on a larger scale, the public switched telephone network.

If a significant portion of the network traffic does not meet this typical bursty model, the Polling MAC adjusts to maximize the user capacity. In this case, the maximum number of users is less than the case where most of the traffic is bursty. As described in *Specialized Applications* on page 155, the Polling MAC can also be optimized to support LMS4000 applications, which have been designed, for example, to cost-effectively extend the coverage range.

Association

The Polling MAC has been designed to take advantage of the bursty, intermittent nature of Internet usage through the concept of association. When users are transferring bursts of data, their EUMs are *associated* with the CCU, and they are allocated a portion of the polling sequence. In between bursts, the EUM is *disassociated*, freeing that part of the polling sequence for other users. The determination of when to disassociate an EUM is based on the time that has expired since any data was transferred to or from that EUM. As more and more EUMs become *associated*, the bandwidth allocated to each EUM gets smaller and smaller, consistent with the GOS constraints discussed below.

When an EUM is not *associated* but has data to send, it uses the random access mechanism to send the first packet. On receiving this first packet, the CCU considers the EUM associated and begins to poll it. The EUM remains *associated* as long as traffic continues to flow, but after a short period of inactivity it is directed to disassociate.

If the CCU has data to send to a *disassociated* EUM, the status of the EUM changes to *associated*, and the data is sent to the EUM the first time it is polled.

The maximum number of EUMs that can be *associated* at any one instant of time is 75. Any EUMs trying to associate beyond this limit are denied access until the number of *associated* EUMs falls below the limit.

Grade of Service (GOS)

In the Polling MAC, the grade of service (GOS) determines how often, and when, an *associated* EUM is polled. Since the EUM can only send one packet each time it is polled, the data rate is related to the polling rate.

Operational objectives that are factored into the determination of the basic polling rate include the following:

- Maximize overall user capacity and minimize the overhead related to empty polls.
- Accommodate different types of data; for example, short, bursty data, such as email and browsing, and large file transfers.
- Support differentiation of user classes in terms of committed information and maximum burst rate throughput levels.
- Control packet latency to support interactive services such as VoIP and chat.
- Support both symmetrical and asymmetrical data applications.
- Control unauthorized web hosting or gaming applications.
- Support multi-user network applications at a single EUM

To accommodate these often-conflicting operational objectives, WaveRider has designed a patented Polling MAC layer that incorporates an integrated GOS management algorithm. Within this algorithm, a total of 11 GOS parameters (GOS parameter set) are controlled to achieve specific performance objectives.

To maximize the performance of the GOS algorithm, and therefore Polling MAC, control of the following factors is key:

- Delay between packets transmitted to (or from) an EUM
- Relative weighting of different GOS classes
- Determination of when an EUM is *active* or *inactive*.

Manipulating these factors through the GOS parameter set can provide

- differentiated levels of service to end-users, which are defined in terms of average committed and maximum burst throughput rates, and
- other special service classes.

The polling algorithm controls packet rates and timing, which in turn provide varying data throughput in kbps, depending on the packet sizes for a given application.

GOS classes are defined based on particular combinations of the GOS parameter set. The system operator assigns a GOS class to each EUM, and the CCU gets the EUM's polling parameters from that class.

In determining the order in which to poll the EUMs, the CCU tries to

- ensure consecutive polls of an EUM occur within the range defined by the EUM's grade of service,
- maintain the average time between polls defined by the grade of service, and
- divide the total number of polls among EUMs consistent with the grades of service of the EUMs being polled.

Since it is inefficient to poll an EUM if there is no data to send either way, an EUM can be polled less often if it has not recently transmitted or received traffic. The GOS parameter set essentially provides for independent control of the polling characteristics for both *active* EUMs (those that have recently had traffic) and for *inactive* EUMs (those that have recently had no traffic), where “recently” is defined by the GOS parameter set.

In addition to efficiently managing the usage of the radio link and providing differentiated service capabilities, the polling MAC inherently smooths the upstream (EUM-to-CCU) packet arrival times. It also has a smoothing effect on the downstream traffic arrivals, which positively impacts network performance by reducing

- surges in data traffic,
- transients in queue occupancy, and
- packet discards.

GOS Configuration Files

Each GOS is defined by configuration files that are stored in the CCU. The CCU can maintain up to five GOS configuration files, consisting of

- up to four assignable GOS configuration files, and
- one GOS configuration file for broadcast messages.

The operator assigns each EUM to one of the four assignable GOS configuration files, which have the fixed labels of Gold, Silver, Bronze, and Best Effort. Although the labels are fixed, the actual service level is determined by the configuration file that is associated with label.

Although only four assignable GOS configuration files can exist simultaneously in the CCU, each of these files can be readily changed by FTPing a new configuration file to the CCU, to replace the existing one. This change can be done while the CCU is active and takes effect immediately.

As specific requirements are identified, WaveRider creates and makes available sets of predefined configuration files. To illustrate the operation of the GOS configuration files, the performance of the factory default GOS service levels is summarized in Table 8. This default GOS configuration file is tailored for networks consisting of both residential and business-class users.

Table 8 Factory Default GOS Configuration File

Service Class	Polling Rate (polls/second)	FTP Rate (see note)	Operator Assigned
Best Effort	1 - 34	0 - 384 kbps	Yes
Bronze	1 - 90	0 - 1024 kbps	Yes
Silver	12 - 22	128 - 256 kbps	Yes
Gold	22 - 46	256 - 512 kbps	Yes
Broadcast	Varies with channel load, from 16 to 935	Not applicable	No
Denied	0	0	Yes

NOTE: While recognizing that the performance of data transmission through packet radio networks is randomly dependent on many variables, typical FTP rates based on empirical data are included in the table to demonstrate the performance that the operator might expect on single, large FTP transfers using maximum-sized packets.

There are several important observations that can be made about the above service-class descriptions:

- All of the default service classes impose a limit on the maximum polling rate.
- The Silver and Gold service classes have a lower bound on the polling rate (12 and 22 polls per second [pps] respectively). The Polling MAC treats this limit as a minimum committed level, which is subject to overall radio link capacity.
- In determining the order and frequency with which to poll EUMs, the CCU first tries to ensure all *associated* EUMs are polled no more frequently than the maximum service class polling rate, and no less frequently than the minimum service class polling rate.
- As the system usage increases, the end-user throughput in all classes decreases from the maximum. Bronze users see the largest reduction, then Gold users, and then Best Effort users. When all users have been reduced to 256 kbps (the minimum threshold for Gold), the next reduction will be shared by the Best Effort, Bronze, and Silver class users (Gold will not be reduced further), until the minimum threshold for Silver is reached. After this, if further reductions are required, this reduction would be shared equally between the Best Effort and Bronze users.

  In practice, the bursty nature of Internet usage is such that this methodical reduction in throughput is not apparent to the end-user, and these variations in service level tend to be instantaneous and transitory. Overall, end-users tend to see a relatively high average throughput consistent with their assigned GOS class, as is shown later in detailed simulation results based on real user data.

Transmit Queue Limits

CCU transmit buffer space is a limited resource shared between the EUMs. If more traffic is received at the CCU for transmission to an EUM than can actually be transmitted to it, that EUM might eventually use up all available CCU buffer space, effectively starving all other users. Therefore, the number of packets in each EUM's transmit queue is intentionally limited.

Packets arriving beyond this limit are discarded, resulting in retransmission of TCP/IP packets by the host computer and TCP/IP adjusts by slowing down. The EUM transmit queue length limit, which is never less than the lower bound given in the GOS parameter set, is dynamic and based on total queue occupancy.

EUM transmit queue length limit determines the optimal TCP receive window size (the maximum allowed number of outstanding unacknowledged bytes) used by the host application. Some Internet Speed Boost programs intended for DOCSIS or ADSL connections, simply increase the receive window size to very large values. This increase results in very long queues at the CCU, more discarded packets, increased retransmissions, and reduced throughput. To maximize throughput, WaveRider recommends setting the receive window size of these applications to between 18000 bytes (~12 packets) and 24000 bytes (~16 packets).

TIP: Utilities are commercially available for optimizing the TCP receive window size in the end-user’s computer, through manipulation of the Windows registry.

Polling MAC Statistics

A wide range of Polling MAC statistics are recorded by the CCU and EUM. These statistics are very useful, particularly during installation and as an aid to troubleshooting. A complete list of statistics provided by entering the <stats mac> command through the CLI can be found in *Monitoring the Network* on page 127.

Performance Modelling

The performance of packet radio systems like the LMS4000 900MHz Radio Network cannot easily be derived from analytic calculations. However, using computer simulations that are designed to accurately reflect the system implementation, and user and network traffic distributions, it is possible to produce statistical representations of LMS4000 system performance.

WaveRider has developed a model that simulates LMS4000 system processes, tasks, protocols, propagation delays, and queue sizes. The model can simulate systems with large numbers of EUMs and wide ranges of user traffic. The inputs to the model include

- number and geographical distribution (distance from CCU) of EUMs,
- user traffic statistics, and
- RF link-quality distributions.

These inputs are based on WaveRider’s experience with actual customer installations. The outputs of the model are statistical representations of system performance.

To illustrate the output of the model, consider the following example. First of all, make the following general assumptions:

- LMS4000 900 raw channel rate is MHz 2.75 Mbps
- There are no channel errors
- Servers are fast and do not present a bottleneck
- There are no external link or backhaul bottlenecks
- Typical CCU to EUM range is 0 to 3 km
- GOS is unlimited

Furthermore, assume that typical end-user traffic is Web browsing, averaging one 60 kbyte HTTP transfer every two minutes. This traffic pattern is based on analyses of busy-hour data collected from LMS systems consisting primarily of residential users. In normal usage, users randomly and independently download a file or Web page, take time to process the information, and then download another file or Web page. Assuming this type of traffic, the performance shown in Figure 23 results.

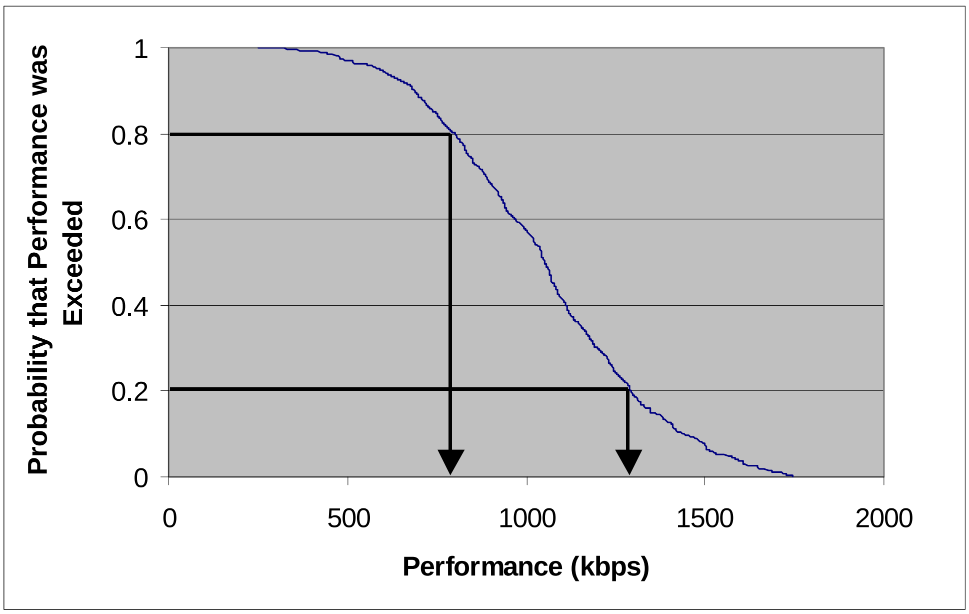


Figure 23 Net Throughput per EUM — 100 EUMs, 60 kbyte HTTP every 2 minutes

From Figure 23, each of the 100 end users can expect a net throughput better than 800 kbps 80% of the time, and better than 1.3 Mbps 20% of the time. You can also assess system performance based on the number of EUMs that are *associated* at any given time, as is illustrated in Figure 24..

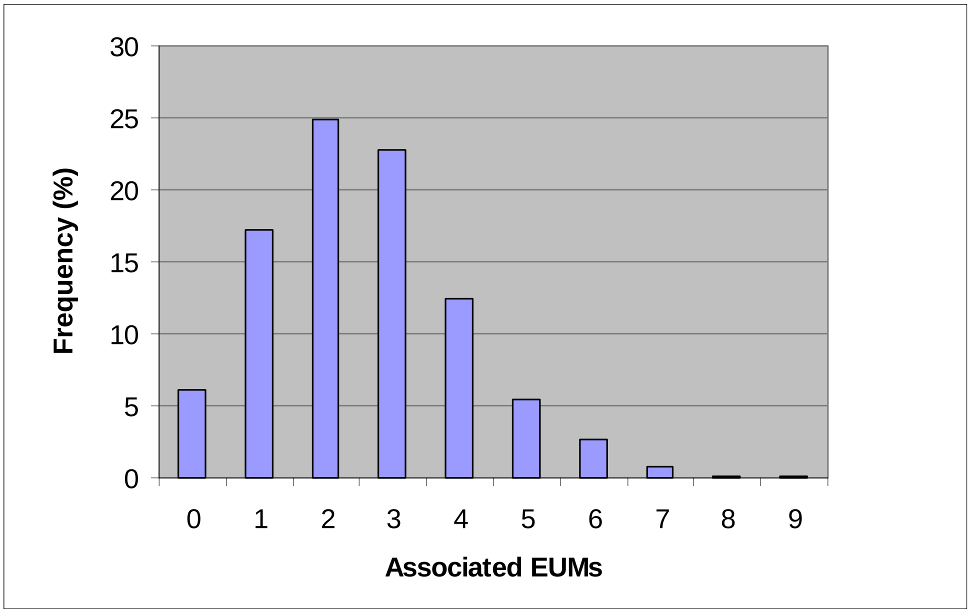


Figure 24 Associated EUMs — 100 EUMs, 60 kbyte HTTP every 2 minutes

Of the 100 EUMs, each is *associated* at random times and for random intervals, so the probability of having more than ‘n’ EUMs *associated* must be determined statistically.

From Figure 24, 25% of the time only 2 of the 100 EUMs are *associated* at the same time. Less than 1% of the time, there are only 7 *associated* EUMs. Even with 100 EUMs, where end users are browsing and downloading during the same period, 6% of the time no EUM is *associated.*

By increasing the number of EUMs to 300 and maintaining the same level of traffic per EUM, the modelled performance becomes

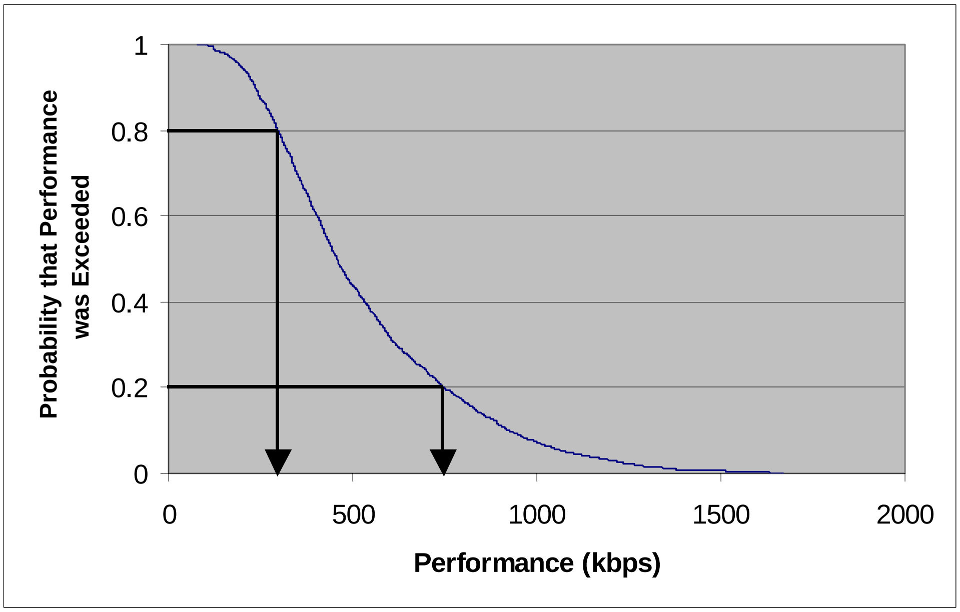


Figure 25 Net Throughput per EUM — 300 EUMs, 60 kbyte HTTP every 2 minutes

From Figure 25, each of the 300 end users can expect a net throughput better than 300 kbps 80% of the time, and better than 750 kbps 20% of the time. Once again, you can assess system performance based on the number of EUMs that are *associated* at any given time, as is illustrated in Figure 26.

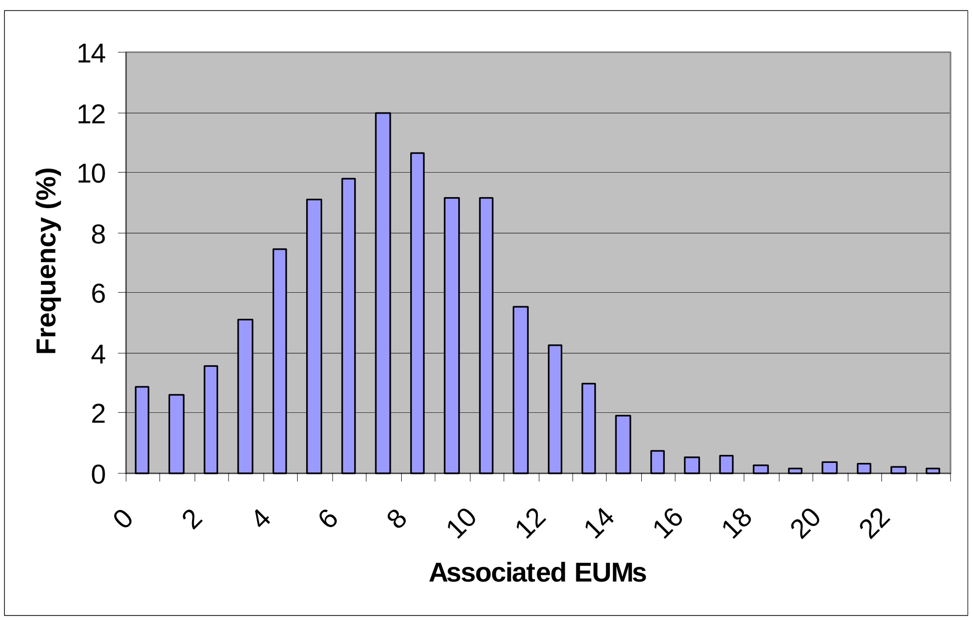


Figure 26 Associated EUMs — 300 EUMs, 60 kbyte HTTP every 2 minutes

From Figure 26, of 300 EUMs, eight were *associated* 12% of the time, and 14 were *associated* less than 3% of the time. The amount of time 25 or more EUMs were *associated* was less than 0.4%.

All of these charts illustrate that **many (LMS4000) users can share the limited bandwidth of the channel, yet most of the time, each perceives that they have most of the channel to themselves.**

Atypical Applications

The Polling MAC has been optimized for normal user applications. One basic assumption that has been made in the design of the Polling MAC is that users are only *associated* for a small fraction of the time they are sitting in front of their computers. This usage is typified, for example, by a file transfer (Web page for example) every two minutes or so—each transfer taking a second or two. The MAC takes advantage of this usage pattern by only associating with *active* EUMs.

A second assumption is that EUMs become *active* independently. If many EUMs simultaneously attempt to use the random access opportunity, they will collide multiple times and may not get through.

If the above assumptions are reasonable, then it is also reasonable to assume that a limited number of EUMs will be *associated* at any given time, as demonstrated in *Performance Modelling* on page 42.

There are several computer applications where usage is not consistent with the above assumptions. These applications, which are discussed below, can compromise the efficient operation of the LMS4000 network and may cause the network to slow down.

Broadcast Applications

Some applications broadcast messages to which all or a large number of hosts are expected to respond. If these applications are running over the system, not only will responses from *disassociated* EUMs collide as the random access opportunities are overwhelmed, but those that do get through will quickly use up all of the available associations. With so many *associated* EUMs, polls are farther apart and throughput degrades, even if the newly *associated* EUMs have no further traffic to send. As well, EUMs that are not *associated* are not able to associate and are therefore be blocked for a few seconds. The following applications can cause this type of problem:

- **Broadcast pings:** WaveRider recommends not using broadcast pings.
- **SNMP broadcast requests:** WaveRider recommends not using SNMP broadcast requests.
- **Windows Network Neighborhood:** This traffic can be blocked using port filtering at the CCU or EUM level, as discussed in *Port Filtering* on page 49.

Periodic Packet Sources

Some applications send individual packets at fixed, often large, intervals, expecting only a single packet or small number of packets in response. The direct impact of these applications is that EUMs that are sent periodic packets remain *associated* for a longer period of time than that warranted by their end-user traffic level and continue to be polled unnecessarily. The atypical applications themselves will function very well; however, they will use up a significant amount of the channel bandwidth. This group includes the following applications:

- **Pings** (interval is typically 1 second): WaveRider recommends the operator avoid running applications that generate a lot of pings, such as *What's Up Gold*.
- **Network gaming** (interval is typically 0.25 seconds): WaveRider can provide a GOS class for managing this kind of traffic if specific end users are running this type of application.
- **SNMP poll** (interval is typically 30 seconds): This traffic is usually generated by the operator. WaveRider recommends increasing the SNMP poll interval to a large value, for example, greater than one hour and, if possible, that the SNMP application not poll all EUMs in the same short interval.

TIP: Consult WaveRider for a special GOS Configuration File to limit the impact of these atypical applications for specific EUMs.

Network Monitoring

Some applications send packets to each host on the network, usually to determine whether the host is accessible and/or functioning. These applications, which may be run by the system operator, cause EUMs that otherwise would not be *associated* to become *associated*. Often, the additional load from applications of this type can even exceed the end-user traffic load on the system. Since these applications tend to be periodic, the load is presented to the system regularly over an indefinite period. Also, with large networks, application polling may soon exceed the maximum number of associations. In this case, the application may not be able to receive responses from some EUMs, presenting the operator with misleading status information. This group includes the following applications:

- **SNMP polling:** As noted above, WaveRider recommends increasing the SNMP poll interval to a large value, for example, greater than one hour, and staggering polls to groups of EUMs.
- **SNMP service discovery:** Service discovery is not required for management of the LMS4000 900 MHz Radio Network.
- **Ping scripts**, such as *What's Up Gold*: WaveRider recommends obtaining a tool to stagger the pings.

Since the network operator controls most of the above applications, WaveRider recommends limiting or at least delaying their use until non-busy hours.

Voice Over IP (VoIP)

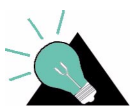
Voice over IP (as opposed to streaming audio or video) requires small packets to be sent at very short intervals — usually around 20 ms — with very little latency allowed in either direction. While the LMS4000 900 MHz Radio Network may be able to support this level, either as a guaranteed grade of service class parameter or on a best effort basis, VoIP applications result in a high per packet overhead on the radio channel. This overhead and the requirement for low latency mean the VoIP call occupies about 10% of the available bandwidth for the duration of the call. It obviously does not take very many VoIP users to significantly affect system performance. Also, unless this grade of service guarantee is given, the quality of the call may be affected as other users become *associated*, increasing the polling interval beyond 20 ms. Since the grade of service applies to an EUM and not to an individual service, a VoIP user would have to be given a very high grade of service, to the possible detriment of other end users.

3.6 CCU and EUM Feature Description

3.6.1 DHCP Relay

IP address information for CCUs and EUMs are manually entered. In the case of end-user PCs, IP addresses can be entered manually or obtained automatically from a DHCP server, if CCU DHCP relay is enabled.

Once DHCP Relay is *enabled* in the CCU, DHCP requests from the end-user's computer pass transparently through the CCU and EUM to the operator's DHCP server. Since the IP address assigned to the end-user's computer must be on the same subnet as the CCU radio port, the operator needs to preassign an appropriate block of IP addresses in the DHCP server.



TIP: It is helpful to assign meaningful names, such as the customer name, to customer computers or home network routers. Then, if a DHCP server is implemented, the address leases pool includes this name with the client IP address, facilitating easier identification.

The gateway router can provide DHCP server functionality, or you can implement a dedicated DHCP server, as shown in Figure 27.

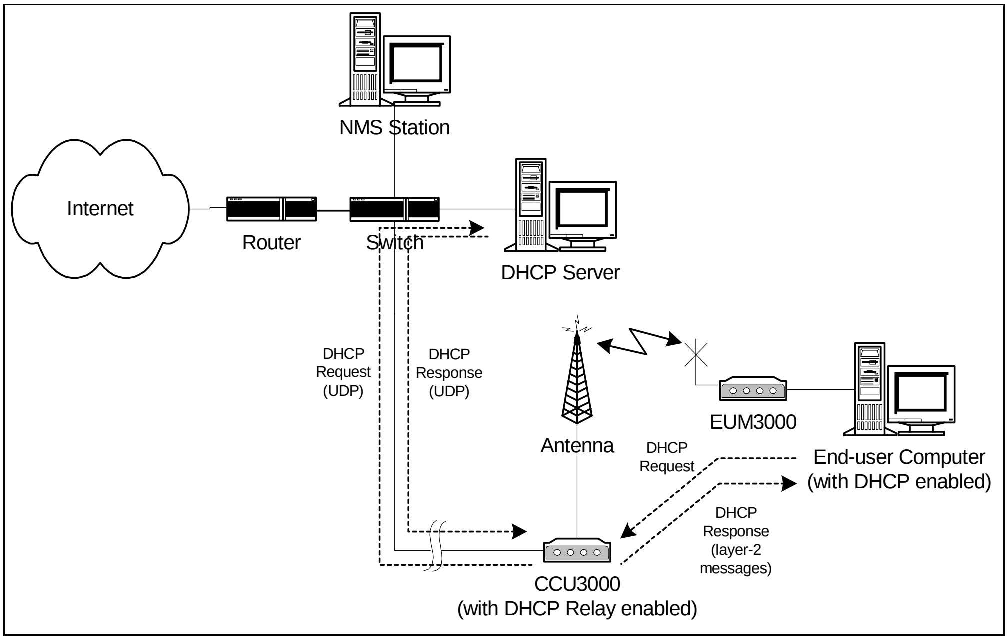


Figure 27 DHCP Relay

3.6.2 Port Filtering

The CCU and EUM both support TCP and UDP port filtering. The IP protocol suite is made up of many subcomponents consisting of ports and protocols. Up-to-date listings of TCP and UDP ports can be obtained off the Web. Some of these ports are required for normal LMS4000 operation, but most are not. The system operator can configure the CCU and EUM to filter packets on specific TCP or UDP ports to improve network performance, security, or privacy.

For example, to prevent end-users from having visibility of, and access to, other end-users through Windows Network Neighborhood, filter the following ports at the CCU for both UDP and TCP packets:

- Port 137 NETBIOS Name Service
- Port 138 NETBIOS Datagram Service
- Port 139 NETBIOS Session Service
- Port 1512 Microsoft's Windows Internet Name Service

CAUTION: The EUM is delivered with port filtering enabled.

CAUTION: Do not enable filters to block Telnet (port 23), FTP (ports 20 and 21), or SNMP (ports 161 and 162); otherwise, you will not be able to manage your network.

3.6.3 SNTP/UTC Time Clock

The Simple Network Time Protocol (SNTP)/UTC feature provides LMS4000 devices with an accurate clock for time stamping events in the log file.

SNTP/UTC Time Clock operation is illustrated in Figure 28.

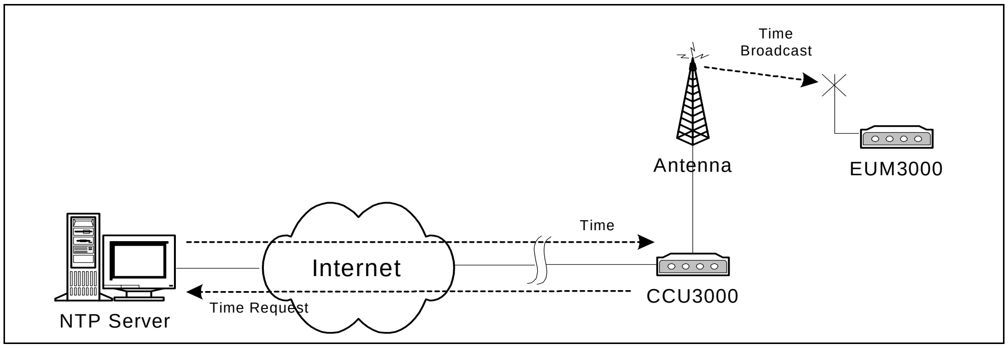


Figure 28 SNTP/GMT Time Clock

The CCU, acting as an SNTP time client, regularly resynchronizes to one of several NTP Servers from which it obtains UTC (Universal Coordinated Time). The CCU resynchronization and retry periods can be set by the operator. The resynchronization period is the time between a successful CCU resynchronization and the next CCU resynchronization attempt, typically set to one hour. The retry period is the time between an unsuccessful resynchronization attempt and the next resynchronization attempt, typically set to 30 seconds.

The operator can configure the CCU to act as an SNTP time server to the EUMs and broadcast time information to all EUMs after it has synchronized with the NTP server. It also broadcasts this information whenever an EUM powers up and registers.

UTC, the international time standard, is based on a 24-hour clock. It is the current term for what was commonly referred to as Greenwich Mean Time (GMT). Universal time is based on a 24 hour clock. SNTP, specified in RFC1769 and RFC2030, is a simplified version of NTP, which is specified in RFC1305.

By default, the CCU SNTP client is *disabled*. Once SNTP is *enabled*, the CCU tries to synchronize with an NTP server. The operator can configure the CCU to synchronize with

- a local router or network device, if the router or network device is configured as an NTP time server,
- any open-access NTP server of the operator’s choosing, or
- one of the five factory-default open-access NTP servers listed below:
  - 132.246.168.148 time.nrc.ca stratum 2, Canada
  - 140.162.8.3 ntp.cmr.gov stratum 2, US
  - 136.159.2.1 ntp.cpsc.ucalgary.ca stratum 2, Canada
  - 192.5.5.250 clock.isc.org stratum 1, US
  - 127.0.0.1 local host (the CCU itself)

CAUTION: The *local host* entry, 127.0.0.1, is required to avoid the problem where the CCU cannot find a real NTP server (i.e., if the network is down).

3.6.4 Customer List

For each EUM, the system operator can control the number of end-user computers that can access the LMS4000 network for the purpose of controlling network performance or service differentiation. The use of this list is described in *Customer Table (EUM only)* on page 192.

3.6.5 SNMP Support

Simple Network Management Protocol (SNMP) allows a network management server to monitor, control, and remotely configure LMS4000 network devices. In SNMP, these devices are also referred to as agents.

Community Strings

Community strings act as passwords to facilitate communication between the SNMP server and a network device. There are three types of community strings:

- **Read community strings**, which enable SNMP servers to retrieve information from a network device
- **Write community strings**, which enable SNMP servers to send information, such as configuration commands, to a network device.

  NOTE: At this time, there are no writable SNMP MIB entries. All configuration is done via the CLI.

- **Trap server IP address and community strings**, which enable SNMP servers to receive unsolicited messages from a network device. These unsolicited messages indicate asynchronous events, such as an interface going down or coming up, a unit performing a cold or warm start, or an operational failure.

Each network device monitored by SNMP must have at least one of each type of community string defined. Each CCU and EUM can have up to five read or read/write and five trap servers/community strings defined. Non-WaveRider devices may have only one of each type of community string defined. Community strings are case sensitive.

Table 9 Factory Configured Community Strings

Community String Type	Community String
Read	public
Write	private
Trap	<none>

CAUTION: By convention, most equipment ships with the default community strings defined in Table 9. WaveRider recommends that you change the community strings before you bring the LMS4000 equipment online, so that outsiders cannot see information about the internal network or configure system components.

Management Information Bases (MIBs)

All messages sent between the SNMP server and a network device are based on number codes. Each of these number codes corresponds to a specific type of information (such as the quantity of data packets received) associated with a specific type of network device (such as a CCU). These number codes and their meanings are stored in a management information base (MIB). The SNMP server and network devices use these MIBs as lookup tables for translating messages sent between them.

LMS4000 implements SNMPv2c and includes a number of standard and enterprise MIBs:

- RFC1157 (MIB-II)
- RFC1493 (bridging)
- WaveRider Enterprise MIB (defined in Appendix G on page 199)

You can download WaveRider Enterprise MIBs, which include a comprehensive set of CCU and EUM parameters and statistics, from the technical support page at www.waverider.com.

4 IP Network Planning

This section describes a plan for assigning IP addresses to LMS4000 900 MHz Radio Network components.

4.1 LMS4000 IP Addressing

Before discussing IP planning, there are a few concepts that are worth reviewing. The first concept is that in the LMS4000 900 MHz Radio Network, IP addresses are assigned to devices for several reasons:

- The device is a router, such as the gateway (NAP) router or the CCU. IP addresses are required for each router port.
- The device is a destination or source for user data. End-user PCs and network servers (such as DHCP servers) fall into this category.
- The operator wants to configure, control, or monitor the device. Virtually all LMS4000 components fall into this category.

The second concept is the segmentation of the LMS4000 network into distinct subnets, as illustrated in Figure 29.

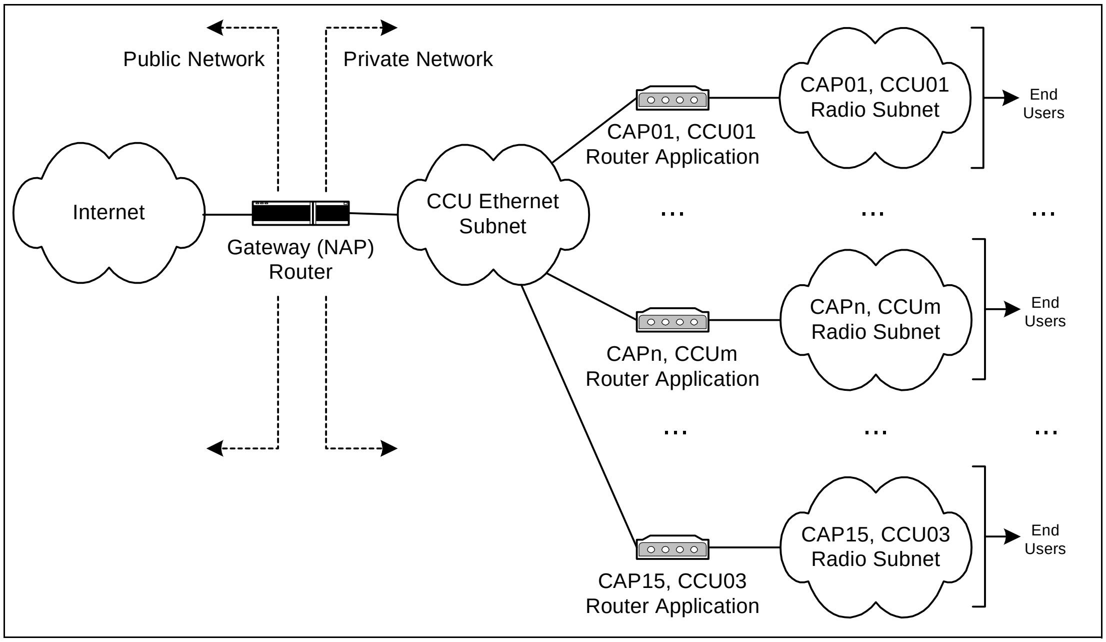


Figure 29 LMS4000 Subnets

Routers isolate the subnets from each other or from the Internet. The router application isolates the CCU radio subnets from the CCU Ethernet subnet, and the gateway (NAP) router isolates the CCU Ethernet subnet from the public Internet.

The number of CAPs that can be supported by one gateway is limited only by the capacity of the gateway router. If a system has 15 CAPs, each supporting three CCUs, the system consists of 45 radio subnets.

The radio subnets extend from the CCU radio port through the EUMs to the end-user PC Ethernet ports. Each radio subnet includes the following elements, all of which, from the standpoint of the LMS4000 network, require a unique, most likely private, IP address:

- CCU radio port one per radio subnet
- EUM up to 300 per radio subnet
- End-user PC (or LAN router)
- Ethernet port one per EUM (up to 300 per radio subnet)

Based on the above, each radio subnet requires a maximum of 601 IP addresses, which necessitates a subnet with a 22-bit subnet mask, which provides 2^{10} = 1024 addresses.

The CCU Ethernet subnet extends from the CCU Ethernet port through backhaul facilities and Ethernet switches to the gateway (NAP) router Ethernet port. The CCU Ethernet subnet includes the following elements, all of which, from the standpoint of the LMS4000 network, require a unique IP address:

- CCU Ethernet ports
- RFSMs, if provisioned

- CAP-NAP backhaul equipment, if provisioned
- CAP and NAP UPS, if provisioned
- Ethernet switches
- SNMP manager, if provisioned
- Gateway (NAP) router Ethernet port

The number of CAPs is limited by the capacity of the gateway (NAP) router. WaveRider suggests allocating a minimum of 256 addresses to the CCU Ethernet subnet, which accommodates 15 CAPs and requires a 24-bit subnet mask.

4.2 IP Planning Process

For reference purposes, an example of an IP Plan is included in Appendix I on page 241.

Before you configure and operate your LMS4000 900 MHz Radio Network, you must define your IP addressing scheme based upon the following guidelines and recommendations:

- WaveRider recommends that LMS4000 subnets use IP addresses that have been reserved for private networks. WaveRider recommends 192.168.10.0 /24 for the CCU Ethernet subnet, and 10.0.0.0 /22 for the CCU radio subnet, since these addresses are quite distinct from each other. If you are already using 10.0.0.0 /22, then you can alternatively use 172.16.0.0 /22.
- The IP addressing plan for the CCU Ethernet subnet should allow for growth to a maximally equipped system, as follows:

• CCU Gateway IP address	one
• NAP equipment IP addresses	up to 10
• CAP equipment Ethernet IP addresses	number of CAPs x 16

  For a 15-CAP system, set aside 251 IP addresses, which requires a subnet with a 24-bit mask, for example 192.168.0.0 /24.

  In the example shown in Appendix I on page 241, the IP addressing plan for the CCU Ethernet subnet is summarized as follows:

CCU Ethernet Subnet	192.168.10.0 /24
Gateway Router	192.168.10.1 /24
NAP Switch	192.168.10.5 /24
NAP UPS	192.168.10.6 /24
SNMP Manager	192.168.10.7 /24
CAP01, CCU01 Ethernet port	192.168.10.11 /24
CAP01, CCU02 Ethernet port	192.168.10.12 /24
CAP01, CCU03 Ethernet port	192.168.10.13 /24
CAP02, CCU01 Ethernet port	192.168.10.27 /24
.....	
CAP15, CCU02 Ethernet port	192.168.10.236 /24

CAP15, CCU03 Ethernet port 192.168.10.237 /24

- As noted above, the IP addressing plan for each CCU radio subnet should allow for growth to a maximally equipped system. Providing 601 IP addresses on the same subnet requires a subnet with a 22-bit mask, for example 172.16.0.0 / 22.

  In the example shown in Appendix I on page 241, the IP addressing plan for the CCU radio subnets is summarized in Table 10:

Table 10 Example — CCU Radio Subnet IP Addressing

CCU	CCU Radio Port	EUM Range	End-user PC Range
CAP01, CCU01	172.16.4.1	172.16.4.2 - 172.16.5.47	172.16.6.1 - 172.16.7.46
CAP01, CCU02	172.16.8.1	172.16.8.2 - 172.16.9.47	172.16.10.1 - 172.16.11.46
CAP01, CCU03	172.16.12.1	172.16.12.2 - 172.16.13.47	172.16.14.1 - 172.16.15.46
CAP02, CCU01	172.16.16.1	172.16.16.2 - 172.16.17.47	172.16.18.1 - 172.16.19.46
...	...	...	...
CAP15, CCU02	172.16.176.1	172.16.176.2 - 172.16.177.47	172.16.178.1 - 172.16.179.46
CAP15, CCU03	172.16.180.1	172.16.180.2 - 172.16.181.47	172.16.182.1 - 172.16.183.46

- The end-user PC Ethernet IP address can be entered statically, or dynamically using DHCP. If DHCP Relay is enabled in the CCU, which WaveRider recommends, and the system operator has installed and properly configured a DHCP server in the network, then the end-user computer can be simply configured to automatically request its IP address from the DHCP server. The operation and configuration of DHCP Relay is discussed in *DHCP Relay* on page 48. To use DHCP, the system operator must allocate, for each CCU radio subnet, a pool of IP addresses from the CCU subnet, such as the contiguous sets of end-user PC IP addresses defined in Table 10.
- If you are using unregistered IP addresses for the EUMs and end-user PCs, these addresses must be translated to globally unique Internet registered addresses before they leave the private domain. Although the CCU functions as a router, it does not provide address translation.

  For end users to access the Internet, you must provide NAT (Network Address Translation). Normally, NAT is provided in the gateway (NAP) router. Refer to *section 4.3*, Network Address Translation for further information.

4.3 Network Address Translation

The following address translation alternatives are listed for reference purposes. Choose the best alternative for your system. Your choice depends on the number of available registered IP addresses. It also depends on the nature of your subscriber base; for example, static NAT may be required to support some of your business users, but dynamic NAT may be adequate for most of your home users.

Static NAT

Static NAT maps an unregistered IP address to a registered IP address on a one-to-one basis. This method of translation is recommended if, for example, end users are using VPN facilities to access remote applications.

Dynamic NAT

Dynamic NAT maps an unregistered IP address to a registered IP address, taken from a pool of registered IP addresses. This method of translation is useful when you have a large number of unregistered users who wish to access the Internet. Depending on the traffic pattern, 10 registered IP addresses may be able to serve 40 end users.

Overloading

Overloading, which is a form of dynamic NAT, maps multiple unregistered IP addresses to a single registered IP address by using different ports. This technique is also known as port address translation (PAT), single-address NAT, or port-level multiplexed NAT. PAT greatly reduces the number of necessary registered IP addresses. When overloading is configured, the router maintains enough information from higher-level protocols to translate the registered address back to the unregistered address for traffic inbound from the Internet.

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5 Radio Network Planning

An important task in the implementation of LMS4000 900 MHz Radio Networks is RF system planning and design. Whether you are deploying a single CCU or a complex multi-CAP, multi-CCU network, proper system design is necessary to provide and maintain high-quality service to end users in your target serving area.

5.1 Design Methodology

The following sections are not intended to provide detailed system design instructions; instead, they provide system design guidelines. WaveRider used this approach for the following reasons:

- Factors affecting system design and implementation vary widely and differ from system to system.
- System design and implementation cannot be encapsulated in a simple formula or set of formulas.

Each system design is unique and must take into account all of the design factors that can influence system operation and performance:

- Topography: Hills and valleys that create coverage holes or conversely, areas that may be very exposed from an RF standpoint, exposing subscribers in these areas to high levels of interference generated from outside the system or by other CAP sites.
- Clutter: Obstructions such as trees and buildings, which tend to reduce the desired signal level and coverage.
- Network Topology: The configuration of the network, implemented to provide optimum service. Network topology is driven by factors such as the location of the Internet point of presence, the availability of towers and roof-top locations that can be used to establish antenna and equipment sites, and the target coverage area.
- Interference: The presence of interference, either in-band (in the ISM band) or out-of-band in your target serving area constrains the freedom that you have for determining the location of CAP sites and for choosing operating frequencies.

In all cases, these wide-ranging factors drive the system design and as a result, no two systems will be implemented the same way.

The design methodology presented in this chapter uses a building-block approach. If the system you are designing is based on a single CCU, you need only read and learn about the guidelines presented in *Basic System Design* on page 60. If you need multiple CCUs or CAPs to satisfy your network requirements, you must perform a much more detailed engineering design based on the general guidelines provided in *Multi-CAP RF Network Design Considerations* on page 67.

For purposes of illustration, coverage areas are presented using the popular cellular hexagonal coverage pattern. In practice, radio coverage does not conform to hexagonal shapes; however, hexagons are used to represent radio coverage because graphically, they can fully cover a plane surface and because they provide an easy-to-understand representation of coverage cells.

5.2 Basic System Design

Basic system design guidelines apply to all LMS4000 system implementations, from a simple, single-CCU system, to more complex multi-CCU CAPs and multi-CAP networks.

5.2.1 Overview of Basic System Design

The basic design of the LMS4000 900 MHz radio network involves the following procedures:

- Conducting a spectral survey to identify, quantify, and assess the impact of existing in-band and out-of-band interference.
- Determining single- or multi-CAP system requirements based on RF coverage, CAP locations, and system loading.

5.2.2 Spectral Survey of the Target Service Area

Before starting the system design, WaveRider recommends conducting a spectral survey of the target serving area to determine the radio landscape—that is, to determine if there are any in-band or out-of-band interferers and how, and to what degree, these interferers constrain your system design (site location, frequency, equipment).

The spectral survey involves travelling to key locations throughout the target serving area, especially to locations that may be potential CAP sites, or where there are significant numbers of potential end users, and recording the radio spectrum (ISM band +/- 10 MHz) at each of these locations. The survey requires the use of a spectrum analyzer and a trained RF engineer who is capable of interpreting the results. There are a number of independent RF engineering firms that can provide this service, including the WaveRider Professional Services Group. If you have access to the required equipment and in-house skill set, you can also conduct this survey yourself.

The spectral survey is a critical first step in the system design. Not only does it provide the starting point for the RF network design, it establishes a baseline for the use and occupancy of the spectrum. Keep in mind that one of the major attractions of the ISM band is the fact that it is license free; as such, it is shared spectrum. To regulate the band, regulatory bodies, such as FCC and Industry Canada, require that new operators in the band take responsibility for resolving interference issues when their newly installed system interferes with systems that are already in operation. The spectral survey identifies systems that are operating in the ISM band and establishes a documented baseline, which may provide you some protection from future ISM-band installations that interfere with the operation of your system.

It cannot be overemphasized that radio communications is, by nature, a non-static environment. As a wireless ISP, the more you know about the RF environment in which you are operating, the better prepared you will be to address future service-affecting changes in this environment. Given that the RF environment is dynamic, WaveRider recommends performing spectral surveys on a regular basis, perhaps every 3-6 months.

5.2.3 In-band Interference

In-band interference occurs when other wireless systems are operating in the same band and in the same geographical area as your system. The impact of in-band interference may be limited—that is, the unwanted signal level may be so low as to have no impact at all, or it may only affect service to a single end user or a small number of end users. In-band interference may, however, be system wide, particularly if it is geographically dispersed around your serving area or it is in close proximity to the CAP. System-wide interference obviously causes the most impact to system operation since it affects all end-users in the serving area.

A primary purpose of the spectral survey is to identify in-band interference so that, if it is present, the RF network design can address the interference sources through careful location of the CAP, equipment configuration, and frequency selection, with the goal of maximizing the ratio of the desired to the interfering signals throughout the serving area. If these measures are not adequate, channel filters can in many cases reduce the interference to levels within the operating tolerance of the LMS4000 radio equipment. Channel filters are discussed in *Using Bandpass Filters at CAP Sites* on page 63.

5.2.4 Out-of-band Interference

The radio spectrum is a finite commodity, which in the growing world of wireless communications, means that all users must compete for this limited resource. The implication is that throughout the service life of your LMS4000 system, you need to be aware of your “RF neighbors” and the impact they may have on your system operation and performance. As described in *Physical Layer (DSSS Radio)* on page 28, the LMS4000 900 MHz product operates in the 902–928 MHz ISM band. In many areas of the world, including North and South America, the 900 MHz ISM band is sandwiched between the top end of the cellular radio band and the bottom end of the commercial paging band.

Cellular radio and paging systems are common in many regions, so you must take precautions when planning your LMS4000 900 MHz radio network. Specifically, you need to know the location of all cellular and paging transmitters that are in, close by, or planned for, your serving area, so that you can limit the impact of these potential interferers through proper site location, equipment configuration, and frequency selection.

Figure 30 shows an actual spectral sweep, recorded using a spectrum analyzer as part of a spectral survey, which shows the location of the cellular and paging transmitters in relation to the ISM band. Note the relative levels of the interfering signals.

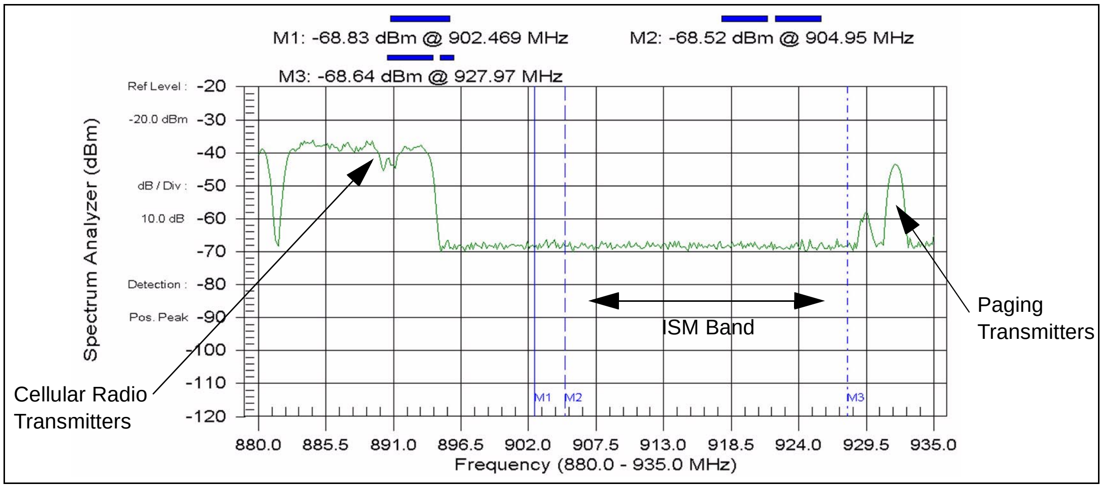

Figure 30 Example of a Spectral Sweep

Cellular and paging systems in the bands adjacent to the ISM band can interfere with your network and need to be addressed as follows:

- Identify and quantify all potential sources of interference by conducting and applying the results of the spectral survey.
- If your CCUs or EUMs are close to cellular or paging sites, their receivers may be desensitized by the high levels of the interfering transmitters, which can operate at very high levels (100 W per cellular radio carrier, 1500 W for paging transmitters). To provide service to these EUMs, choose an operating frequency that is as far from these cellular and paging transmitters as possible.

  Try to assign frequencies that are not adjacent to the cellular or paging channels identified in your serving area. Consider the scenario illustrated in Figure 31. As shown, a cellular tower is located in sector A of the LMS4000 radio network. Since cellular frequencies are located just below the ISM band, a reasonable design approach would be to assign a higher frequency to sector A, such as 915 MHz or 925 MHz.

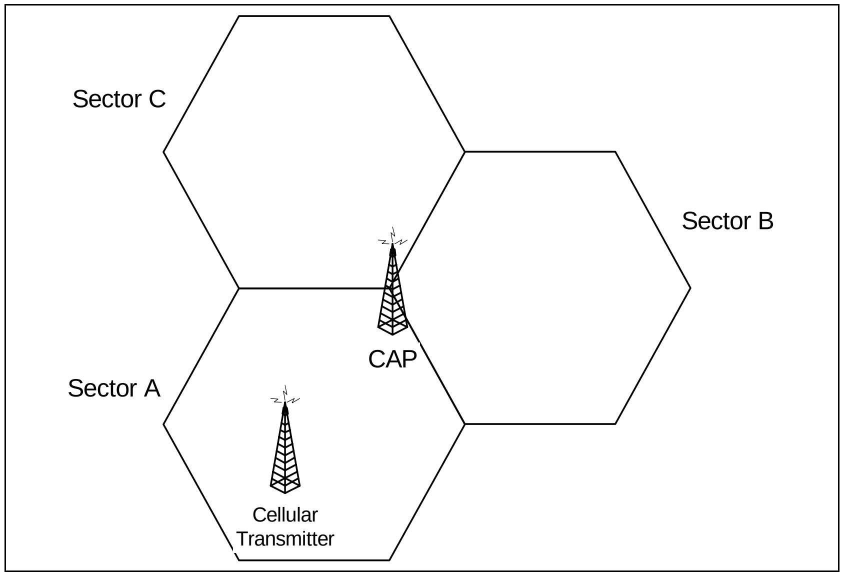

Figure 31 Network Design in the Presence of Out-of-band Interference

5.2.5 Using Bandpass Filters at CAP Sites

WaveRider provides high-quality, specially designed bandpass filters for use with the CCU. These filters reduce the effect of unwanted out-of-band and off-channel in-band interference.

As discussed in *Propagation Path* on page 31, it is highly desirable to locate the CAP site so that the CCU antennas are high enough to provide clear line of sight paths to the maximum number of EUMs in the serving area. The goal is to make sure the CCU can see the maximum number of EUMs and conversely, to make sure the maximum number of EUMs can see the CCU.

Attaining this goal, however, has a consequence since it may mean the CCU will be in an ideal location to see interferers in its sector as well. Bandpass filters at the CCU reduce the effect of interference from out-of-band or off-channel in-band interferers.

On-channel interference may result from

- on-channel interferers in the ISM band, or
- transmitter phase noise or intermodulation products generated by out-of-band interferers.

Bandpass filters cannot resolve on-channel interference; instead, you must change to a more suitable CCU operating frequency.

For CAP sites in which multiple CCUs are installed, use of bandpass filters to ensure non-interfering operation of CCUs is mandatory. It is important to remember that in the 900 MHz ISM band, the radio transmit and receive occur on the same frequency and use Time Division Duplexing (TDD) to switch between the transmit and receive cycles. Multi-CCU installations pose the highest threat of CCU to CCU adjacent channel interference. For the RF network engineer, as specified in Appendix A Specifications, the minimum separation between colocated channels is 6.6 MHz (an orthogonal adjacent channel) and requires a C/I ratio of 50 dB or better for non-interfering CCU operation. Once the antenna system gains and power output of the CCU radio are accounted for, the only way to practically provide adequate isolation for the required adjacent channel isolation is through the use of bandpass filters.

5.2.6 Single- or Multi-CAP Implementation

An important step in basic system design is to determine if a single CAP site adequately covers your target serving area, or if a second CAP site, or multiple CAP sites, will be required. The main factors that drive this decision are the RF coverage and the system loading.

RF Coverage

The RF coverage of the sector is a function of many different factors.

Commercially available radio coverage prediction software calculates radio coverage based on the following factors:

- Propagation characteristics (frequency, distance from the site)
- Radio characteristics (transmit power, receiver sensitivity)
- Antenna system and height
- Topography
- Clutter

Using this coverage prediction software, a qualified RF design engineer is able to produce RF coverage estimates. Again, there are a number of independent RF engineering firms that can provide this service, including the WaveRider Professional Services Group. If you have the required software and in-house skill set, you can perform this coverage analysis yourself.

The location of the CAP site in relation to the serving area determines whether the site will be a corner- or center-illuminated cell. Figure 32 illustrates the difference between these two methods of illumination.

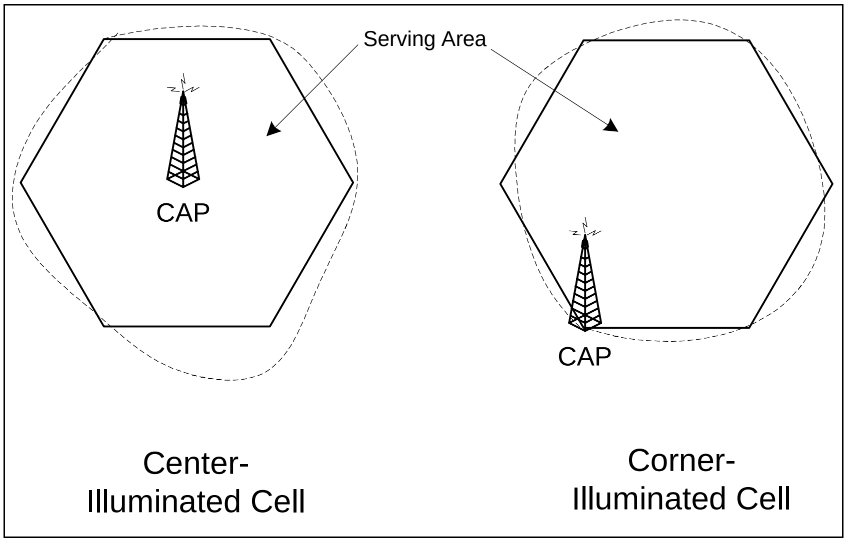

Figure 32 Corner- and Center-illuminated cells

Although the difference between the two approaches may seem academic at first, the choice you make affects the system design, in particular, the selection of sites, site antennas, and the system growth path.

Center Illumination

A center-illuminated cell is generally the simplest to implement. In this case, a site is established at a suitable location near the middle of the target serving area. An omnidirectional antenna is usually installed to deliver 360-degree coverage around the site.

When system traffic increases beyond the capacity of a single CCU because, for example, many subscribers have been added to the system, more CCUs can be added to the CAP site (up to a total of three operating CCUs per CAP site). The omnidirectional antenna would, in this case, be replaced with sectored antennas, for example, three 120-degree sectored antennas. The selection of the sectored antennas would depend on how evenly the subscribers are distributed throughout the serving area. In this example, the resulting configuration would triple the traffic-handling capacity of the site. Figure 33 illustrates the sectoring of a previously center-illuminated omnidirectional cell.

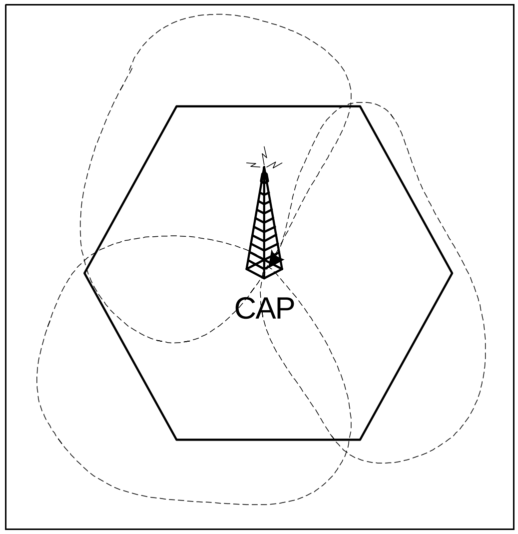

Figure 33 Sectored Cell

Corner Illumination

Corner illumination is generally used when it is not possible to establish a suitable CAP site near the middle of the target serving area. Implementation of a corner-illuminated cell requires more extensive site and system engineering than does the implementation of a center-illuminated cell. This is particularly true when additional traffic-handling capacity is required, since techniques such as overlay/underlay sectors (adding a second CCU to provide coverage to the same geographical area) may have to be applied.

The use of omni-directional antennas at CAP sites, although simple in implementation, is only recommended for simple network installations with low risk of interference and limited exposure to other sites. Omni-directional antennas, by definition, are designed to provide coverage in all directions (360°) horizontally around the antennas. This wide angle-of-view provides for simplicity of an omni-directional antenna installation but also means that the omni-directional antenna is susceptible to any interference in the area. As such, the RF network designer, when faced with interference or system expansion will generally need to replace the omni-directional antenna(s) (and possibly multiple CCUs) in order to serve the same coverage area and to make use of the directional properties of the antennas to address system issues.

System Loading

Sometimes, even with well-engineered RF coverage, the user traffic may be so high that you need to expand the network to a multi-CAP system.

The answer to the question “How many subscribers can each CCU support?” is a qualified “It depends.” Refer to *Performance Modelling* on page 42 for a description of the method used by WaveRider to predict the number of end-users that can be supported by the LMS4000 network. Total system traffic is very dependent on the usage profile of the end users and the tariff structure that has been implemented by the system operator. For instance, an LMS4000 900 MHz system that is providing service to a number of small businesses, each supporting multiple users, likely generates a lot more daytime traffic than a simple residential service used for Web browsing and email.

In summary, the network design engineer must be aware of the intended use of the system — the customer profile, tariff rates, and committed grades of service — since these factors all influence the traffic demand on the system.

5.3 Multi-CAP RF Network Design Considerations

One of the differentiating features of the LMS4000 900 MHz radio system is its ability to support multi-CAP networks. The design of multi-CAP networks is significantly more complex than the design of single-CCU or single-CAP systems. WaveRider highly recommends the use of a qualified RF engineering firm, such as the WaveRider Professional Services Group, to carry out multi-CAP system design. If you are confident that you have the required skill set available in house, you can carry out this design yourself.

5.3.1 Multi-CAP Network Design Process

The process for designing a multi-CAP network can be summarized as follows:

1. Conduct a preliminary site survey and selection.
2. Apply a frequency grid to the sites that you have selected.
3. Determine the site-to-site signal levels by
    - Determining site-to-site distances,
    - Calculating site-to-site propagation loss,
    - Normalizing the signal levels at each site, and
    - Factoring in the antenna isolation.
4. Using the C/I information presented in *C/I Requirements* on page 68, formulate a frequency plan and channel assignment.
5. Perform and apply antenna down-tilt calculations.
6. Assess the impact of known in-band and out-of-band interferers.
7. Verify and iterate the design as many times as necessary.

This chapter does not provide detailed instructions on how to carry out each of the above tasks as it is beyond the scope of the document. It does, however, provide you with the LMS4000-specific information that you or your RF engineering firm need to be able to carry out the above steps.

5.3.2 Frequency Selection — Standard Frequency Set

LMS4000 900 MHz equipment (CCUs and EUMs) can operate on all channels from 905 to 925 MHz, in increments of 0.2 MHz (refer to Table 6 on page 29 for channelization information). Throughout this manual, however, WaveRider has referred to the standard frequency set shown in Table 11.

Table 11 Standard Frequency Set

905.0MHz
915.0MHz
925.0MHz

The standard frequency set represents a convenient and safe set of frequency assignments. The frequencies are orthogonal in that they do not overlap, and they provide enough separation between the frequencies so that one channel does not interfere with either of the other channels, even if they are installed at the same CAP site with appropriate filters. Using the standard frequency set, you can implement small systems without much concern for self-generated interference.

In the case of a multi-CAP network, however, the standard frequency set may not be inadequate. Instead, you must use other sets of frequencies at neighboring CAP sites. The selection of these other frequency sets is governed largely by the minimum C/I requirement for the CCU and EUM radio; i.e., the amount of interference, from within or from outside the system, that the LMS4000 radio equipment can tolerate.

5.3.3 C/I Requirements

The CCU/EUM C/I requirements are outlined in Table 12.

Table 12 Required C/I Ratio for Multi-CAP Design

C/I Ratio	Frequency Separation	PER
22dB	0.2MHz	$\leq$ 1%
19dB	1.6MHz	$\leq$ 1%
11dB	3.4MHz	$\leq$ 1%

As shown in Table 12, as the frequency separation between the desired LMS4000 signal and an interfering LMS4000 signal increases, the level of an interfering signal that can be tolerated also increases. Consider the case where the frequency separation between the desired channel and an interfering channel from a remote site is 0.2 MHz. To maintain a packet error rate of 1% in the local cell, you would need to ensure that the EUMs in the local cell are receiving the desired CCU signal at a level which is at least 22dB higher than the interfering CCU signal, 0.2MHz away.

Using this information, and information about the number and location of the required CAP sites, your RF designer should be able to define a frequency plan for your system.

As an example, consider the frequency plan shown in Table 13.

Table 13 Sample Frequency Plan — Multi-CAP Design

Frequency Set A	905.0	-	911.6	-	918.4	-	925.0
Frequency Set A'	-	908.4	-	915.0	-	921.6	-

In Table 13, *Frequency Set A* uses the minimum frequency spacing that should be considered for a single CAP site, 6.6MHz. *Frequency Set A'* represents a set of channels which are interstitial to those in *Frequency Set A*. The channels in *Frequency Set A'* fall midway between the channels in *Frequency Set A* yet still adhere to the minimum recommended spacing between any two colocated channels, 6.6MHz.

From Table 12, if two sites have a frequency separation of 3.4 MHz (*Frequency Set A* to *Frequency Set A'*, for example), a C/I signal margin of 11dB is required.

CAUTION: The concept of frequency reuse patterns, commonly used in the design of cellular radio systems, cannot be directly applied in the design of LMS4000 900MHz radio networks. Instead, due to the nature of the Polling MAC, you should never reuse frequencies in networks where a CCU or EUM can receive a signal from a unit in another sector or coverage area. The minimum channel separation cannot be less than 0.2MHz s a minimum. When Polling MAC is applied in a multi-CAP environment, it is possible for an EUM to inadvertently lock onto the signal from a remote CCU if that CCU is operating on the same frequency. This situation does not occur if the remote CCU is offset by 0.2MHz or more from the local CCU, and the required C/I ratio is maintained. In summary, no two CCUs in a single network can be assigned exactly the same frequency .

5.3.4 Dealing with External Interference

Up to this point, the discussion has been concentrating on the effect of self-generated interference—that is, interference between CAPs or EUMs in the same network.

As indicated in *Basic System Design* on page 60, you must also account for the effect of external interferers such as cellular and paging systems. The RF system design engineer needs to make sure external interference sources do not affect system operation. You can use a similar treatment to the one developed above for self-generated interference to assess the effects of external interference sources.

5.3.5 Verifying the Design

No matter how carefully the system has been designed, you must verify the system in the field before turning it up to ensure network operation is consistent with the design standards set out by the system design engineer. With this in mind, your system implementation plan must provide enough time and resources for the engineering team to verify the design in the field through testing and signal-level measurements.

Once you have established your CAP sites on the air, you can verify received signal levels throughout the network using a portable spectrum analyzer. You can then compare these with those predicted by the RF system design. In many cases, discrepancies between predicted and actual results can be corrected, if necessary, through adjustment of antenna azimuths and/or down-tilting.

As the system grows and capacity is added, the frequency plan may have to be adjusted and more attention given to fine-tuning the isolation between CAP sites.

Verification Checklist

When reviewing and verifying the design of a multi-CAP network, here is a checklist of items that might be considered:

- General system design considerations:
    - Paging transmitters
    - Cellular transmitters
    - In-band interference
    - Frequency assignments
- CAP-to-CAP frequency assignments and isolation, achieved through
    - Lowering antenna heights,
    - Antenna mounting, and the use of mounting structures to achieve greater isolation (building, towers),
    - Antenna radiation patterns (directionality and side lobes), and
    - Antenna characteristics, back to front isolation.
- CAP-to-EUM propagation must provide coverage to all EUMs from selected sites. Run the RF model with the specified system parameters to verify thorough propagation.

5.3.6 Summary of RF Design Guidelines

A summary of guidelines presented in this chapter can be found in Table 14.

Table 14 Summary of RF Design Guidelines

DO	DO NOT
• DO read and understand this chapter before you start your system design activity. • DO contact WaveRider Professional Services Group if you need assistance with spectral surveys, RF coverage analyses, or system engineering. • As a first step, always DO a spectral survey. • DO understand the RF environment in your serving area, and DO learn as much as you can about potential sources of interference. • DO verify your system design through field testing, prior to turning up the service to end users. • DO try to design your system to take advantage of your existing real estate or radio sites. • DO use bandpass filters to reduce the effect of off-channel in-band and out-of-band interference. • DO use different frequency assignments or take advantage of antenna patterns to address on-channel interference. • Wherever you can, DO use the standard frequency set. • In the design of multi-CAP networks, DO maintain the required C/I ratio shown in Table 12 on page 68. • In a multi-CAP network, DO use a minimum frequency offset of 0.2 MHz between CCUs. • DO migrate from an omnidirectional to a sectored cell when your traffic warrant it, or interference is an issue.	• DO NOT assume a static RF environment. • DO NOT install the CAP site in proximity to in-band or out-of-band interferers. • DO NOT install the CAP site in a low area, or area surrounded by clutter and obstructions. • DO NOT use frequencies that are close to the edges of the ISM band if you have identified cellular and paging transmitters above or below the band. • DO NOT ignore the usage patterns of your end users when designing your network. • DO NOT assign the same frequency to two or more CCUs in your network.

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6 Installation/Diagnostic Tools

The CCU and EUM are equipped with the following features that facilitate unit installation, operation, maintenance, monitoring, and diagnostics:

CAUTION: When entering IP addresses in the CCU or EUM, note that a leading ‘0’ forces the CCU or EUM operating system to interpret the entry as octal rather than decimal. For example, pinging 10.0.2.010 actually pings 10.0.2.8

6.1 Indicators and Connectors

The CCU and EUM are equipped with LED indicators that provide a visual indication of the status of the unit and its interfaces. The EUM LED indicators are illustrated in Figure 34, the CCU LED indicators in Figure 35, and a detail view of the Ethernet connector in Figure 36.

Figure 34 EUM LEDs and Connectors

Figure 35 CCU LEDs and Connectors

The LEDs are described below:

6.1.1 Network LED

Table 15 Network LED

LED State	Ethernet Traffic Status
OFF	No Ethernet traffic present
ON Solid	Ethernet traffic present but no radio traffic
Fast Flash	Ethernet and radio traffic present

NOTE: A Network LED *fast flash* flashes at 2.5 Hz, 50% duty cycle, about two or three times per second.

6.1.2 Radio LED

In the following table, RSS is the Radio Signal Strength, in dBm.

Table 16 Radio LED

LED State	RSS Value
OFF	No radio signal present
Slow Flash	Receive Threshold < RSS < -80 dBm
Fast Flash	-80 dBm ≤ RSS < -70 dBm
ON Solid	RSS ≥ -70 dBm

NOTE: A Radio LED *slow flash* flashes at 0.83 Hz, 33% duty cycle, about once per second. A Radio LED *fast flash* flashes at 2.5 Hz, 50% duty cycle, about two or three times per second.

6.1.3 Power LED

Table 17 Power LED

LED State	Power Status
OFF	No power
ON	Power

6.1.4 Ethernet LEDs

The Ethernet connector used in the CCU and EUM, shown in Figure 36, has two LEDs. These LEDs are described in Table 18.

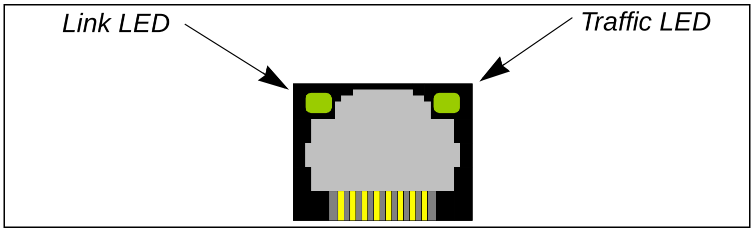

Figure 36 Ethernet LEDs

Table 18 Ethernet LEDs

LED State	Ethernet Status
Link LED	If the Link LED is ON, the Ethernet physical connection is configured and working properly. If the Link LED is OFF, then the Ethernet physical connection is not working properly, which could be because the wrong type of cable was used (a straight-through cable at the EUM instead of a crossover cable) or there is a problem with the host or device Ethernet interface.
Traffic LED	The Traffic LED flashes whenever the link is transferring data.

The CCU is equipped with the same LEDs as the EUM but in a slightly different physical configuration. As shown in Figure 35, the CCU indicator LEDs are closely grouped and are, in order left to right: Power LED, Radio LED (not used on CCU), and Network LED.

6.2 Command-line Interface

The CCU and EUM are equipped with a simple command line interface through which you can monitor unit status and configure all unit parameters. The command-line syntax is defined in Appendix C on page 123.

The command-line interface can be accessed

- locally or remotely, using a Telnet session, or
- directly, through the DB-9 console port on the CCU and EUM, using a PC equipped with terminal emulation software, using the console settings specified in Table 19.

Table 19 Console Settings

Bits per second	9600
Data bits	8
Parity	None
Stop bits	1
Flow Control	None

6.3 EUM Configuration Utility

The EUM can also be configured and monitored using the EUM Configuration Utility, a Windows-based graphical user interface (GUI) running on a PC. The PC connects to the CCU or EUM through the DB-9 console port, the unit Ethernet port, or from anywhere in the LMS4000 900 MHz Radio Network. The Configuration Utility and Configuration Utility User Guide can be downloaded from the WaveRider Web site at www.waverider.com.

6.4 RSSI/Tx Quality/Antenna Pointing

The EUM Radio LED and the continuous Receive Signal Strength Indication (RSSI) reading provide an indication of the level of the signal received from the CCU and an excellent tool for locating and aligning the EUM antenna. Since the system is based on a polling MAC, there will always be a signal to receive and monitor from the CCU.

The procedure for aligning the EUM antenna, which is discussed in more detail in *Positioning the Antenna* on page 111, can be summarized as follows:

1. Connect the indoor antenna to the EUM and power up the EUM.
2. Once the EUM is fully booted, monitor the Radio LED while moving the antenna around the room between suitable installation sites until you find the best signal. Use Table 16 on page 75 as a guide.
3. If the best location produces a *Fast Flash* or *ON Solid* Radio LED, then the received signal level is good to excellent, and this is a good location to install the antenna.
4. If the best location produces a *Slow Flash* Radio LED, then the received signal is marginal. To attain the best possible signal below the Fast Flash LED level, turn on the Continuous RSSI through the command-line interface, as follows:

```
Console> radio rssi
Press any key to stop

     RSSI         RX;  TX;  R1;  R2;  R3;   F;Retry%
RSSI:  73          0;   0;   0;   0;   0;   0;   0%
```

```
RSSI:  73        865;   0;   0;   0;   0;   0;   0%
RSSI:  73        932;   0;   0;   0;   0;   0;   0%
RSSI:  73        933;   0;   0;   0;   0;   0;   0%
RSSI:  74        709;   0;   0;   0;   0;   0;   0%
RSSI:  73        743;   0;   0;   0;   0;   0;   0%
RSSI:  74        747;   1;   0;   0;   0;   0;   0%

Console>
```

Adjust the antenna location and pointing for maximum RSSI. You may need to adjust the antenna and then step back each time to read the RSSI, so you do not obstruct the signal from the CCU.

Note that the RSSI value is only a representation and does not give a true indication of receive signal level. A higher RSSI value does, however, indicate a higher receive signal level, so it can be used to indicate a best antenna placement.

To calculate the true receive signal level, use the calibration table contained in the PCF file, described in *Permanent Configuration File (CCU and EUM)* on page 193.

The EUM Configuration Utility can also be used to optimize antenna pointing and does provide a true reading of receive signal strength.

6.5 Transfer a File to or from a CCU Using FTP

You can run a simple FTP test from the EUM to verify the performance and integrity of the communications between the CCU and EUM. The procedure outlined below will *get* a file from the CCU (we suggest using the backup file for the CCU application, *sa1110.bak*), and then (temporarily) *put* a file onto the CCU. In both cases, you can record the file transfer performance. WaveRider recommends doing this procedure with a screen capture, so you have a permanent record to baseline the performance of the link, for example.

Before you carry out the FTP test, you may want to baseline the performance of the computer you are using at the EUM, by first connecting it directly to an FTP server and running an FTP test back-to-back with the server. This back-to-back FTP test should be at least 3 Mbps, or you may have a problem with your server or computer setup.

To Transfer a File to or from a CCU Using FTP

1. From the end-user computer at the EUM, bring up the Windows command line interface.
2. At the Enter prompt, type **`ftp <aaa.bbb.ccc.ddd>`**, where <aaa.bbb.ccc.ddd> is the CCU radio IP address.
3. In the FTP window, enter the following commands to *get* sa1110.bak from the CCU:

```
Connected to <aaa.bbb.ccc.ddd>.
220 FTP server ready
User (<aaa.bbb.ccc.ddd>:(none)):  Enter <user name> or <cr> if none set
331 Password required
Password:                        Enter <pwd> or <cr> if none set
230 User logged in
ftp> hash
```

```
Hash mark printing On  ftp: (2048 bytes/hash mark) .
ftp> binary
200 Type set to I, binary mode
ftp> get sa1110.bak
200 Port set okay
150 Opening BINARY mode data connection
############################################################################
###
############################################################################
###
##################################################################
226 Transfer complete
ftp: 463713 bytes received in 10.80Seconds 42.96Kbytes/sec.
ftp>bye
221 Bye...See you later.
```

4. Enter the following commands to *put* the sa1110.bak file to the CCU.

```
Connected to <aaa.bbb.ccc.ddd>.
220 FTP server ready
User (<aaa.bbb.ccc.ddd>:(none)):
331 Password required
Password:
230 User logged in
ftp> hash
Hash mark printing On  ftp: (2048 bytes/hash mark) .
ftp> binary
200 Type set to I, binary mode
ftp> put sa1110.bak null
200 Port set okay
150 Opening BINARY mode data connection
############################################################################
####
############################################################################
####
##################################################################
226 Transfer complete
ftp: 463713 bytes sent in 8.30Seconds 55.86Kbytes/sec.
ftp>bye
221 Bye...See you later.
```

Entering `null` after the *put* command ensures the file will not be permanently stored to CCU memory. If you inadvertently forget to enter `null` after the *put* command and save the file to CCU memory, the throughput performance of the CCU may be reduced significantly. You can remove the file using the CCU file services, available through the command line interface. As long as you enter `null` after the *put* command, any size file can be used.

The FTP throughput should correspond to a value slightly less than the maximum allowed by the GOS, assuming no other traffic is being carried by the CCU.

6.6 Operating Statistics

The CCU and EUM collect a wide range of IP, radio, MAC, and network layer statistics, which can be used for measuring system performance and troubleshooting. These statistics can be accessed through the command line interface, outlined in Appendix C on page 163 or by using an SNMP manager. A list of available statistics and their meanings can be found in Appendix H on page 223.

6.7 SNMP

The CCU and EUM are SNMP-ready. To make use of the CCU and EUM SNMP capabilities, you must obtain the associated WaveRider MIBs from the technical support page at www.waverider.com and install them on your SNMP manager (SNMPc, or HP OpenView, for example).

Once you have obtained and installed these MIBs, you will, from the SNMP manager, be able to carry out the following functions for both CCUs and EUMs:

- Read hardware and software configuration parameters, such as unit serial number, MAC address, regulatory domain, and hardware and firmware version.
- Read operator-configurable parameters, such as IP addresses, radio frequency, transmit power level, and the contents of the CCU Authorization and Registration Tables.
- Read system operating statistics from the MAC layer, and the radio and Ethernet drivers.
- Receive trap messages such as CCU or EUM power cycles.

In addition, you can program your SNMP manager to perform the following operations:

- Generate a warning or alarm whenever an operating statistic falls outside an acceptable range.
- Perform mathematical calculations on a collection of statistics and generate a warning or an alarm if the result of the calculation falls outside an acceptable range. This calculation is done when a statistic, in isolation, cannot be interpreted; i.e., it can only be interpreted properly when compared with the current value of other statistics.
- Perform a trend analysis on a statistic or group of statistics and generate a warning or alarm when the statistic or group of statistics is starting to move towards an unacceptable limit.

For more detailed information on how to use SNMP to monitor the performance of your LMS4000 900 MHz Radio Network, refer to *Monitoring the Network* on page 127 and Appendix G on page 199.

6.8 Field Upgrade Process

CCU and EUM operating software can be upgraded using FTP. The upgrade mechanism is designed to be robust and reliable.

Hash codes are generated with each new software image. The new image is FTPed with the hash code to the unit that is being upgraded, and the new software is received and written to memory. A hash code for the new image is generated locally and compared with the hash code that was FTPed with the new image.

If the hash code comparison is unsuccessful, the downloaded image will not be written to the file system, and a report will be returned.

If the hash code comparison is successful, then the existing executable software is copied as a backup (.bak file), and the newly downloaded image becomes the unit executable.

The unit is automatically rebooted. If the new executable is found to be corrupt for any reason, then the unit reverts to the backed-up, older image.

6.9 FTPing CCU and EUM Configuration Files

FTP enables you to transfer configuration files to CCUs and EUMs from anywhere that has network access to the LMS4000 900 MHz Radio Network. FTP is a useful tool for the following operations:

- Restoring a unit to an earlier working state.
- Restoring configuration files that have been corrupted.
- Configuring replacement CCUs and EUMs when units have failed.
- Changing default configurations, such as GOS.

Some of the configuration files may be the same throughout the network (port filter configuration file, for example), and others are different for all units. Some configuration files are loaded instantly (as soon as the file is FTPed), and some require a unit reboot to take effect. Table 20 provides a summary of the configuration files used in the CCUs and EUMs, whether they are typically the same throughout the system, and whether they require a unit reboot to take effect.

Table 20 FTPing Configuration Files

Configuration File	File Name	CCU	EUM	Reboot Required?	System-wide? (note 1)
GOS Configuration File	gosbe.cfg gosbronz.cfg gossilve.cfg gosgold.cfg	Yes		No	Yes
Authorization Configuration File	authdb.cfg	Yes		No	No
DHCP Configuration File	dhcp.cfg	Yes		Yes	Yes
Port Configuration File	port.cfg	Yes	Yes	Yes	Yes
Route Configuration File	route.cfg	Yes		Yes	No
SNTP Configuration File	port.cfg	Yes	Yes	Yes	Yes
Basic Configuration File	basic.cfg	Yes	Yes	Yes	No

NOTE: System-wide means that the configuration file in question (for example, the port configuration file) will normally be the same throughout your network. Configuration files, such as the route configuration file, vary from CCU to CCU.

CAUTION: Use FTP to transfer configuration files between like units only; for example, from a CCU to another CCU. (Ensure the file is transferred using image or binary mode.) Although port filters are used in both the CCU and EUM, there may be differences between the port configuration file for the CCU and the port configuration file for the EUM.

One way of using this feature is to build configuration files using a spare CCU and a spare EUM, both of which have their RF outputs terminated in 50-ohm loads (or they could be connected to each other through an attenuator), to ensure

- the units are not transmitting signals that could interfere with operating CCUs and EUMs, and
- the units are not damaged by transmitting into an open circuit.

Once the CCU or EUM configuration files are built and saved in the spare units, they can be downloaded to target CCUs and EUMs, as necessary. GOS configuration files are provided by WaveRider.

Alternately, the configuration files could be built and saved in operating units, then downloaded from these units to other CCUs and EUMs in the system.

FTP takes the specified configuration files from CCU or EUM memory, so changes must be saved to show up in the downloaded files. Use the CLI <save> command to ensure they have been written to the file system with the proper checksum attached.

7 Configuring the CCU

This section explains the following procedures and topics:

Before you configure the CCU

- Familiarize yourself with the CLI commands, syntax and shortcuts, outlined in Appendix C on page 163. This appendix provides a complete list of the available CCU commands, some of which are not discussed in this section.
- Connect a PC to the CCU directly to the console port, or through a Telnet session. See *Command-line Interface* on page 76 for console settings.

CAUTION: Remember to regularly enter **save** or **commit** and press **Enter**, to save your configuration changes to the file system. As well, some parameters and configuration files (refer to Table 20 on page 81 for details) do not take effect until you reboot the unit, specifically the RF frequency, transmit power, and IP addressing.

CAUTION: After you have finished making your configuration changes, remember to disconnect your terminal from the CCU.

CAUTION: When entering IP addresses in the CCU or EUM, note that a leading '0' forces the CCU or EUM operating system to interpret the entry as octal rather than decimal. For example, pinging 10.0.2.010 actually pings 10.0.2.8

7.1 CCU and EUM Serial Number, MAC Address, and Station ID

The EUM/CCU product ID, serial number, station ID, and Ethernet and radio MAC addresses, are related:

- **Product ID:** The product ID is the 14-character string just below the bar code on the product label, which is affixed to the case of the unit, for example:
  - EUM3000AB02A129E00A32
- **Serial Number:** The serial number is the last six characters of the product ID. In the above example, the serial number is:
  - E00A32
- **Station (CCU or EUM) ID:** The station ID is derived by prefacing the last four characters of the serial number with '60'. In the above example, the station ID, in hexadecimal notation, is:
  - 60:0A:32
- **Ethernet MAC Address:** The Ethernet MAC address is derived by prefacing the serial number with the characters '00:90:c8'. In the above example, the Ethernet MAC address is:
  - 00:90:c8:E0:0A:32
- **Radio MAC Address:** The radio MAC address is derived by prefacing the station ID with the characters '00:90:c8'. In the above example, the radio MAC address is:
  - 00:90:c8:60:0A:32

7.2 Setting the CCU Password

To Change the CCU Password

1. Type **password** and press **Enter**.
2. At the **Enter Current Password** prompt, type the old password.
3. At the **Enter New Password** prompt, type the new password.

TIP: Passwords are alphanumeric and case-sensitive. For example, "abc" is not the same as "aBc".

4. At the **Verify password** prompt, type the new password again.

   The system displays a message that your password has been successfully changed.

Example:

```
Console> password
Enter Current Password: ********
Enter New Password: ********
Verify password: ********
Saving new password
Password Changed
Console>
```

CAUTION: Remember to record the password. Unlocking the CCU can only be performed by contacting WaveRider Technical Support.

7.3 Configuring the CCU RF Parameters

To set the CCU Operating Frequency

1. Type **radio frequency <frequency>** and press **Enter**.
   - <frequency> is the CCU operating frequency in tenths of a MHz. For example, 917.0 MHz is entered as `9170`.
2. Type **save** or **commit** and press **Enter**.
3. Before the new radio frequency will take effect, you must reboot the CCU by typing **reset** and pressing **Enter**.

To set the CCU Power Level

1. Type **radio rf <power level>** and press **Enter**.
   - <power level> is the CCU transmit power level, either `high` (+26 dBm) or `low` (+15 dBm). In most cases, the CCU power level should be set to `high`.

   NOTE: Use the HIGH power level unless your site has unique requirements for which the LOW power level is more appropriate.

2. Type **save** or **commit** and press **Enter**.
3. Before the new power level will take effect, you must reboot the CCU by typing **reset** and pressing **Enter**.

Example:

The following example

- Sets the CCU operating frequency to 917 MHz,
- Sets the transmit power level to `high`,

- Saves the new settings,
- Reboots the CCU so that the new parameters take effect, and
- Displays the CCU RF parameters.

```
Console>
Console> radio frequency 9170
Console> radio rf high
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved
Console>
Console> reset
rebooting CCU ...

(... Power On Self Test ...)

WaveRider Communications, Inc. LMS3000
Password:
Console>
Console> radio
RF Power: HIGH
Radio Frequency: 9170
Console>
```

7.4 Configuring CCU IP Parameters

In *IP Network Planning* on page 53, you determined the following:

- CCU gateway IP address and subnet mask
- CCU radio IP address and subnet mask
- CCU Ethernet IP address and subnet mask

To set the CCU Ethernet IP address

1. Type **ip ethernet <aaa.bbb.ccc.ddd> <net mask>** and press **Enter**.
    - <aaa.bbb.ccc.ddd> is the CCU Ethernet IP address.
    - <net mask> is the net mask.

CAUTION: The CCU only accepts subnet masks using the shorthand notation; for example, it accepts '`16`', but not '`ffff0000`' or '`255.255.0.0`'.

2. Type **save** or **commit** and press **Enter**.
3. Before the new CCU Ethernet IP address will take effect, you must reboot the CCU by typing **reset** and pressing **Enter**.

To set the CCU radio IP address

1. Type **ip radio <aaa.bbb.ccc.ddd> <net mask>** and press **Enter**.
   - <aaa.bbb.ccc.ddd> is the CCU radio IP address.
   - <net mask> is the net mask.
2. Type **save** or **commit** and press **Enter**.
3. Before the new CCU radio IP address will take effect, you must reboot the CCU by typing **reset** and pressing **Enter**

   NOTE: The CCU Ethernet and gateway IP addresses must be on the same subnet, as explained in *LMS4000 IP Addressing* on page 53.

To set the CCU gateway IP address

1. Type **ip gateway <aaa.bbb.ccc.ddd>** and press **Enter**.
   - <aaa.bbb.ccc.ddd> is the CCU gateway IP address.
2. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Sets the CCU Ethernet IP address to 10.0.4.48 / 16,
- Sets the CCU radio IP address to 10.5.0.1 / 16,
- Sets the CCU gateway IP address to 10.0.0.1,
- Saves the new settings,
- Reboots the CCU so that the new parameters take effect, and
- Displays the CCU IP parameters.

```
Console>
Console> ip ethernet 10.0.4.48 16
Console> ip radio 10.5.0.1 16
Console> ip gateway 10.0.0.1
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved
Console>
Console> reset
rebooting CCU ...

(... Power On Self Test ...)

WaveRider Communications, Inc. LMS3000
Password:
Console>
Console> ip
Ethernet IP Address: 10.0.4.48
```

```
Ethernet Net Mask  : ffff0000
Gateway IP Address: 10.0.0.1
Radio IP Address: 10.5.0.1
Radio Net Mask  : ffff0000
Console>
```

7.5 Configuring DHCP Relay

To configure DHCP relay

- Determine the DHCP server IP address.
- Enable DHCP Relay.
- Add the DHCP server to the CCU.

To add a DHCP server

1. Type **dhcp relay add <aaa.bbb.ccc.ddd> <net mask>** and press **Enter**.
   - <aaa.bbb.ccc.ddd> is the IP address of the DHCP server you want to add.
   - <net mask> is the net mask of the DHCP server.
2. Repeat step 1 for any alternate DHCP servers in your network. WaveRider recommends that your network have at least one alternate DHCP server.
3. Type **save** or **commit** and press **Enter**.

To enable DHCP Relay

1. Type **dhcp enable** and press **Enter**.
2. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Enables DHCP relay,
- Adds a DHCP server with IP address 192.168.50.1 /24,
- Adds an alternate DHCP server with IP address 192.168.50.15 /24,
- Saves the new settings, and
- Displays the DHCP status.

```
Console> dhcp enable
Console>
Console> dhcp relay add 192.168.50.1 24
Console> dhcp relay add 192.168.50.15 24
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
```

```
DHCP Server Config saved
Console>
Console> dhcp relay
DHCP Relay Enabled:

DHCP Server Table:

DHCP Server Table:

  IP Address: 192.168.50.1
  Mask      : ffffff00

  IP Address: 192.168.50.15
  Mask      : ffffff00

Console>
```

7.6 Configuring Port Filtering

To add a port filter

- Determine the port number you want to filter.
- Determine whether you want to filter UDP, TCP, or both types of packets.
- Add the port filter to the CCU.

To add a port filter

1. Type **port add <number> <type>** and press **Enter**.
   - <number> is the number of the port you want to filter.
   - <type> is the type of IP packet you want to filter, either `udp, tcp,` or `both.`
2. Repeat step 1 for any other ports that you want to filter out.
3. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Configures the CCU to filter both UDP and TCP packets on ports 137, 138, 139 and 1512,
- Saves the new settings, and
- Displays the TCP/UDP port filters.

```
Console> port add 137 both
Console> port add 138 both
Console> port add 139 both
Console> port add 1512 both
Console>
Console> save
Basic Config saved
Port Filter Config saved
```

```
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved
Console>
Console> port
PORT FILTERS
    Port                   Filter
---------------------------------
      137                   both
      138                   both
      139                   both
     1512                   both
----------------------------------
Console>
```

NOTE: The EUM factory default settings have ports 137, 138, 139, and 1512 filtered out for both TCP and UDP, to prevent Network Neighborhood from seeing other end users' computers.

7.7 Configuring the SNTP/UTC Time Clock

To configure the SNTP/UTC clock

- Add an NTP server, if the one to which you want the CCU to synchronize has not already been added. You may want to delete the default NTP servers, to force the CCU to synchronize to the server you are adding.
- Set the SNTP client resynchronization period. The factory default setting is 3600 seconds, and WaveRider recommends not changing this default setting.
- Set the SNTP client retry period. The factory default setting is 30 seconds, and WaveRider recommends not changing this default setting.
- Enable the SNTP client, to force the CCU to synchronize to an NTP server.
- Enable the SNTP relay, if you want the EUMs to be synchronized to the CCU.

To add an NTP server

1. Type **time add <aaa.bbb.ccc.ddd>** and press **Enter**.
    - <aaa.bbb.ccc.ddd> is the IP address of the NTP server you are adding.
2. Type **save** or **commit** and press **Enter**.

CAUTION: The CCU NTP server list must always contain the local host, which is 127.0.0.1. This entry is required for the case where the CCU loses connectivity with the other NTP servers in the list.

NOTE: Up to four NTP servers can be configured in the CCU, which is shipped from the factory configured factory-default NTP servers. To add an NTP server, you must delete one of the four defaults.

Once again, **do not delete 127.0.0.1**. If you inadvertently delete it from the list, when you use the `flush` command, for example, it must be re-entered.

NOTE: It is a good idea to ping the time servers from the CCU before adding them, to ensure you have connectivity.

To set the SNTP client resynchronization time

The SNTP client resynchronization period is the time between a successful CCU resynchronization and the next CCU resynchronization attempt, typically set to 3600s (one hour).

1. Type **time client resync <seconds>** and press **Enter**.
   - <seconds> is the resync period in seconds.
2. Type **save** or **commit** and press **Enter**.

To set the SNTP client retry period

The SNTP client retry period is the time between an unsuccessful resynchronization attempt and the next resynchronization attempt, typically set to 30 seconds.

1. Type **time client retry <seconds>** and press **Enter**.
   - <seconds> is the retry period in seconds.
2. Type **save** or **commit** and press **Enter**.

To enable the SNTP client

1. Type **time client enable** and press **Enter**.
2. Type **save** or **commit** and press **Enter**.

To enable SNTP relay

1. Type **time relay enable** and press **Enter**.
2. Type **save** or **commit** and press **Enter**.

To display the SNTP configuration and NTP server list

- Type **time print** and press **Enter**.

To display system time

- Type **time** and press **Enter**.

Example:

The following example

- Flushes all existing NTP servers from the CCU,
- Adds the local host to the NTP server list (always 127.0.0.1),

- Adds a local NTP server, IP address 10.0.0.1,
- Sets the resynchronization time to 3600 seconds,
- Sets the retry time to 30 seconds,
- Enables the SNTP client,
- Enables the SNTP relay,
- Saves the new entries,
- Displays the SNTP configuration and NTP server list, and
- Displays the system time.

Example:

```
Console> time flush
Console> time add 127.0.0.1
Console> time add 10.0.0.1
Console> time client resync 3600
Console> time client retry 30
Console> time client enable
Console> time relay enable
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved
Console>
Console> time print
SNTP Client and Relay Configuration
-----------------------------------

Relay
    Enabled :                Yes
    Destination :            Default Net Broadcast. (radio IF)
    Send time on...
        Boot :               Yes
        EUM Registration :   Yes

Server (send/listen)
    Port :                   123
    Unsynchronized Stratum : 15
    Synchronized Stratum :   Received NTP Stratum +5

Client (fetch only)
    Enabled :                Yes
    Port :                   123
    Resync period :          3600 seconds.
    Retry period :           30 seconds.

NTP SERVERS
-----------------------------------
    10.0.0.1
    127.0.0.1
-----------------------------------
Console>
Console> time
28-FEB-2002 17:03:30
Console>
```

7.8 Configuring SNMP

To fully configure SNMP

- Set the SNMP contact (name of the WISP, for example).
- Set the SNMP system location (physical location of the CCU, for example).
- Add an SNMP read community.
- Add an SNMP write community.
- Add an SNMP trap community.

To set the SNMP contact

1. Type **snmp contact <contact>** and press **Enter**.
   - <contact> is text field, often used for a contact name and phone number, a URL, or an email address, from 1-80 characters in length.
2. Type **save** or **commit** and press **Enter**.

To set the SNMP system location

1. Type **snmp location <location>** and press **Enter**.
   - <location> is the location of the CCU, from 1-80 characters in length.
2. Type **save** or **commit** and press **Enter**.

To add an SNMP read community

1. Type **snmp community add <community> read** and press **Enter**.
   - <community> is the name of the read community string. The default read community string is “public”. The read community string can be from 1-32 characters in length, but spaces are not allowed.
2. Type **save** or **commit** and press **Enter**.

To add an SNMP write community

1. Type **snmp community add <community> write** and press **Enter**.
   - <community> is the name of the write community string. The default write community string is “private”. The write community string can be from 1-32 characters in length, but spaces are not allowed.
2. Type **save** or **commit** and press **Enter**.

To add an SNMP trap server

1. Type **snmp trap add <aaa.bbb.ccc.ddd> <community>** and press **Enter**.
   - <aaa.bbb.ccc.ddd> is the IP address of the trap server
   - <community> is the name of the community on the trap server, from 1-64 characters in length.
2. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Sets the SNMP contact as WaveRider,
- Sets the SNMP location as Calgary_South,
- Adds SNMP read community `WaveRider_Calgary`,
- Adds SNMP write community `WaveRider_Calgary`,
- Adds SNMP trap server `WaveRider_Calgary`, IP address `10.0.1.68`,
- Saves the new settings, and
- Displays the SNMP settings.

Example:

```
Console>
Console> snmp contact WaveRider
Console> snmp location Calgary_South
Console> snmp community add WaveRider_Calgary read
Console> snmp community add WaveRider_Calgary write
Console> snmp trap add 10.0.1.68 WaveRider_Calgary
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved
Console>
Console> snmp
Contact: WaveRider
Location: Calgary_South
Name: LMS3000
SNMP Read Communities:
        WaveRider_Calgary

SNMP Write Communities:
        WaveRider_Calgary
SNMP Traps:
       10.0.1.68 WaveRider_Calgary
Console>
```

7.9 Adding EUMs to the Authorization Table

To add EUMs on the system, enter them in the CCU Authorization Table.

To add an EUM to the CCU Authorization Table

1. Type **auth add <eum id> <gos>** and press **Enter**.
    - <eum id> is the hexadecimal representation of the EUM ID
    - <gos> is the grade of service that you want to assign to the EUM, one of:
        - be (best effort),
        - bronze,
        - silver,
        - gold, or
        - denied.
2. Type **save** or **commit** and press **Enter**.

The following example

- Adds EUM ID `60:0a:32` to the Authorization Table, and assigns it the `silver` grade of service,
- Saves the new settings, and
- Displays the Authorization Table.

```
Console>
Console> auth add 60:0a:32 silver
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Route Config saved
Authorization Database saved
DHCP Server Config saved

Console>
Console> auth

EUM ID       GOS CLASS
----------------------
60:0a:32     silver
Default      be
Total of 1 entries

Console>
```

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8 Configuring the EUM

This chapter covers the following procedures:

- *Setting the EUM Password* on page 98
- *Configuring the EUM RF Parameters* on page 98
- *Configuring EUM IP Parameters* on page 99
- *Configuring Port Filtering* on page 101
- *Configuring SNMP* on page 102
- *Configuring the Customer List* on page 104

Before you configure the EUM

- Familiarize yourself with the CLI commands, syntax and shortcuts, outlined in Appendix C on page 163. *Command-line Syntax* provides a complete list of the available EUM commands, some of which are not discussed in this section.
- Connect a PC directly to the EUM console port, or through a Telnet session. See *Command-line Interface* on page 76 for console settings.

CAUTION: Remember to regularly enter **save** or **commit and press Enter,** to save your configuration changes to memory. As well, some parameters will not take effect until you reboot the unit, specifically the RF frequency, transmit power and IP addressing.

CAUTION: After you have finished making your configuration changes, remember to disconnect your PC from the EUM console port

CAUTION: When entering IP addresses in the CCU or EUM, note that a leading ‘0’ forces the CCU/EUM operating system to interpret the entry as octal rather than decimal. For example, pinging 10.0.2.010 actually pings 10.0.2.8

8.1 Setting the EUM Password

To Change the EUM Password

1. Type **password** and press **Enter**.
2. At the **Enter Current Password** prompt, type the old password.
3. At the **Enter New Password** prompt, type the new password.

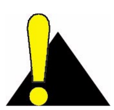
TIP: Passwords are alphanumeric and case-sensitive. For example, “abc” is not the same as “aBc”.

4. At the **Verify password** prompt, type the new password again.

   The system displays a message that your password has been successfully changed.

Example:

```
Console> password
Enter Current Password: ********
Enter New Password: ********
Verify password: ********
Saving new password
Password Changed
Console>
```



CAUTION: Remember to record the password. Unlocking the EUM can only be performed by contacting WaveRider Technical Support.

8.2 Configuring the EUM RF Parameters

To set the EUM Operating Frequency

1. Type **radio frequency <frequency>** and press **Enter**.
   - <frequency> is the EUM operating frequency in tenths of a MHz. For example, 917.0 MHz is entered as `9170`.
2. Type **save** or **commit** and press **Enter**.
3. Before the new radio frequency will take effect, you must reboot the EUM by typing **reset** and pressing **Enter**.

To set the EUM Power Level

1. Type **radio rf <power level>** and press **Enter**.
   - <power level> is the EUM transmit power level, either `high` (+26 dBm) or `low` (+15 dBm). In most cases, the EUM power level should be set to `high`.

2. Type **save** or **commit** and press **Enter**.

3. Before the new power level will take effect, you must reboot the EUM by typing **reset** and pressing **Enter**.

Example:

The following example

- Sets the EUM operating frequency to 917 MHz,
- Sets the transmit power level to `high`,
- Saves the new settings,
- Reboots the EUM so that they new parameters take effect, and
- Displays the EUM RF parameters.

```
Console>
Console> radio frequency 9170
Console> radio rf high
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Console>
Console> reset
rebooting EUM ...

(... Power On Self Test ...)

WaveRider Communications, Inc. LMS3000
Password:
Console>
Console> radio
RF Power: HIGH
Radio Frequency: 9170
Console>
```

8.3 Configuring EUM IP Parameters

In *IP Network Planning* on page 53, you determined the following:

- CCU radio IP address and subnet mask
- EUM Ethernet IP address and subnet mask
- End-user PC Ethernet IP address and subnet mask

To set the EUM Ethernet IP address

1. Type **ip ethernet <aaa.bbb.ccc.ddd> <net mask>** and press **Enter**.
   - <aaa.bbb.ccc.ddd> is the CCU Ethernet IP address.
   - <net mask> is the net mask.

CAUTION: The EUM only accepts subnet masks using the shorthand notation; for example, it accepts ‘`16`’, but not ‘`ffff0000`’ or ‘`255.255.0.0`’.

2. Type **save** or **commit** and press **Enter**.
3. Before the new EUM Ethernet IP address will take effect, you must reboot the EUM by typing **reset** and pressing **Enter**.

To set the EUM gateway IP address

1. The EUM gateway is the CCU radio, so the EUM gateway IP address is the CCU radio IP address.
2. Type **ip gateway <aaa.bbb.ccc.ddd>** and press **Enter**.
   - <aaa.bbb.ccc.ddd> is the CCU radio IP address.
3. Type **save** or **commit** and press **Enter**.
4. Before the new EUM gateway IP address will take effect, you must reboot the EUM by typing **reset** and pressing **Enter**.

Example:

The following example

- Sets the EUM Ethernet IP address to 10.0.4.48 / 16,
- Sets the EUM gateway IP address to 10.5.0.1,
- Saves the new settings,
- Reboots the EUM so that the new parameters take effect, and
- Displays the EUM IP parameters.

```
Console>
Console> ip ethernet 10.0.4.48 16
Console> ip gateway 10.0.0.1
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Console>
Console> reset
rebooting EUM ...

(... Power On Self Test ...)

WaveRider Communications, Inc. LMS3000
Password:
Console> ip
Ethernet IP Address: 10.0.4.48
Ethernet Net Mask  : ffff0000
Gateway IP Address: 10.0.0.1
Radio IP Address: 10.5.0.1
Radio Net Mask  : ffff0000
Console>
```

8.4 Configuring Port Filtering

To add a port filter:

- Determine the port number you want to filter.
- Determine whether you want to filter UDP, TCP, or both types of packets.
- Add the port filter to the EUM.

To add a port filter

1. Type **port add <number> <type>** and press **Enter**.
   - <number> is the number of the port you want to filter.
   - <type> is the type of IP packet you want to filter, either `udp, tcp,` or `both.`
2. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Configures the EUM to filter both UDP and TCP packets on ports 137, 138, 139 and 1512,
- Saves the new settings, and
- Displays the TCP/UDP port filters.

```
Console> port add 137 both
Console> port add 138 both
Console> port add 139 both
Console> port add 1512 both
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Console>
Console> port
PORT FILTERS
    Port                  Filter
---------------------------------
      137                  both
      138                  both
      139                  both
     1512                  both
----------------------------------
Console>
```

8.5 Configuring SNMP

To fully configure SNMP

- Set the SNMP contact (name of the WISP, for example).
- Set the SNMP system location (physical location of the EUM, for example).
- Add an SNMP read community.
- Add an SNMP write community.
- Add an SNMP trap server.

To set the SNMP contact

1. Type **snmp contact <contact>** and press **Enter**.
    - <contact> is a name and phone number, a URL, or an email address, from 1-80 characters in length.
2. Type **save** or **commit** and press **Enter**.

To set the SNMP system location

1. Type **snmp location <location>** and press **Enter**.
    - <location> is the location of the EUM, from 1-80 characters in length.
2. Type **save** or **commit** and press **Enter**.

To add an SNMP read community

1. Type **snmp community add <community> read** and press **Enter**.
    - <community> is the name of the read community string. The default read community string is “public”. The read community string can be from 1-32 characters in length, but spaces are not allowed.
2. Type **save** or **commit** and press **Enter**.

To add an SNMP write community

1. Type **snmp community add <community> write** and press **Enter**.
    - <community> is the name of the write community string. The default write community string is “private”. The write community string can be from 1-32 characters in length, but spaces are not allowed.
2. Type **save** or **commit** and press **Enter**.

To add an SNMP trap server

1. Type **snmp trap add <aaa.bbb.ccc.ddd> <community>** and press **Enter**.
    - <aaa.bbb.ccc.ddd> is the IP address of the trap server
    - <community> is the name of the community on the trap server, from 1-64 characters in length.
2. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Sets the SNMP contact as `WaveRider`,
- Sets the SNMP location as `Calgary_South`,
- Adds the SNMP read community `WaveRider_Calgary`,
- Adds the SNMP write community `WaveRider_Calgary`,
- Adds the SNMP trap server `WaveRider_Calgary`, IP address `10.0.1.68`,
- Saves the new settings, and
- Displays the SNMP settings.

Example:

```
Console>
Console> snmp contact WaveRider
Console> snmp location Calgary_South
Console> snmp community add WaveRider_Calgary read
Console> snmp community add WaveRider_Calgary write
Console> snmp trap add 10.0.1.68 WaveRider_Calgary
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Console>
Console> snmp
Contact: WaveRider
Location: Calgary_South
Name: LMS3000
SNMP Read Communities:
        WaveRider_Calgary

SNMP Write Communities:
        WaveRider_Calgary
SNMP Traps:
       10.0.1.68 WaveRider_Calgary
Console>
```

8.6 Configuring the Customer List

You can set the maximum number of customers or PCs (*customer_max*) that can concurrently access the radio link through the EUM, as described in *Customer Table (EUM only)* on page 192.

CAUTION: The simulation data presented in *Performance Modelling* on page 42 is based on one end user (one PC) per EUM. If *customer_max* is set to a value greater than ‘1’, and there is more than one end user per EUM, the throughput performance of the radio link will be affected.

TIP: When you are locally troubleshooting the EUM installation, if *customer_max* is set to ‘1’ and you want to substitute and use a known-working PC in place of the end-user’s PC, you will have to reset the EUM or wait for the Customer Table to time out.

To set *customer_max*

1. Type **cust max <value>** and press **Enter**.
    - <value> is the maximum number of customers (PCs), from 1-50.
2. Type **save** or **commit** and press **Enter**.

Example:

The following example

- Sets *customer_max* to 3,
- Saves the new setting, and
- Displays the value of *customer_max*.

```
Console>
Console> cust max 3
Maximum customers: 3
Console>
Console> save
Basic Config saved
Port Filter Config saved
sntp cfg file saved
Console>
Console> cust max
Maximum customers: 3
Console>
Console>
```

9 Installing the EUM

9.1 Before you Start the EUM Installation

Before you start the EUM installation, ensure the following points have been addressed:

- The EUM has been configured with at least the following settings:
  - IP address
  - Subnet mask
  - Gateway IP address
  - Radio frequency
- The CCU network is installed and verified.
- DHCP relay is enabled at the CCU, with network access to a valid DHCP server.
- The end-user PC is equipped with an Ethernet interface card, and is configured to obtain its IP address remotely, using DHCP.
- The installer knows the direction from the EUM to the CCU (WISP radio site).
- The installer has read this chapter.
- The installer knows the EUM IP address.
- The WISP has authorized the EUM at the CCU (or no communications will be possible).

Procedures are provided below for addressing situations where some of the above items could not be taken care of prior to the EUM installation.

9.2 Other EUM Programming Considerations

Although the IP settings identified above are required for basic EUM operation, you should also consider pre-configuring the following EUM parameters:

SNMP

SNMP communities can be configured in the EUM to enable remote monitoring of the EUM using an SNMP manager. Refer to *Configuring SNMP* on page 102.

Customer List

The factory default configuration allows only one PC to be logically connected to the EUM at any given time. If you want to use a separate PC as an aid to installing and confirming the EUM link prior to connecting the end-user PC, then you will have to reset the EUM when changing between the end-user PC and the installation test PC.

Port Filtering

Port filtering is set in the EUM to filter out Network Neighborhood. You can edit Port filtering in the EUM, if desired. Refer to *Configuring Port Filtering* on page 101.

Output Power

In most cases, the EUM output power should be set to HIGH.

9.3 Installation Overview

Installing the EUM involves the following procedures:

1. *Opening the Box* on page 107
2. *Turning off the End-user's Cordless Phones* on page 108
3. *Choosing a Location for the EUM and Antenna* on page 108
4. *Connecting the EUM Components* on page 108
5. *Conducting a Preliminary Check of the EUM* on page 110
6. *Positioning the Antenna* on page 111
7. *Mounting the Antenna* on page 112
8. *Connecting the End-user's PC* on page 115
9. *Obtaining Valid IP Addresses for the End-user's PC* on page 116
10. *Testing the Data Link* on page 116

11. *Configuring the Browser Application* on page 119
12. *Completing the Installation* on page 120
13. *Baselining the Installation* on page 120

9.4 Installation Procedures

9.4.1 Opening the Box

Before you install the EUM components, verify that the EUM kit is complete.

EUM Kit Components

- EUM modem
- AC/DC power supply with 2-meter DC power cable
- 2-meter AC power cable
- Crossover Ethernet cable

Antenna Kit Components

- Indoor antenna with attached 3-meter cable
- Flush-mountable antenna bracket
- Two antenna-mount suction cups, two drywall plugs, and two screws

Refer to Figure 37 for an illustration of each EUM component.

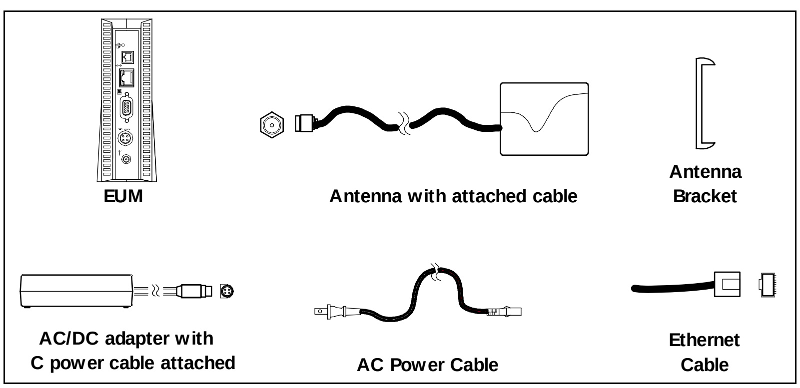


Figure 37 EUM Components

NOTE: The antenna-mount suction cups, drywall plugs, and screws are not shown in Figure 37.

9.4.2 Turning off the End-user’s Cordless Phones

Turn off all cordless phones in the customer’s premises, and any other equipment that uses the 900 MHz ISM band. Once the installation is complete, turn this equipment back on.

9.4.3 Choosing a Location for the EUM and Antenna

The location of the antenna has a significant effect on the performance of the EUM installation. Before you connect the EUM components, follow the guidelines provided below for choosing the best location for the antenna and the EUM.

Choosing the Best Location for the EUM

The best location for the EUM is

- indoors,
- upright,
- on a stable, flat surface, and
- in a position where its air vents are unobstructed.

NOTE: Avoid placing the EUM in direct sunlight or near other sources of heat (such as an electric heater).

Choosing the Best Location for the Antenna

The best location for the antenna is

- indoors,
- near an outside entrance or window, preferably in the location with the best possible path to the CCU, and
- a minimum of 20 cm (8 in.) from personnel.

9.4.4 Connecting the EUM Components

Now that you have chosen a suitable location, use the instructions in this section for connecting the following components to the EUM, in the order shown in Figure 38:

- Antenna
- EUM AC/DC adaptor (DC cable first, then AC cable)

When you have completed the above tasks, connect the EUM AC/DC adaptor to an AC power bar or outlet.

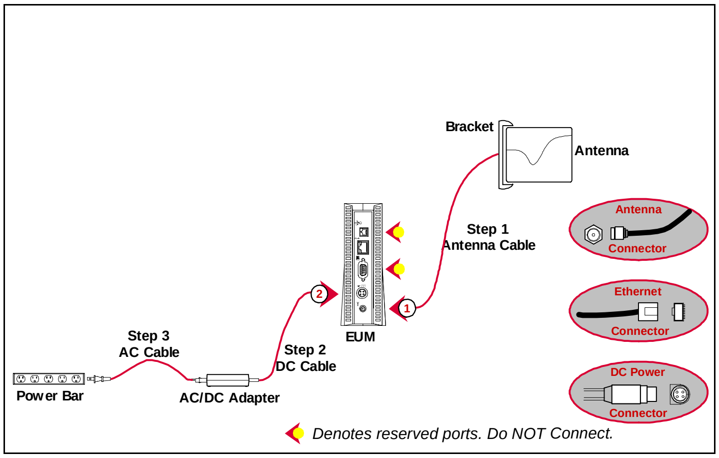


Figure 38 Connecting the EUM Components

To Connect the EUM Components

1. Finger-tighten the antenna cable onto the corresponding connector at the back of the EUM (refer to Step 1 in Figure 38). Do not use wrenches or pliers. Do not cross-thread or over tighten.

WARNING!

You must connect the antenna to the modem before operating the system. Failure to do so may result in permanent equipment damage.

2. Connect the AC/DC adaptor to the EUM. To do this, line up the guides in the DC power cord connector with the notches in the power plug on the EUM and press the connector firmly into place (refer to Figure 39).

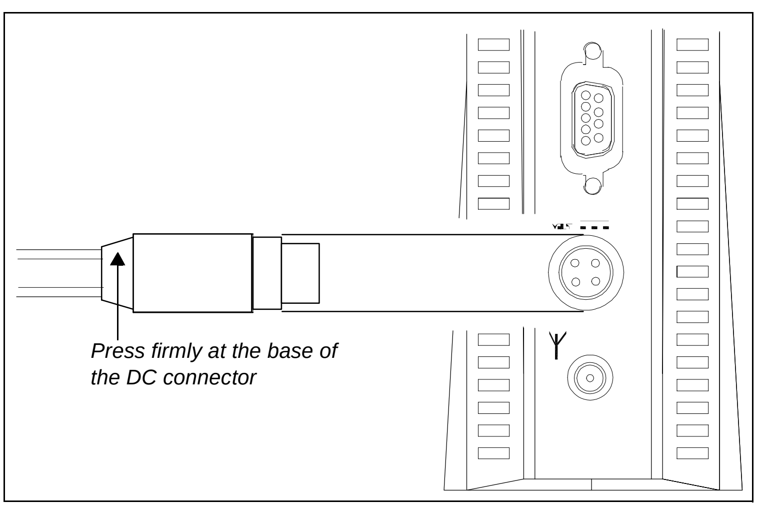


Figure 39 Connect the DC Power Cord to the EUM

NOTE: The DC power cable features a secure locking connector. To disconnect the cable, pull the collar back on the connector, then continue pulling to detach the DC power cable from the EUM.

The EUM uses a custom antenna cable and connector. If you need to extend this cable, contact WaveRider.

---

3. Connect the AC power cord between the AC/DC adaptor and either an AC power bar (preferred) or AC outlet (Figure 40). The EUM immediately powers up since it does not have an ON/OFF switch.

   NOTE: To avoid potential damage to the EUM components in the event of a power surge, WaveRider recommends using a power bar with surge protection (instead of connecting the AC power cord directly to an AC outlet).

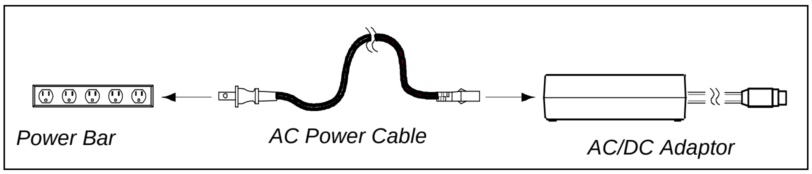


Figure 40 Connect the AC Power Cord

9.4.5 Conducting a Preliminary Check of the EUM

Check the LED indicators on the front of the modem to ensure that the EUM is functioning properly.

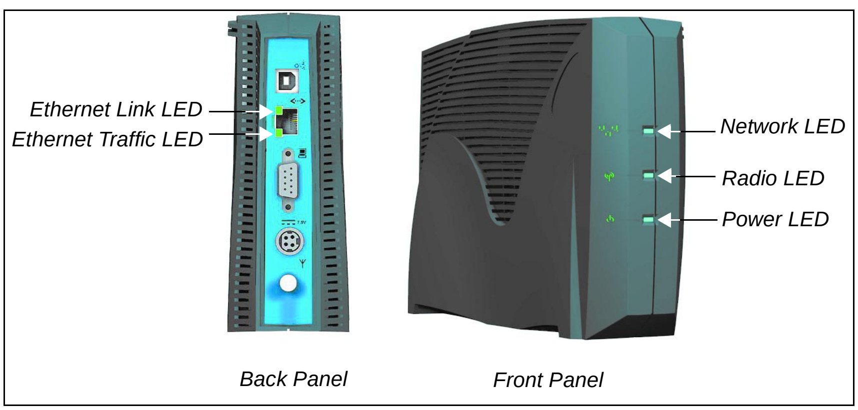


Figure 41 EUM LEDs

To Verify Proper EUM Function

- Check that the Power LED is ON. It takes about 7 or 8 seconds to come on after you have plugged in the unit.

9.4.6 Positioning the Antenna

1. To begin with, point the antenna in the general direction of the CCU, as shown in Figure 42:

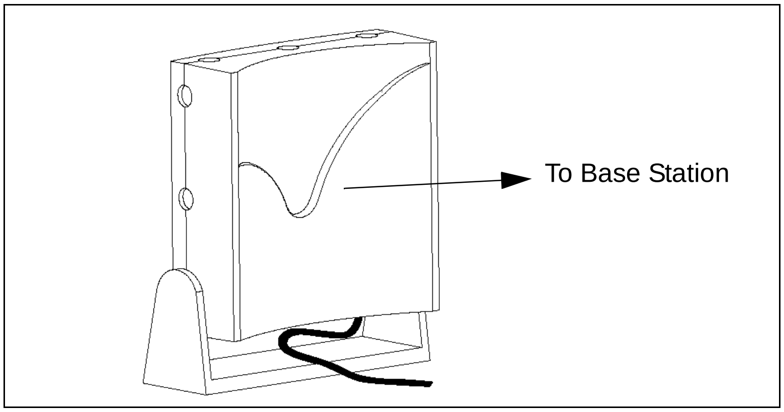


Figure 42 Preliminary Orientation of the Antenna (Top View)

As illustrated, for maximum signal reception, point the concave surface of the antenna toward the CCU, and ensure your body (including fingers) are not between the antenna and the CCU.

2. Monitor the Radio LED, shown in Figure 41 on page 110 and refer to Table 21. Move the antenna until the Radio LED is flashing quickly, or is ON solidly, indicating that you have a good to very-good radio signal. After each repositioning or reorientation of the antenna, you may have to step back from the antenna so that you are not interfering with the received signal.

Table 21 Radio LED Status Displays

Radio LED Display	Status
Off	No radio signal present.
Slow Flash	ON/OFF 1.25 times per second. The signal strength is poor to marginal.
Fast Flash	ON/OFF 2.5 times per second. The signal strength is good.
Solid On	The signal strength is very good.

3. If the Radio LED is off or flashes slowly, then the antenna should be moved to a better location. Keep in mind that the antenna and EUM do not have to be located in the same room as the end-user's PC since up to 100 m (300 ft.) of CAT5 data cable can connect the EUM to the PC.

4. If you cannot find an indoor antenna location that provides a solid ON or fast-flashing LED, refer to *Troubleshooting* on page 121.

5. Once you have found a good location, you are ready to mount the antenna, as described in *section 9.4.7*, Mounting the Antenna.

9.4.7 Mounting the Antenna

The antenna bracket is designed to accommodate the RF cable and act as a strain relief.

To Mount the Antenna

1. Thread the attached antenna cable through the guides in the back of the antenna bracket, as necessary.

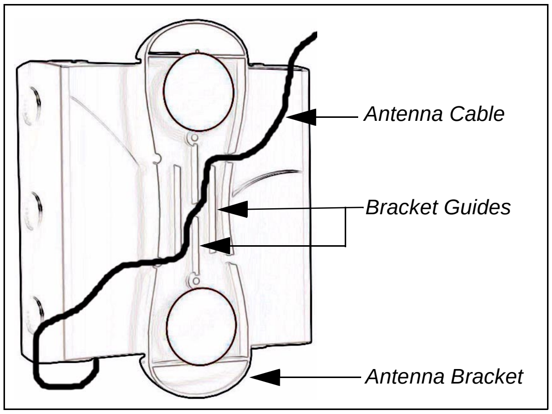


Figure 43 Rear View of Antenna Bracket

NOTE: Bending the antenna cable too sharply can degrade EUM performance. Never allow less than a 1.25 cm (0.5 in.) bend radius. If a quarter (25-cent piece) fits into the curve, the bend is acceptable.

The EUM kit includes suction cups, drywall plugs, and screws to allow a variety of mounting options:

Table 22 Antenna Mount Guidelines

Mounting Method	Guidelines
Suction Cups	Use on flat, smooth surfaces, such as glass, plastic, laminates or metal. Remove all grease, oil, and grit before securing the antenna bracket with suction cups.
Drywall Plugs	Use on all commercial drywall and other plaster surfaces.
Screws	Use on hardwood surfaces.

2. Insert the suction cups or screws into the base of the antenna bracket, then mount the bracket onto the desired surface.

NOTE: If you mount your antenna bracket on a vertical surface, orient the bracket so that the spring clip is closest to the ceiling.

Figure 44 shows the location of the spring clip, suction cup holes, and screw holes on the antenna bracket.

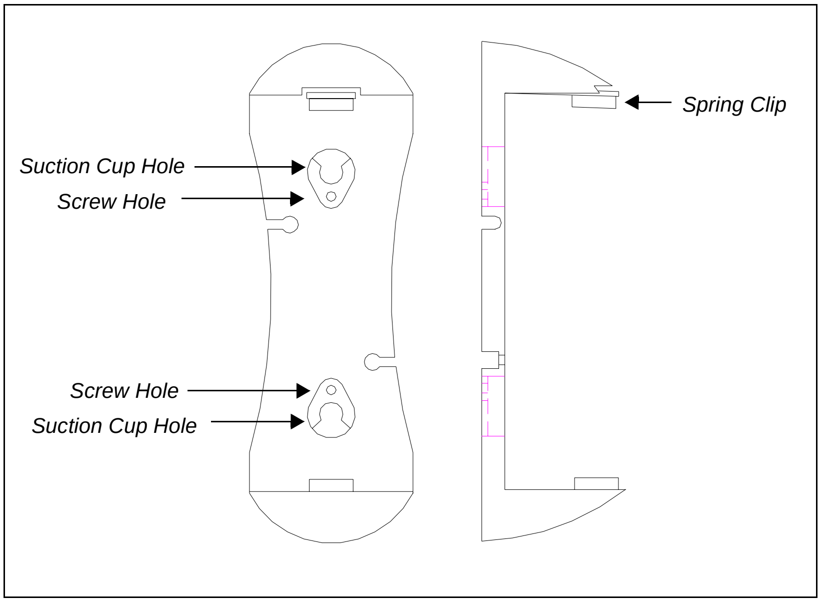
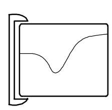
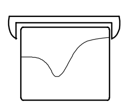
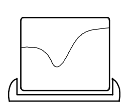


Figure 44 Antenna Bracket Components

Table 23 Surface Mounting Options for the Antenna

Side Mount 	Mount the antenna on a wall, window, window frame, or solid furniture with spring clip side closest to the ceiling.
Top Mount 	Hang the antenna from a ceiling or the shelf of a bookcase.
Bottom Mount 	Mount the antenna on solid furniture (a desk or shelf) or on a window sill.

WARNING!

The antennas for the EUM must be fix-mounted, indoors or outdoors, to provide a separation distance of 20 cm or more from all persons, to satisfy RF exposure requirements. The distance is measured from the front of the antenna to the human body. WaveRider recommends installing the antenna in a location where personnel are not able to bump into it, obstruct the signal from the base station, or trip over antenna cables.

3. Position the antenna in the bracket according to one of the configurations illustrated in Figure 45. Click and lock the antenna in place. For maximum signal reception, ensure the concave surface of the antenna points toward the WISP antenna and the trough of the inset wave points towards the floor.

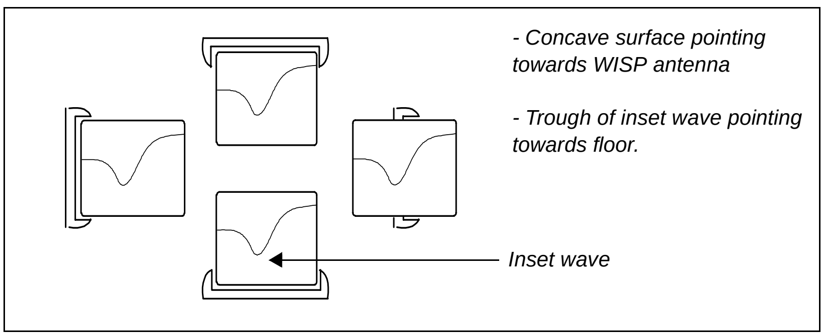


Figure 45 Mounting the Antenna in the Bracket

NOTE: The location, position, and orientation of the antenna affects the robustness of the Internet connection. Pointing the antenna at buildings or other obstacles often impedes communications, but some surfaces may provide desirable signal bounce. For optimal reception, try various positions before fix-mounting your antenna.

4. Once the antenna is permanently mounted, re-align it for best signal.

9.4.8 Connecting the End-user's PC

1. Connect the end-user's PC, shown in Figure 46, by attaching the crossover Ethernet cable that is included with the kit between the Ethernet port on the end-user's computer and the Ethernet port on the EUM.

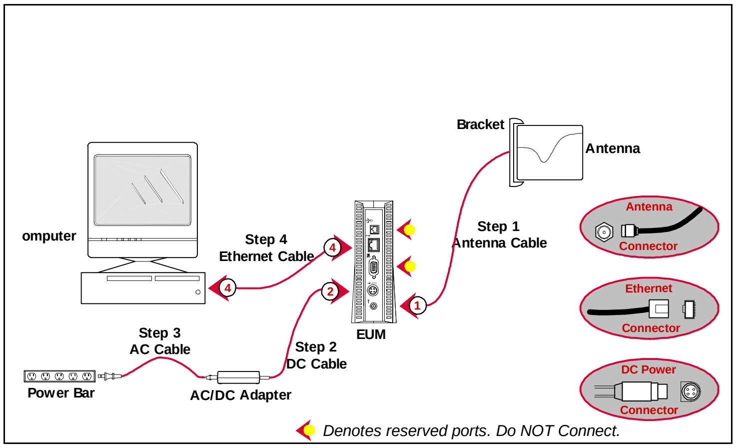


Figure 46 Connecting the End-user's PC

2. Check the Ethernet LEDs on the back panel of the EUM to ensure the Ethernet connection between the EUM and the end-user's PC is active. Refer to Table 24 for an explanation of the Ethernet LED status displays.

Table 24 Ethernet LED Status Displays

Ethernet LED	Status
Ethernet Link LED	This LED is lit when there is a correct connection to the computer, and both ends are powered ON.
Ethernet Traffic LED	Flashes when data passes through the Ethernet connection in either direction.

3. When attempting to send data to, or receive data from, the Internet, check the Ethernet Traffic LED to ensure data transmission is taking place. This LED flashes as data traffic passes between the end-user's PC and the EUM. The network LED on the front of the EUM also flashes and is more accessible than the Traffic LED on the rear of the EUM.

9.4.9 Obtaining Valid IP Addresses for the End-user's PC

1. To obtain IP addresses for the end-user's PC, including the PC IP address, Gateway IP address, and DNS server address, the PC must request an update from the DHCP server. This procedure varies depending on which version of Windows operating system is running on the end-user's PC, but a general method is outlined as follows:

   For Windows 95, 98:
   - Using Windows utility `winipcfg`, select **Start** > **Run**, type <`winipcfg`> in the command line, and press **Enter.**
   - From the `winipcfg` menu, select **Release All**, then **Renew All**.
   - Using DOS, select **Start** > **Run**, type `cmd` or `command` (the exact process may vary, so consult your operating system manual)
   - Using the <`ipconfig`> command set, **Renew** all adaptors.

2. If no error messages are returned, the WISP network has successfully provided an IP address to the end-user's PC. You can confirm the success by checking the assigned IP addresses. If the assigned Gateway IP address corresponds to the EUM Gateway IP address, then the operation was successful.

3. If a valid IP address cannot be achieved, see *Troubleshooting* on page 121.

9.4.10 Testing the Data Link

The fact that the IP address was successfully obtained indicates that the data link from the PC to the WISP's network is functioning properly. WaveRider recommends more thorough testing of the EUM-to-CCU data link, as outlined below. These tests can also be used to troubleshoot simple problems if DHCP access is not available.

There are several tools available for testing the quality of the link between the end-user PC and the WISP network. The most important tool is the `ping` utility, which is available in the CCU, EUM, and the end-user PC. The ping command can be used to progressively test the data link, as follows:

- *To Test the Data Link from the End-user's PC to the EUM*, on page 116
- *Testing the Data Link from the End-user's PC to the Network*, on page 118
- *Testing the Data Link from the End-user's PC to the Internet*, on page 119

To Test the Data Link from the End-user's PC to the EUM

1. Ping the EUM's IP address from the end-user's PC, as follows:
   - Open a DOS window in the end-user's PC.
   - At the command prompt, type **ping <aaa.bbb.ccc.ddd>**, where <aaa.bbb.ccc.ddd> is the IP address of the EUM and press **Enter**.

2. If there is no response, check the following:
   - PC IP address settings.
   - Ethernet crossover cable between the EUM and the end-user's PC, to ensure that the pins have not been damaged and that the pin-outs are consistent with those shown in *General Troubleshooting Information*, on page 151.

3. If there is a response, but with errors, check the Ethernet crossover cable.

To illustrate data link testing between the PC and the EUM, consider the sample configuration shown in Figure 47.

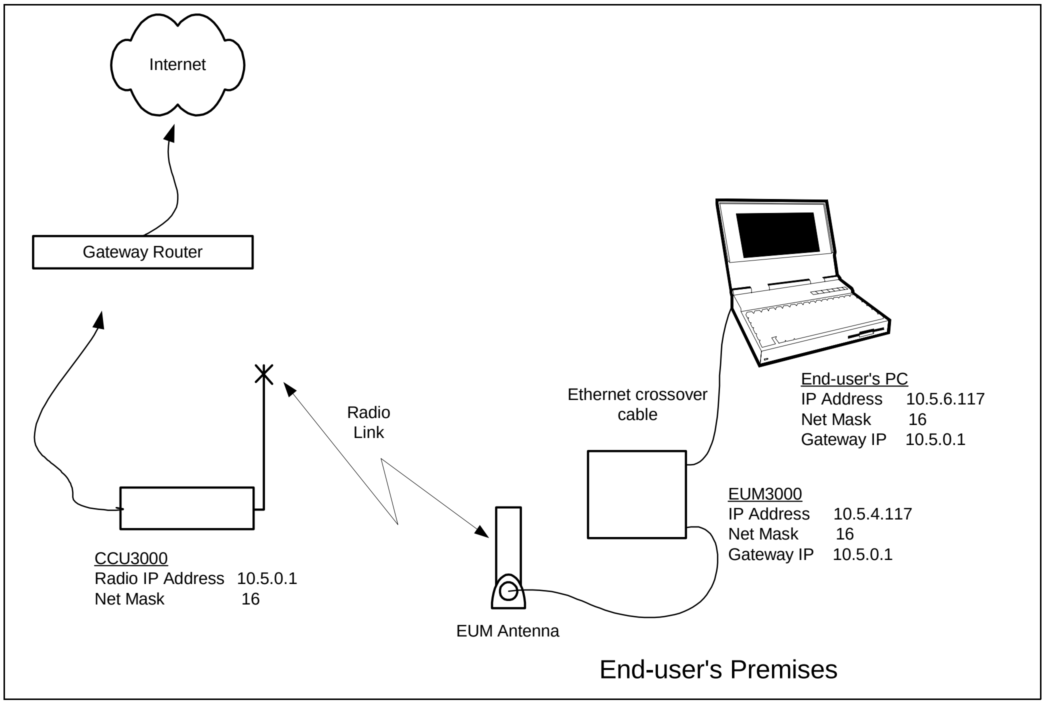


Figure 47 Sample Configuration — Testing the Data Link

Using the sample configuration shown in Figure 47, confirm the connection between the end-user's PC and the EUM as demonstrated below:

This is what successful ping from the end-user's PC to the EUM looks like:

```
C:\>ping 10.5.4.117

Pinging 10.5.4.117 with 32 bytes of data:

Reply from 10.5.4.117: bytes=32 time<10ms TTL=64
Reply from 10.5.4.117: bytes=32 time<10ms TTL=64
Reply from 10.5.4.117: bytes=32 time<10ms TTL=64
Reply from 10.5.4.117: bytes=32 time<10ms TTL=64

Ping statistics for 10.5.4.117:
 Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
 Minimum = 0ms, Maximum =  0ms, Average =  0ms

C:\>
```

This is what an unsuccessful ping from the end-user's PC to the EUM looks like:

```
C:\>ping 10.5.4.116

Pinging 10.5.4.116 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.
```

```
Ping statistics for 10.5.4.116:
 Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
Approximate round trip times in milli-seconds:
 Minimum = 0ms, Maximum =  0ms, Average =  0ms

C:\>
```

If you are not able to <ping> the EUM from the PC, go to *Troubleshooting* on page 121.

Testing the Data Link from the End-user's PC to the Network

Once the connection from the PC to the EUM is confirmed, ping the EUM gateway address from a PC DOS window. Ping with short packets first to confirm function, and then with long packets (1472 byte packets) to confirm performance. Errors observed on pings with long packets indicate a high error rate on the channel, caused by low signal levels or interference.

To Ping a CCU with the maximum packet size

1. Open a DOS window.
2. At the command prompt, type ping <aaa.bbb.ccc.ddd> -t -L 1472, where <aaa.bbb.ccc.ddd> is the CCU radio IP address and press **Enter**.
3. Press **Ctrl**+**c** to end the test.

NOTE: If this test fails, but pinging the CCU with the default packet size succeeds, then the connection is working but is not operating at maximum capacity, possibly due to poor antenna placement or orientation.

This following example uses the sample configuration shown in Figure 47:

Pinging the CCU from the end-user's PC (with maximum packet size):

```
C:\>ping 10.5.0.1 -t -l 1472

Pinging 10.5.0.1 with 1472 bytes of data:

Reply from 10.5.0.1: bytes=1472 time=40ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=81ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=80ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=40ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=60ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=80ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=40ms TTL=64
Reply from 10.5.0.1: bytes=1472 time=110ms TTL=64

Ping statistics for 10.5.0.1:
 Packets: Sent = 8, Received = 8, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
 Minimum = 40ms, Maximum =  110ms, Average =  66ms
Control-C
^C
C:\>
```

More advanced tests and troubleshooting procedures are included in *Troubleshooting* on page 135.

Testing the Data Link from the End-user's PC to the Internet

Use the following test to determine whether the end-user's PC can communicate with the Internet.

Pinging an Internet site from the PC using the site's IP address:

```
C:\>ping 207.23.175.75

Pinging 207.23.175.75 with 32 bytes of data:

Reply from 207.23.175.75: bytes=32 time=90ms TTL=113
Reply from 207.23.175.75: bytes=32 time=80ms TTL=113
Reply from 207.23.175.75: bytes=32 time=80ms TTL=113
Reply from 207.23.175.75: bytes=32 time=70ms TTL=113

Ping statistics for 207.23.175.75:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 70ms, Maximum =  90ms, Average =  80ms

C:\>
```

Use the following test to verify that the DNS server IP address is correctly configured in the end-user's PC and is operating properly:

Pinging an Internet site from the PC, using the site's domain name:

```
C:\>ping www.waverider.com

Pinging waverider.com [207.23.175.75] with 32 bytes of data:

Reply from 207.23.175.75: bytes=32 time=70ms TTL=113
Reply from 207.23.175.75: bytes=32 time=90ms TTL=113
Reply from 207.23.175.75: bytes=32 time=60ms TTL=113
Reply from 207.23.175.75: bytes=32 time=50ms TTL=113

Ping statistics for 207.23.175.75:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 50ms, Maximum =  90ms, Average =  67ms

C:\>
```

9.4.11 Configuring the Browser Application

Follow the manufacturer's instructions for configuring the end-user's browser, so that it correctly uses the PC Ethernet interface. Once you have done this:

1. Launch the browser
2. Confirm access to sites of interest.
3. Monitor the access speed using a test site, such as http://speed-test.net

9.4.12 Completing the Installation

1. Configure the remaining PC applications, as required.
2. Re-activate the end-user’s cordless phones, and any other 900 MHz ISM-band equipment that was turned off at the beginning of the installation. Note the following points:
    - Cordless phones operating in the 900 MHz ISM band can disrupt service to the EUM if precautions are not taken.
    - Browse to http://speed-test.net, and turn on the cordless phones in sequence, while monitoring the downlink throughput. Since there is naturally a wide variation in the downlink speed, for reasons more associated with the network than with the performance of the LMS4000 wireless service, repeat the tests several times to confirm whether or not the end user’s cordless phones are going to affect the EUM performance.
    - If the cordless phones do affect the performance of the EUM, move the cordless phone base station to a location as far from the antenna as possible. Instruct the end user to avoid using the cordless handset in the proximity of the antenna, particularly when the EUM is being used.

9.4.13 Baselining the Installation

Once you have completed the installation, WaveRider recommends recording the following information:

- EUM IP addresses
- EUM radio settings
- RSSI readings
- Tx retry rate readings (displayed with the RSSI readings)

If you have problems with the EUM at a later date, you can compare the latest site settings and RSSI readings with the original settings in the site installation record.

You can record and save this information in several ways:

- using the WaveRider Configuration Utility. Through the Configuration Utility, you can also upload and store the EUM’s complete configuration file. You can also do this locally, through a serial connection to the EUM, or remotely through a Telnet session.
- through the EUM command-line interface locally, using:
    - HyperTerminal, with the PC connected to the EUM console port.
    - a DOS Telnet session, through the EUM Ethernet connection.
- through the EUM command-line interface remotely, using:
    - a DOS Telnet session, over the wireless link between the network and the EUM.

Record the information from the following session, and store it to a file.

```
EUM Console>
EUM Console> ip
Ethernet/USB IP Address: 10.5.4.117
Ethernet/USB Net Mask  : ffff0000
```

```
Gateway IP Address: 10.5.0.1
Console>
Console> radio
RF Power: HIGH
Radio Frequency: 9170
Console>
Console> ra rssi
Press any key to stop

     RSSI          RX;  TX;  R1;  R2;  R3;   F;Retry%
RSSI:  44            0;   0;   0;   0;   0;   0;   0%
RSSI:  60          712;   0;   0;   0;   0;   0;   0%
RSSI:  59          706;   0;   0;   0;   0;   0;   0%
RSSI:  62          812;   0;   0;   0;   0;   0;   0%
RSSI:  58          819;   0;   0;   0;   0;   0;   0%
RSSI:  60          809;   0;   0;   0;   0;   0;   0%
RSSI:  45          829;   0;   0;   0;   0;   0;   0%
RSSI:  61          834;   0;   0;   0;   0;   0;   0%
RSSI:  60          818;   0;   0;   0;   0;   0;   0%

EUM Console>
```

9.4.14 Troubleshooting

Q: I cannot receive a good signal, regardless of where I place the antenna. What should I do?

A: The threshold receive signal level for the fast flashing Radio LED is -80dBm, which provides an operating margin of up to 9dB. In some cases, an installation will not require this much margin, and the unit will function at a lower signal level. If the LED is flashing slowly, the amount of receive signal can be determined using the EUM CLI command <ra rssi> or the EUM Configuration Utility. If the signal is above -84dBm, it may be adequate, and detailed tests should be carried out to determine the link robustness under these signal conditions.

If it is not possible to obtain an adequate signal level from the indoor antenna, an outdoor antenna may be required. Installation of an outdoor antenna requires the services of a qualified Professional Installer, proficient in the use and installation of ISM-band radio equipment, and knowledgeable about local codes related to the installation of outdoor antennas. Once an appropriate antenna is installed, and an adequate signal level is achieved, the installation can proceed as outlined above.

Q: I have found a great location for the antenna but unfortunately, this location is a fair distance from the end-user's PC. As a result, I am unable to connect the antenna, EUM, and the end-user's PC using the cables included in the EUM kit. How can I resolve this problem?

A: To connect the antenna cable, place the EUM closer to the antenna; then, use a longer Ethernet cable to connect the EUM to your PC. Longer Ethernet cables are readily available from local electronics shops.

> **NOTE:** The use of a longer Ethernet cable has no effect on network performance if you use a good quality cable and the cable length is less than 100 meters.

Q: I have adequate radio signal strength, but cannot access the network. What should I do?

A: There are two conditions that might prevent or compromise Internet access by the end-user through the EUM, even when the network is operating properly and the radio signal strength is adequate:

Improper PC configuration

If the PC IP address set is incorrect, then communications between the PC and the EUM will not be possible. If the DHCP function does not provide a valid IP address to the PC, then the PC IP address will have to be entered manually. More advanced troubleshooting may be required to find out why DHCP is not working properly in this case. As well, if the Ethernet card in the PC is not properly configured, you will not be able to communicate through the EUM.

A quick, simple test for confirming that there is a radio link between the EUM and the WISP network, which does not rely on having the correct configuration in the end-user's PC, is to ping the CCU (or some other destination in the WISP network) through the EUM console port, using HyperTerminal and the EUM command-line interface. If this test is successful, then the problem is either the PC connection to the EUM, or the PC configuration.

Interference

If there is a strong radio interferer in the vicinity of the end-user's premises or, more specifically, to the EUM installation, this may impact the ability of the EUM to communicate over the radio link, either preventing communications, or at least, causing a higher than expected error rate.

If the interference originates from inside the end-user's premises, then it can be controlled by relocating either the EUM antenna or the source of the interference.

If the interference originates from outside the end-user's premises, the problem may be addressed by relocating the indoor antenna or, if an outdoor antenna is being used, by carefully siting the antenna to provide adequate isolation from the interferer.

Without the use of special test equipment, such as a spectrum analyzer, interference problems may be difficult to positively diagnose and resolve.

Q: DHCP is not available on the network. Is there anything else I can do?

A: DHCP is a tool that allows you to re-use IP addresses and simplifies the procedure for configuring the end-user PC. If DHCP is not available, the WISP must provide the installer with the following IP addresses for the end-user's PC:

- PC IP address
- Subnet mask
- Gateway IP address
- DNS IP address

These addresses can be directly entered into the end user's PC through the operating system.

Once these addresses are entered and activated (which may require re-booting the PC), the installation process can proceed as outlined above. To confirm the data link to the WISP network, use the tests outlined in *Testing the Data Link* on page 116, or configure and activate the end-user's browser, as shown in *Configuring the Browser Application* on page 119.

Q: The EUM keeps shutting off automatically. How can I prevent this?

A: The EUM may be overheating due to inadequate ventilation. Lightly touch the modem case. If the case is hot, the solution may be to find a new location for the EUM, where it can stand upright and away from other objects that may be blocking or interfering with its ventilation. If these measures have no effect, and the EUM is still running hot, unplug it and return it to the WISP for a replacement.

Similarly, if the EUM is operating in an environment below 10°C, the EUM may repeatedly shut down and restart. Moving the EUM to a warmer location resolves this problem.

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10 Maintaining the Network

The LMS4000 900MHz radio network requires virtually no maintenance. This chapter describes what you need to do to maintain the CCU and EUM operating environments.

The CCU and EUM must be kept in a temperature-controlled and dust-free environment, as described under the following headings:

- *Maintaining Temperature and Humidity* on page 125
- *Cleaning the Equipment* on page 125
- *Checking the CCU Shelf Cooling Fans* on page 126

Maintaining Temperature and Humidity

Make sure the CCU and EUM sites meet the environmental requirements outlined in Table 25.

Table 25 Temperature and Humidity Requirements

Equipment	Operating Temperature	Non-condensing Relative Humidity	Storage Temperature
CCU	0° to +50°C	5% to 95%	-40° to +70°C
EUM	10° to +40°C	5% to 95%	-40° to +70°C

Cleaning the Equipment

WARNING!

Make sure you follow ESD precautions when you touch and clean CCU and EUM components.

When cleaning CCU and EUM components:

- Use dry, static-free cloths to wipe dust from the devices.
- Make sure you do not disconnect any cables or wires when cleaning.

Checking the CCU Shelf Cooling Fans

WARNING!

Exercise caution when you are in close proximity to the CCU Shelf cooling fans. Disconnect AC power to the fans prior to handling.

Verify that the cooling fans in the CCU Shelf are rotating freely and at a high speed when connected to the power supply to ensure proper cooling of the CCUs.

11 Monitoring the Network

Although there are a large number of detailed statistics available for the various data handling applications in the CCU (refer to Appendix H on page 223 for a complete list), there are only a few that are key for monitoring system performance on an on-going basis. These statistics are described in detail in the material below.

11.1 CCU Transmit Statistics

As described in *MAC Layer (Polling MAC)* on page 36, the MAC continuously transmits polls to the EUMs. These polls can contain specific user data directed to the EUM or the PC connected to the EUM, control data directed to the EUM, broadcast data directed to all EUMs, or empty polls, which containing no information data.

In an ideal system, all data transmitted would be received error free by the EUMs, and no re-transmissions would be required. In the real world, unfortunately, low signal conditions, interferers, system engineering problems, and equipment malfunction can result in the need to retransmit data over the radio link. These retransmissions, which are key to maintaining data integrity for the end user, come with the trade-off of reduced network capacity.

Statistics reported by the CCU can assist in identifying when retransmissions are occurring and at what rate they are occurring. They can also be used to troubleshoot the cause of retransmissions.

The statistic *txPayloads* gives the total number of transmitted payloads, consisting of

- user data received by the CCU Ethernet port, and transmitted over the radio network,
- user data received from an EUM, that is “switched” to the CCU radio port for transmission to another EUM,
- MAC control data,
- broadcast data, and
- data retransmitted because it was not acknowledged by an EUM and is assumed lost.

Examining this statistic in more detail, *txPayloads* includes

- Tx Data Payloads which, in turn, includes
  - data coming from the Ethernet port of the CCU (either end-user data or operator monitoring [SNMP] data),
  - data coming from EUM-originated data payloads that have been “switched” to the CCU radio port (for transmission to other EUMs), and
  - broadcast data to all EUMs(*TxPayloadsBCast*).

  NOTE: The Tx Data Payloads described above are both transmitted during specific EUM poll periods.

- Tx Ctrl Payloads — Control data generated in the CCU, and used to configure, or request status from, the EUMs. Tx Ctrl Payloads are transmitted during specific EUM poll periods.
- Retransmitted data — Data that is not acknowledged after a transmission and is assumed to be lost or corrupted.

Understanding the relationship between these values helps you monitor the integrity of a CCU radio environment.

All non-broadcast payloads (hence, “directed” payloads) are explicitly acknowledged by the EUMs. For these payloads, the result of a transmission during an EUM poll cycle will be one of the following:

Table 26 Possible Transmission Outcomes

Result of Transmission	Reported Statistic
Payload is delivered to an EUM and acknowledged on the first poll.	*txPayloads1Ok*
Payload is transmitted twice, after which an acknowledgement is received.	*txPayloads2Ok*
Payload is transmitted three times, after which an acknowledgement is received.	*txPayloads3Ok*
Payload is transmitted four times, after which an acknowledgement is received.	*rxPayloads4Ok*
No acknowledgement received after four transmissions, and the payload is discarded.	*txPayloadsFailRetry*
Payload is not transmitted at all.	*txPayloadsFailAssocDeleted*

To put these values in perspective, the following samples have been taken from a live CCU, using the `<stats mac>` CLI command:

Table 27 Typical CCU Transmit Statistics

	Statistic	Sample
A	*tx Data Payloads*	67,790
B	*tx Ctrl Payloads*	901
C	*txPayloadsBCast*	445
D	*txPayloads1Ok*	66,001
E	*txPayloads2Ok*	1,761
F	*txPayloads3Ok*	281
G	*txPayloads4Ok*	91
H	*txPayloadsFailRetry*	102
I	*txPayloadsFailAssocDeleted*	11

The objective of the first level analysis of this data is to determine the relative amount of radio traffic resulting from retransmissions. Ideally, the percentage would be 0. In practice, local engineering limitations result in a certain normal level. Once this normal level is established, the statistics can be used to monitor changes.

Since not all of these CCU transmit statistics are independent, you have to be careful when interpreting and using results which are based on these statistics. For example, since broadcast payloads are not acknowledged, the retry data is not relevant to these payloads, and they have to be netted out of the total. In addition, the *txPayloadsFailAssocDeleted* payloads are not actually transmitted. So they also have to be netted out of the total. The calculations to do this are shown below:

Using this data, the following calculations can be made:

Total number of desired payloads = A + B = 68,691

Net Payloads sent via EUM polls (see note) =
A + B - C - I = 67,790 + 901 - 445 - 11 = 68,235

This same result can be calculated as follows:

Net Payloads sent via EUM polls (see note) = D + E + F + G + H = 68,236

NOTE: Due to real-time issues (at any given time, some packets are being processed or queued), the numbers often differ by the small number of packets that are in queues.

The percentage of payloads that are delivered on the first transmission

= 66,001 / 68,235 = 97%

Similarly, the percentage of payloads not delivered on the first transmission, but delivered on the second transmission

= 1,761 / (68,235 - 66,001) = 78%

It is generally a good indication if most payloads that fail on the first try are then successful with only one retry.

The percentage of payloads that are not able to be delivered

= 102 / 68,680 = 0.15%

A very low undeliverable payload rate implies that user service has a high level of integrity, and that the radio link is not significantly impacting higher-level TCP/IP applications.

The impact of the retransmissions can be calculated by looking at the total number of transmissions requiring acknowledgments:

= 1xD + 2xE + 3xF + 4xG + 4xH = 71,138.

Adding to this value the non-acknowledged broadcast payloads (*txPayloadsBCast* = 445) results in total txPayloads - 71,583.

A simple metric of overall sector link quality is the effective utilization of the channel, which can be readily calculated as desired payloads transmitted/actual payloads transmitted, or:

(*Tx Data Payloads* + *Tx Ctrl Payloads* - *txPayloadsBCast* - *txPayloadsFailAssocDeleted*) / (*TxPayloads* - *txPayloadsBCast*)

= (67,790 + 901 - 445 - 11) / (71,583 - 445) = 68,235 / 71,138 = 96%

which suggests that 4% of the radio traffic is used to retransmit packets, which is referred to in this document as the Retransmission Rate.

From an operational point of view, it is important to keep the number of retransmissions to a minimum since they reduce the total air time available and the total network throughput.

Although these calculations can appear tedious since all of the referenced statistics are available through MIBs, SNMP management tools, such as SNMPc can directly collect the statistics, calculate the above metric, and track and report its value over time.

11.2 CCU Receive Statistics

Similar to the case for CCU transmit statistics, there are several key CCU receive statistics that you can use to monitor on-going performance of the CCU radio network. When the CCU sends a directed poll to an EUM, it expects to get an acknowledgement. The following results have been taken from a live CCU using the `<stats mac>` command:

Table 28 Typical CCU Receive Statistic

	Statistic	Description	Sample
A	*rxPktsDirected*	An acknowledgement from the EUM that is correctly received by the CCU.	409,730
B	*rxPktsHCRCFail*	Packet received from an EUM, with a corrupted header. Note: This statistic also includes random access packets that have been received with corrupted headers.	2,464
C	*rxPktsFCS Fail*	Packet received from an EUM, with a corrupted payload.	192
D	*replyOrRssiTimeouts*	No reply. Note: This statistic also includes EUM receive errors, by virtue of the fact that if an EUM does not receive a poll from the CCU, for any reason, then it will not reply to the CCU.	22,688

From these statistics:

Total number of replies expected = A + B + D = 434,882

and the receive packet error rate which, as noted in Table 28, includes EUM receive errors and errors associated with random access attempts, is given by

RxPER = (B + C + D) / (A + B + D) = (2,464 + 192 + 22,688) / 434,882 = 5.8%

One other receive statistic that is important in multi-CAP environments where frequency re-use is implemented is *rxPktsNoMatch*. A high value of *rxPktsNoMatch* indicates that the two CCU radio environments are interfering with each other.

The statistic *rxPktsDuplicate* measures the number of times the EUM sends the same packet of information more than once. A high value of *rxPktsDuplicate* indicates that the acknowledgements from the CCU are not being properly received at the EUM.

11.3 EUM Statistics Monitoring

In general, the statistics collected at the EUM are the same as those collected at the CCU; however, there are some differences in meaning (see Appendix H). More significantly, of course, is that the EUM statistics are unique to the EUM, as opposed to the CCU statistics, which are a collective of the CCU and all EUM interactions.

11.3.1 EUM Transmit Statistics

The relationships of the key EUM statistics are the same as those for the CCU. In the case of the EUM, however, no broadcast packets are transmitted, and the value of *txPayloadsFailAssocDeleted* will always be 0. The key EUM transmit statistics, with sample values, are shown below.

Table 29 EUM Transmit Statistics

	Statistic	Description	Sample	Total Payload		Total Packets
A	*txPayloads*	Number of payloads transmitted.	56,293	-		-
B	*Tx Data Payloads*	Number of data payloads to be transmitted (user data)	44,718	-		-
C	*Tx Control Payloads*	Number of control payloads to be transmitted.	2	-		-
D	*txPayloads1Ok*	Payload is delivered to the EUM and acknowledged on the first poll.	36,889	36,889	x1	36,889
E	*txPayloads2Ok*	Payload is transmitted twice, then acknowledge received.	5,216	5,216	x2	10,432
F	*txPayloads3Ok*	Payload is transmitted three times, then acknowledge received.	1,489	1,489	x3	4,467
G	*txPayloads4Ok*	Payload is transmitted four times, then acknowledge received.	553	553	x4	2,212
H	*txPayloadsFailRetry*	No acknowledge received after four transmissions, packet discarded.	573	573	x4	2,292
			Sum	44,720		56,292

The same combinations used for the CCU case are also included in the table for clarity.

As with the CCU transmit statistics, the following sample calculations can be made using the sample data from Table 29:

Total number of desired payloads = B + C = 44,718 + 2 = 44,720

This is also equal to:

(*txPayloads1Ok* + *txPayloads2Ok* + *txPayloads3Ok* + *txPayloads 4Ok* + *txPayloadsFailRetry*) = (36,889 + 5,216 + 1,489 + 553 + 573) = 44,720

NOTE: Due to real-time issues (the fact that at any given time, some packets are being processed or queued), the numbers frequently differ by the number of packets that are in queues.

NOTE: In the case of the EUM, most payloads are sent in response to directed polls; however, a small number of payloads are sent in response to random access polls.

The percentage of payloads that are delivered on the first transmission

= *txPayloads1Ok* / (B + C) = 36,889 / 44,720 = 82.5%

Similarly, the percentage of payloads that are not delivered on the first transmission but are delivered on the second transmission

= *txPayloads2Ok* / (44,720 - 36,889) = 5,216 / 7,831 = 11.7%

The percentage of payloads that are not able to be delivered

= 573 / 44,720 = 1.3%

Since there are no broadcast or control payloads, the calculation of the Retransmission Rate is fairly straightforward:

Retransmission Rate = (1 - desired payloads/actual payloads) x 100
= (1 - *tx Data Payloads* / *txPayloads*) x 100
= (1 - 44,718 / 56,293) x 100
= 21%

11.3.2 EUM Receive Statistics

Perhaps the most important receive statistic is the Receive Signal Strength Indicator (RSSI), which gives a relative indicator of receive signal strength. Using the calibration table in the PCF table, described in *Permanent Configuration File (CCU and EUM)* on page 193, RSSI can be used to determine the true receive signal level, in dBm. It is important to monitor this statistic.

NOTE: Since the EUM can receive packets that are destined for other EUMs, the EUM receive statistics are not as useful as the CCU receive statistics. They are useful when the EUM is the only EUM that is active, which is seldom the case after more than one EUM have been activated.

The statistic *rxPktsDuplicate* measures the number of times the CCU sends the same packet of information more than one time. A high value of *rxPktsDuplicate* indicates that the acknowledgements from the EUM are not being properly received at the CCU.

11.3.3 User Data

The actual user data is recorded by the statistics *Rx Data Payloads* and *Tx Data Payloads*. These statistics could be viewed as billable data and allow the operator to monitor actual usage at the EUM level.

12 Troubleshooting

Troubleshooting an LMS4000 900 MHz radio network problem is an iterative process. First of all, you need to isolate the general location of the problem, then isolate the problem, and finally, determine the root cause of the problem. There are five general areas to which an LMS4000 operational problem might be isolated:

- End-user's PC
- EUM environment
- CCU radio environment
- Operator's network upstream from the CCU (between the CCU and the Internet)
- Internet

The key to efficient troubleshooting is first verifying that the network and equipment upstream from the CCU is operational. This upstream network and equipment includes

- data path from the CCU to the gateway router,
- DNS servers, and
- DHCP server, if DHCP is enabled.

> **NOTE:** The troubleshooting procedures presented in this section are most effective if the upstream path and equipment have already been verified.

Problems can generally be divided between those that affect all EUMs on a CCU, and those that affect only one EUM.

A. If all EUMs are affected

- Verify that the path from the gateway router to the Internet is up.
- Verify that you can ping the CCU Ethernet port from the gateway router.
- If these tests are successful, go to *CCU Troubleshooting* on page 145.

B. If only one EUM is affected:

- Verify that you can ping from the gateway router to other EUMs on the same CCU. If you cannot, go to A. above.
- If this test is successful, go to *EUM Troubleshooting* on page 136.

12.1 EUM Troubleshooting

The following EUM troubleshooting process can be used at the time of the initial EUM installation or during follow-up service visits. In the latter case, troubleshooting focusses on factors that might have changed, using the setup file record from the initial install as a baseline.

In general, the following items will be verified as part of EUM troubleshooting:

- CCU configuration, particularly as it relates to the affected EUM
- EUM configuration
- Radio link integrity
- User PC configuration

All of these items can be checked out from the end-user's PC, but it may be better to use a separate, known PC for the tests outlined in the troubleshooting tables. Then, you can repeat the tests with the end-user's PC to make sure the end-user's PC is configured and working properly.

When a customer reports a problem, it is usually related to a failure of the browser or email application on the PC to successfully access the Internet, or it is a report of degraded service or slowdown. From the problem report, troubleshooting proceeds as follows:

1. To avoid a service call to the end-user's premises, try to isolate the problem remotely, using the procedures outlined in Table 30 on page 138 (for problems where the service is not available) and in Table 31 on page 139 (for problems where the service is degraded).
2. If you are unable to troubleshoot the problem remotely and must visit the end-user's premises, use the procedures outlined in Table 32 on page 140 (service not available) and in Table 33 on page 142 (service degraded).

Two test utilities are commonly used throughout the troubleshooting process. The term `<ipconfig>` generically refers to a utility that verifies IP addresses in the PC, and to force changes when DHCP is enabled. To force a change through DHCP, use a **release** and **renew** command sequence. The IP set in the end-user's PC refers to the following addresses:

- PC IP address
- PC subnet mask
- Gateway IP address (same as the CCU IP address)
- DNS server IP address (usually two addresses are provided)

To enable the <ipconfig> capability, you can use the Windows utility, <winipcfg> in Windows 95 and 98 operating systems, and the DOS utility in newer Windows operating systems.

The <ping> command is used to test data links. A successful short ping test confirms connectivity but may not indicate link error rates that would cause failures in tests with longer packets. A test performed with a long-packet ping provides a better indication of the channel error rate. If long pings are available, use them in conjunction with the short pings. If long pings are not available, ignore the instructions in the following tables that specify long pings. Instead, if the channel is operational, a PC application such as a browser, can be used to generate longer packets and, during the transmission of these longer packets, the retry rate can be monitored. Note that the CCU only originate (using the CLI through the console port) short pings.

EUM-specific tests can be carried out through the CLI, or using the EUM Configuration Utility.

To verify key EUM settings, use the CLI <ip> and <radio> commands.

Table 30 Remote Troubleshooting — EUM (Service Not Available)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
A	Confirm EUM status	Telnet to the CCU and go to the CLI prompt.	Telnet is successful.	Go to Test B.	Check the upstream data path and equipment, or go to *CCU Troubleshooting* on page 145.
B	Verify the CCU configuration for the affected EUM	Check the Authorization Table in the CCU.	Affected EUM ID is not DENIED.	The affected EUM is *enabled* and can transmit and receive data. Go to Test C.	If the EUM is DENIED, change its GOS to BE, BRONZE, SILVER or GOLD. Retry Test B. If the affected EUM does not appear in the Authorization Table, but the default GOS is BE, Bronze, Silver or Gold, then the EUM will actually be *enabled*, and Test B is a PASS. Go to Test C.
C	Check the radio link to the EUM	`<ping>` the affected EUM from the CCU. Use long and short pings.	No ping failures or time-outs.	The radio link to the EUM is likely good. Go to Test D.	If there is no ping response, the radio link may be down. Go to the local troubleshooting procedures outlined in Table 32 on page 140. If you are having partial ping failures, the radio link may be poor. Go to Test D.
D		Telnet to the affected EUM and, through the CLI prompt, enter `<ra rssi>`.	The RSSI value should correspond to the original installed value. A signal $\geq$ -80 dBm should provide robust service, with a low transmission error rate. Refer to *Permanent Configuration File (CCU and EUM)* on page 193 to find out how to convert from RSSI to received signal level in dBm.	The radio link is confirmed. The reported problem will likely be a PC configuration issue. You may be able to resolve this issue with the end-user on the phone. Alternately, go to the local troubleshooting process outlined in Table 32 on page 140.	Go to the local troubleshooting process outlined in Table 32 on page 140.

Table 31 Remote Troubleshooting — EUM (Service Degraded)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
A	Check the gateway to EUM link	From the Ethernet side of the CCU, <ping> the CCU with short and long pings.	No failures or time-outs.	The link to the CCU is OK. Go to Test B.	Problem is upstream from the CCU, and the upstream data path and equipment need to be checked out.
B		From the Ethernet side of the CCU, <ping> the affected EUM with short and long pings.	No failures or time-outs.	The EUM radio link is probably OK. Check the PC configuration. Go to Test C.	The EUM radio link is poor or down. Go to Test C.
C	Confirm the status of the affected EUM	Telnet to the CCU and go to the CLI prompt.	Telnet is successful.	Go to Test D.	Check the radio link to the CCU.
D		Check the Authorization Table in the CCU.	Affected EUM ID is not DENIED.	There has been no change in the subscribed service level. Go to E.	Add the EUM to the Authorization Table, with its subscribed grade of service, or correct the EUM's GOS setting. Retry Test D.
E		From the CCU, <ping> the affected EUM.	No failures or time-outs.	Re-confirms Test B.	The CCU-to-EUM radio link is suspect or down. If you get no response, go to the local troubleshooting procedures outlined in Table 32 on page 140. If you get errors, go to Test F.
F		Telnet to the affected EUM, go to CLI prompt, and enter <ra rssi>.	The RSSI value should correspond to the original installed value. A receive signal ≥ -80 dBm should provide robust service, and a transmission error rate less than 10%. Refer to *Monitoring the Network* on page 127.	The radio link is confirmed. The reported problem is most likely a PC configuration issue. You may be able to resolve this issue with the end-user on the phone. Alternately, go to Table 32 on page 140.	If the RSSI is too low, go to Table 32 on page 140. If the transmission error rate is inconsistent because there are too few packets being transmitted, ask the end-user to launch a browser and monitor the error rate. If the error rate is too high, go to Test G and/or go to local troubleshooting procedures outlined in Table 32 on page 140.

Table 31 Remote Troubleshooting — EUM (Service Degraded)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
G	TIP	Record key EUM statistics from `<stats mac>` (see Table 27 on page 129 and Table 28 on page 131), clear the statistics, then review and record the statistics after traffic has been passed for 10 or 15 seconds.	The retransmission rate, defined in *Monitoring the Network* on page 127, is low.	The slowdown is likely not due to the radio network. Check the PC.	Go to the local troubleshooting procedures outlined in Table 32 on page 140.

Table 32 Local Troubleshooting — EUM (Service Not Available)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
	TIP	When using a substitute PC as part of the troubleshooting procedure, be sure to clear the Customer Table in the EUM, to allow the substitute PC to be recognized by the EUM. This can be done through the CLI command, by entering `<cust flush>`, or by resetting the EUM.			
A	Verify settings	Connect a PC to the EUM console port with a serial cable. Bring up the CLI prompt, and type `<ip> <cr>`, then `<radio> <cr>`.	The values displayed should be the operator-assigned parameters.	Go to Test B.	Input the proper configuration. Check to see if the reported problem has been resolved. If it has not been resolved, go to Test B.
B	Verify the radio link	Check the received signal level.	The center LED on the EUM is flashing rapidly, or ON solidly.	The received signal is ≥ -80 dBm, which should provide enough margin for stable performance. Go to Test C.	• If there is no LED activity, confirm the radio frequency. • Use the RSSI or Configuration Utility to measure the received signal strength. • Check the antenna connections. • Improve antenna pointing and/or location.

Table 32 Local Troubleshooting — EUM (Service Not Available)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
C	Verify the data link	Check the Ethernet LEDs on the PC and EUM Ethernet connectors.	The Link LED is ON solid green, and the Traffic LED is flashing occasionally with traffic.	Cable connection is good, and the Ethernet interfaces are active. Go to Test D.	• Check the type of cable. The cable between the EUM and PC should be a crossover cable. • Check connector pins. Make sure none of the pins have been damaged. • Check for a pinched cable. • Check for possible hardware problems at the PC. • Change to a different PC, with a shorter cable. • If none of the above resolves the problem, you might suspect a defective EUM.
D	Verify the logical data connection between the PC and EUM	Through the DOS command line on the end-user's PC, `<ping>` the EUM with short and long packets.	No failures or time-outs.	Confirms the physical and logical connection to the EUM, and basic IP addressing. Go to Test E.	• Verify the IP address in the PC, by entering `<ipconfig>` in the DOS command line. If the IP is bad, enter the appropriate IP set (PC's IP, gateway IP, and DNS IP). • If using DHCP, renew through `<ipconfig>`. • If DHCP fails, enter a valid IP set for remaining tests • Change to a different PC, using shorter cable. • If none of the above resolve the reported problem, you might suspect a defective EUM.
E		Through the DOS command line on the end-user's PC, `<ping>` the CCU with short and long packets.	No failures or time-outs.	Confirms data transmission over the radio link, and completes the 900 MHz network-specific troubleshooting. Go to Test F.	If no pings are successful: • Verify the EUM ID in the CCU Authorization Table. • Reboot the EUM. • Reboot the PC. • Refer to *If You Have an Interferer* on page 149. If pings are successful but have errors: • Refer to *If You Have an Interferer* on page 149.

Table 32 Local Troubleshooting — EUM (Service Not Available)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
F	Verify the data connection to the Internet	Through the DOS command line, `<ping> 207.23.175.75` (WaveRider web site)	No failures or time-outs.	The data connection to the Internet is OK. Go to Test G.	Verify network status. It is likely that all EUMs are affected.
G		Through the DOS command line, `<ping> www.waverider.com`.	No failures or time-outs.	DNS server access (required for browser and email applications) is working properly, and so is the EUM installation.	The DNS server is unavailable.
H	If DHCP failed in Test D	Through the DOS command line, <ping> the DHCP server address.	No failures or time-outs.	The DHCP server is present. Go to Test I.	The DHCP server is not available.
I		Enable auto IP mode in the PC. Renew IP.	Valid IP set assigned.	DHCP is operational. Go to Test J.	Suspect the PC configuration. Verify DHCP operation at a different site.
J		Through the DOS command line, `<ping> www.waverider.com`.	No failures or time-outs.	Confirms full Internet availability through the network. EUM installation is working OK.	Suspect the PC IP set, or DHCP or DNS server operation.

Table 33 Local Troubleshooting — EUM (Service Degraded)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
A	Verify the radio link.	Check the received signal level.	The center LED on the EUM is flashing rapidly, or ON solidly.	Received signal is greater than -80 dBm, which should provide enough margin for stable performance. Go to B.	• If there is no LED activity, confirm the radio frequency. • Use the RSSI or Configuration Utility to measure signal strength. • Check antenna connections. • Improve antenna pointing and/or location.

Table 33 Local Troubleshooting — EUM (Service Degraded)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
B	Verify the logical data connection between the PC and EUM.	Through the DOS command line, `<ping>` the EUM with short and long packets.	No failures or time-outs.	Confirms physical and logical connection to the EUM, and basic IP addressing. Go to C.	• Verify the IP address in the PC, by entering `<ipconfig>` in the DOS command line. If the IP is bad, enter the appropriate IP set (PC's IP, gateway IP, and DNS IP). • If using DHCP, renew through `<ipconfig>`. • If DHCP fails, enter valid IP set for remaining tests • Change to different PC, using shorter cable. • If none of the above, suspect defective EUM.
C		Through the DOS command line, `<ping>` the CCU with short and long packets.	No failures or time-outs.	Confirms data transmission over the radio link, and completes the 900 MHz network-specific troubleshooting. Go to E.	If no pings are successful: • Verify the EUM ID in the CCU Authorization Table. • Reboot the EUM. • Reboot the PC. • Refer to procedure <In the Case of Interference>. If pings are successful but have errors: • Refer to procedure <In the Case of Interference>.
D	Verify data transfer across the radio link.	Through the DOS command line, FTP to the CCU, and follow the instructions set out in *Transfer a File to or from a CCU Using FTP* on page 78 (bin, hash, get <file>).	The FTP transfer rate varies depending on system loading; however, you should see a resultant transfer rate corresponding to the assigned GOS for the EUM.	Confirms data transmission over the radio link, and completes the 900 MHz network-specific troubleshooting. Go to E.	If the data transfer rate is poor, or if you observed severe stalling of the transfer progression (minor stalls can be expected and are a normal part of the polling process).

Table 33 Local Troubleshooting — EUM (Service Degraded)

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
E		Open browser to http://speed-test.net, run the download and upload tests.	Throughput in both directions should be consistent with the subscribed service level, with an allowance for the overall traffic level on the CCU.	Customer complaint may be related to the customer's perception of the service level fluctuating with traffic load variation. Go to F.	Repeat the test with a different PC and data cable.
F		Through the console port, enter CLI command `<ra rssi>`. Repeat the long upload test from http://speed-test.net.	Tx error rate less than 10%.	Slowdown is likely at the network level.	Refer to procedure <In the Case of Interference>.
G	TIP	If you are still unclear whether the slowdown is local or at the network level, use FTP test between the PC and CCU, and compare with the speed-test.net result in D. If the results are similar, then the slowdown is likely local. If the FTP between the PC and CCU is faster, then the slowdown is likely at the network level.			

12.2 CCU Troubleshooting

CCU troubleshooting can be broken down into several areas, based on the working history of the CCU, the nature of the reported problem, and the extent of the reported problem. For the purpose of this troubleshooting section, it is assumed that the CCU has been installed according to the guidelines provided by WaveRider and EUMs have been successfully deployed and operated. Subsequent problems can then be divided into the following categories:

- Unable to add new EUMs
  - New EUMs cannot get service
  - Adding new EUMs causes degraded performance to existing EUMs
- Complaints of degraded performance
  - Customer complaints of slow throughput
- Service outages
  - All customers have no service
  - Some customers have no service
- Key Statistics (refer to *Monitoring the Network* on page 127) indicate an increase in retransmitted and/or lost packets

The possible causes for these problems can be identified as follows:

- Configuration error at CCU
- System congestion
  - Impacts EUMs depending on their assigned GOS level
- Presence of an interferer
  - Impacting the CCU
  - Impacting all or most EUMs in the sector
- Hardware failure of the CCU system (CCU, power, antenna, etc.)
  - Impacts all EUMs in the sector

Regardless of the extent of the reported problem, there exist remote and local tests that can be used to isolate the cause.

Since there are so many possible entry levels to a troubleshooting procedure, the following troubleshooting guides are intended to provide suggested tests that can be carried out as part of the troubleshooting process. Some tests may not be required in all scenarios and good judgement should be used when carrying out the tests.

The remote CCU tests outlined in Table 34 on page 146 are generally useful as a starting point for all CCU troubleshooting. These tests should be carried out prior to performing the local tests outlined in Table 35 on page 147, keeping in mind the remote tests can be carried out locally using the serial port to access the CLI command set.

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Table 34 Remote Troubleshooting — CCU

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
A	Confirm the network link to the CCU	Telnet to the CCU.	Access to the CCU is available.	Verifies network access connectivity down to the CCU level.	Either the network connection to the CCU is down, or the CCU Ethernet port is not responding. Confirm the network connection to the CCU site. If OK, go to the local CCU tests outlined in Table 35 on page 147.
B	Confirm EUM status at the CCU	Enter the CLI, type `<air>`.	All EUMs for the sector should be listed.	All EUMs listed have successfully communicated with the CCU during the last 12-hour period. The time since their last transmission is listed in the table. Go to Test C.	If only some EUMs are missing, they may be turned off, or may be unable to communicate with the CCU. Verify that all EUMs are assigned a usable GOS in the Authorization Table (enter `<auth>` in the CLI). If no EUMs are present, all EUMs have been unable to communicate with the CCU. Reset the CCU. If no EUMs register, suspect CCU system failure, or high level of interference. Go to the local CCU tests outlined in Table 35 on page 147.
C	Check for system congestion	In the CLI, type `<ra meter>`.	No indication of violations indicating system congestion. Note *aveIPS* readings for all GOS levels.	No violations means all users are receiving subscribed levels of service. *AveIPS* values that are significantly longer than minimum for the specific GOS may indicate users are seeing “degraded” service with respect to their maximum burst rate. This can happen during busy hour, depending on system traffic load and engineering.	Violations indicate system congestion - too many users at too high a service level. You need to analyze your user traffic levels. *AveIPS* can be used to monitor fluctuation in user-perceived throughput. Slowdowns, even within the bounds of subscribed service, may result in customer complaints.

Table 34 Remote Troubleshooting — CCU

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
D	Check for Key Statistics degradation	in the CLI, type <stats mac>.	Key Statistics, described in *Monitoring the Network* on page 127, should meet general criteria listed, and/or be similar to past values.	No change in the interference environment indicated.	An increase in retry rates is potentially an indication of an interferer at the CCU. If the number of EUMs is small, a specific EUM-link problem could be degrading this statistic, so further analysis may be warranted at the EUM link level.

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Table 35 Local Troubleshooting — CCU

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
A	Check the CCU	Confirm power.	Power LED illuminated.	CCU has adequate powering. Go to Test B.	Check main AC power to CCU AC-DC adaptor. Check AC-DC adaptor power output. Correct or replace, as required.
B		Access the CLI through the serial port.	-	-	-
C		Confirm basic configuration (<ip>, <ra>, <auth>)	Configuration should be as originally configured.	Go to Test D.	Correct the configuration and retest. If system is now functional, review personnel access permission to CCU.
D		Ping CCU Ethernet port.	Successful ping response.	Ethernet port circuitry OK. Go to Test E.	Suspect CCU hardware.
E		Ping the network.	Successful ping response.	Confirms network connection to CCU. Go to Test F.	Check cabling, upstream equipment.
F		Ping the CCU radio port.	Successful ping response.	Radio control circuitry is OK. Go to Test G.	Suspect CCU hardware.
G	Confirm links to EUMs	Type <air>.	All/most EUMs are registered.	EUMs can communicate with CCU. Go to Test H.	Go to Test K. Verify RF system at the CCU. If a captive EUM is available, see TIP I.
H		Ping selected EUMs.	EUMs respond without errors.	Basic CCU network is good. Go to TIP I.	Go to Test K. If a captive EUM is available, see TIP I.

Table 35 Local Troubleshooting — CCU

		What should I do?	What is a good result?	What does a good result mean?	What if I do not get a good result?
I	TIP	Having a captive EUM at the CCU site can be helpful to isolate problems. With a simple antenna, the captive EUM can be accessed from the CCU to confirm the communications capability of the CCU, and the EUM can roughly verify the output signal levels from the CCU.			If a captive EUM cannot be accessed, even when set up in a high-signal receive area, replace the CCU. If access is still not possible, replace the CCU antenna system with a “test antenna”, located 15’ or so from the captive EUM, and repeat Tests G and H.
J	TIP	If only EUMs with high signal levels (i.e., typically those close to the CCU) can be accessed, suspect an interferer.			Go to *If You Have an Interferer* on page 149.
K	Confirm CCU RF network output power.	Check with other EUM sites and confirm that the receive signal level is per the original installed value.	Receive RF signal is per original installed value.	CCU radio network output is normal. Go to Test P.	Go to Test L.
L	Verify RF network and components.	Visually inspect all RF connections.	Connectors look OK.	Go to Test M.	Repair connectors.
M		Use an RF sweep generator test to look for discontinuities in the RF path.	No discontinuities shown.	RF path looks OK. Go to Test N.	RF path component is faulty. Repair/replace, as appropriate.
N		Use a spectrum analyzer to verify the RF system and CCU output.	The CCU transmit power at the CCU radio port should be approximately 26dBm, using a resolution bandwidth > 5MHz.	CCU output is OK. Go to Test O.	Replace the CCU.
O			Measure the CCU receive power with a test antenna on the spectrum analyzer. Adjust the reading based on the distance from the CCU antenna.	RF path is OK. Go to Test P.	Recheck RF path components.
P	Go to if you have an interferer.				

12.3 If You Have an Interferer

The presence of an interferer can cause a variety of performance problems in the radio network. These problems can be quite difficult to positively identify and track down. Typically, the presence of an interferer is first identified by eliminating other potential causes of the observed symptoms.

Interferer problems can be inconsistent, in both the significance of the effect, as well as the duration, since interferers are frequently intermittent.

There are two general types of interferers that have to be addressed — those that share the ISM band with the LMS4000 900 MHz Radio Network, and those that operate adjacent to the ISM band.

The interferers within the ISM band almost always affect individual EUMs since they are generally associated with in-home devices such as cordless phones, baby monitors, and other consumer-oriented ISM band devices. However, there are other outdoor 900 MHz ISM band products. These are typically frequency-hopping spread-spectrum devices that can cover a wide area; therefore, they could impact EUMs and/or the CCU directly. For these devices, it is unlikely that all EUMs would be impacted unless the CCU is directly affected.

Interferers from outside the ISM band include paging signals, which are high power, narrowband transmissions between 929 and 931 MHz (above the 900 MHz ISM band), and cellular transmissions that extend up to 896 MHz (just below the 900 MHz ISM band). For CCU radio networks working at the limits of the ISM band, these out-of-band signals can result in a serious desensitization of the CCU receiver. The RF Planning section of this *User Guide* explains how the frequency planning process must take these signals into account when planning the CCU radio network and how filters are used at the CCU to provide enhanced isolation. If, however, the transmitter sites for these signals are moved after the original CCU design, then the impact can be immediate and significant, frequently requiring that the CCU frequency plan be adjusted. Fortunately, once this problem is diagnosed, changing the frequency plan is relatively straightforward.

In addition to ensuring that the CCU is not impacted by these out-of-band emissions, EUMs can also be impacted if the antenna field of view of the EUMs looks directly at these transmitters. Again, diligent planning is essential.

Interference troubleshooting is divided into two main categories:

- EUM-specific (only one EUM is affected, or a group of EUMs in a small area), suggesting an interferer near these EUMs.
- Many, or all EUMS are affected, suggesting an interferer that is most likely impacting the CCU directly.

As mentioned earlier, the typical impact of an interferer is to effectively increase the noise level at the CCU or EUM, which causes an increased receive error rate. Modems in a CCU network that operate at a lower signal level are more vulnerable to interference, and this provides a tool that can be used to diagnose the problem. For example, if EUMs that normally operate at lower signal levels are seeing higher error levels than those that operate at higher signal levels, then you would suspect an interferer affecting the CCU.

Measuring the level of interference is difficult, unless you have access to a spectrum analyzer and are prepared to shut down the system. In severe cases this may be required as a last resort. Otherwise, the level and location of the interferer has to be deduced from measurements available at the CCU and EUM. Several of these measurements are referenced in the preceding Troubleshooting sections.

Some further clarifications and guidelines are listed here:

- A typical data transmission between the CCU and the EUM requires information packets to go both ways. For example, a payload transmitted from the EUM to the CCU will be acknowledged with an ACK packet returned from the CCU. If the transmission fails, it is difficult to determine directly which direction failed (for an interferer, the failure will occur at the end of the link which is closer to the interferer).
- With the exception of the received signal level, the CCU radio environment is the same for all EUMs. If transmissions from one EUM are unreliable, but transmissions from another EUM with similar received signal strength at the CCU are not, then the likely problem will be found at the affected EUM. If all EUMs of similar signal strength are similarly affected, then the problem will likely be found at the CCU.
- If communications exist, the quality of the transmission can be measured by the transmit retry rate, as indicated in previous sections. This is a powerful diagnostic tool.
- If communications exist, longer packets will suffer more failures (retransmissions) than shorter packets, which can cause the customer to see some applications work better than others (e.g. browsing may be less impacted than FTP file transfers). The ping test, using variable length ping packets, can be a useful device to quantify the extent of this problem.
- If communications from an EUM to the CCU are not possible, the ARP table can be used to divide the link into two sections. A ping from the EUM to the CCU that is received by the CCU will cause the EUM to be entered into the CCU ARP table. Even if the response from the CCU is lost, verifying the entry in the CCU ARP table will confirm the EUM-to-CCU link and suggest that the EUM is in a relatively severe interference environment.
- If the receive signal level at the EUM is above -80 dBm, and the EUM has the correct frequency and valid IP addresses, then if the EUM cannot ping the CCU, it is highly likely there is an interferer in the vicinity of the EUM.
- A local interferer at the EUM location can usually be managed through proper placement of the antenna, and if the interferer is in the same residence, judicious placement of the interfering device.
- For comprehensive diagnosis of an EUM, and determining mitigating actions in severe cases, a spectrum analyzer may be required.

12.4 General Troubleshooting Information

Table 36 provides troubleshooting tips related to general problems that you may be having with trying to operate over the network.

Table 36 General Network Problems

Symptom	Potential Causes
ARP table mismatches	Network devices maintain an ARP table that matches an IP address with a MAC address. Every network device has a unique MAC address. If one network device is replaced by another, and the new device uses the same IP address as the old one, all devices on the network will have an incorrect ARP table. All the network device ARP tables still have the IP address pointing to the MAC address of the old device. This is a temporary problem, as ARP tables are regularly flushed and rebuilt. However, when swapping devices, this could cause a situation where the new device cannot be pinged or accessed until the ARP tables of other devices on the network have adapted to the new configuration. This could take from a few seconds to a few minutes.
IP address conflict	If two network devices have the same IP address, immediate and critical network problems result. Often, both devices shut down.
Network router not configured correctly for new network	When adding a wireless network to an existing Ethernet network, some routing changes may be necessary to the main gateway router of the Ethernet network.
10 to 100 Mbps mismatch between networking equipment	CCUs and EUMs are forced to 10 Mbps on the Ethernet side.

Network Address Translation

If, from an affected host (PC, EUM, or CCU), you find that you can ping the gateway router inside or outside addresses, but cannot ping beyond the gateway router, then you may want to have a look at the operation of the router's network address translation (NAT). In this case, bring up the router NAT translation table, according to the manufacturer's instructions, and check that the host IP address is being properly translated in accordance with the NAT scheme that you have implemented. If it is not being properly translated, then you must reset or clear the NAT translation table in accordance with the manufacturer's instructions.

Ethernet Cable Wiring

Table 37 provides troubleshooting tips related to problems that you may be having with Ethernet cables.

Table 37 Ethernet Cabling Problems

Symptom	Potential Causes
• Unable to ping across a single piece of Ethernet cable. • Lose large-sized ping packets across a single piece of Ethernet cable.	• Ethernet cable wired wrong. • Ethernet cable RJ-45 ends terminated incorrectly or badly. • Wrong cable type (crossover or straight-through) used. • Ethernet cable longer than 100 meters. • Ethernet cable may be damaged, crimped, or bent sharply.

Correct termination of an Ethernet cable is fundamental to preventing problems introduced by crosstalk or noise. If a cable is incorrectly terminated, packet loss and network problems may occur.

An Ethernet cable consists of eight wires, four of which are solid colored, and four of which have white stripes (called tracers). Each solid-color wire and its corresponding color-striped wire are twisted together and considered a pair (e.g. the solid-blue and white-blue wires constitute one pair). The twisting of the wires prevents cross talk and the introduction of noise. Only two of the four available pairs are actually used in data communications — one pair is used for transmitting data and another pair for receiving data. If you look at the bottom of the Ethernet plug (the metal contacts are visible from the bottom). The transmit pair uses pins 1 and 2, and the receive pair uses pins 3 and 6 (see Figure 48).

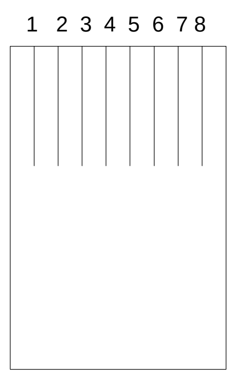

Figure 48 Ethernet Plug (Bottom View)

For a standard straight-through Ethernet cable, both plugs should be set up as follows:

- Pin 1 = White Green
- Pin 2 = Green
- Pin 3 = White Orange

- Pin 4 = Blue
- Pin 5 = White Blue
- Pin 6 = Orange
- Pin 7 = White Brown
- Pin 8 = Brown

For a crossover cable, one plug should be assembled as a standard and the other plug as follows:

- Pin 1 = White Orange
- Pin 2 = Orange
- Pin 3 = White Green
- Pin 4 = Blue
- Pin 5 = White Blue
- Pin 6 = Green
- Pin 7 = White Brown
- Pin 8 = Brown

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13 Specialized Applications

The advanced capabilities of the LMS4000 900 MHz radio network modems can support a variety of special applications.

13.1 EUM Thin Route

In some cases, it may be cost-effective to use an EUM to extend the reach of the LMS4000 900 MHz radio network to small numbers of outlying EUMs, as shown in Figure 49.

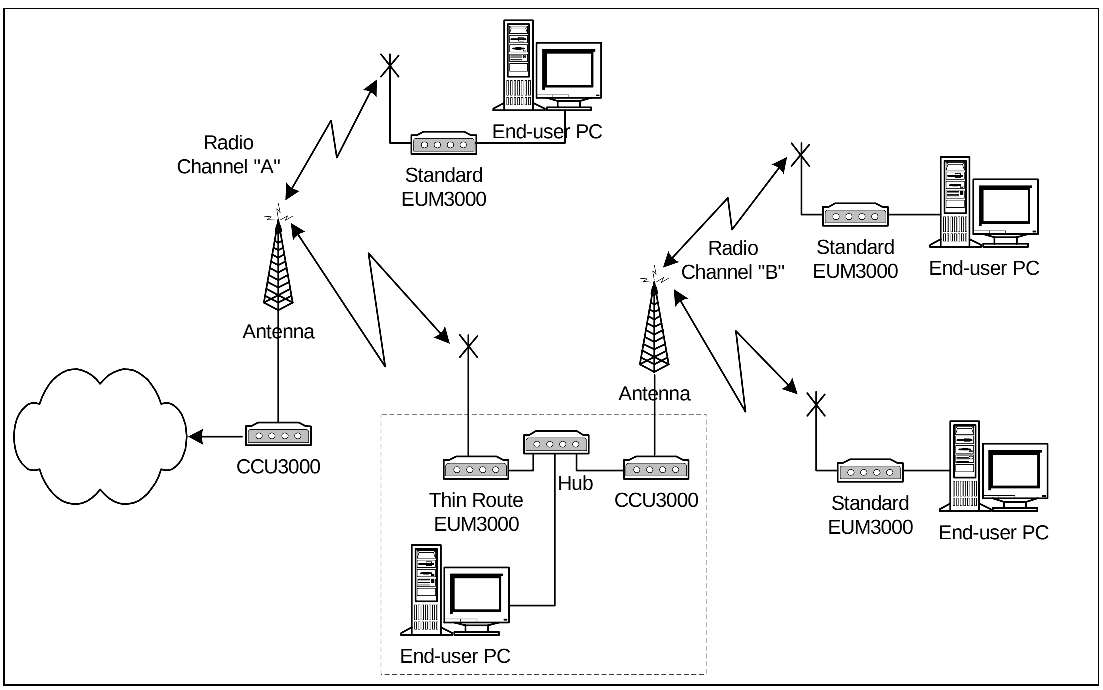

Figure 49 Using an EUM for Thin Route

In this EUM thin-route case, the traffic on the radio channel “b” network traverses two airlinks — the first from the users’ EUMs to the CCU on radio channel “b”, then the second from the thin-route EUM to the CCU on radio channel “a”. This situation reduces the available throughput of the CCU on radio channel “a” by the amount of the traffic on the radio channel “b” network. Depending on the number of EUMs in the radio channel “b” network and their subscribed grades of service, the thin-route EUM may need to be assigned a special grade of service, which can be obtained from WaveRider.

13.2 EUM Backhaul

In some cases, it may be cost-effective to use an EUM as the backhaul link as an alternative to a separate wired or wireless link to the CCU, as is illustrated in Figure 50.

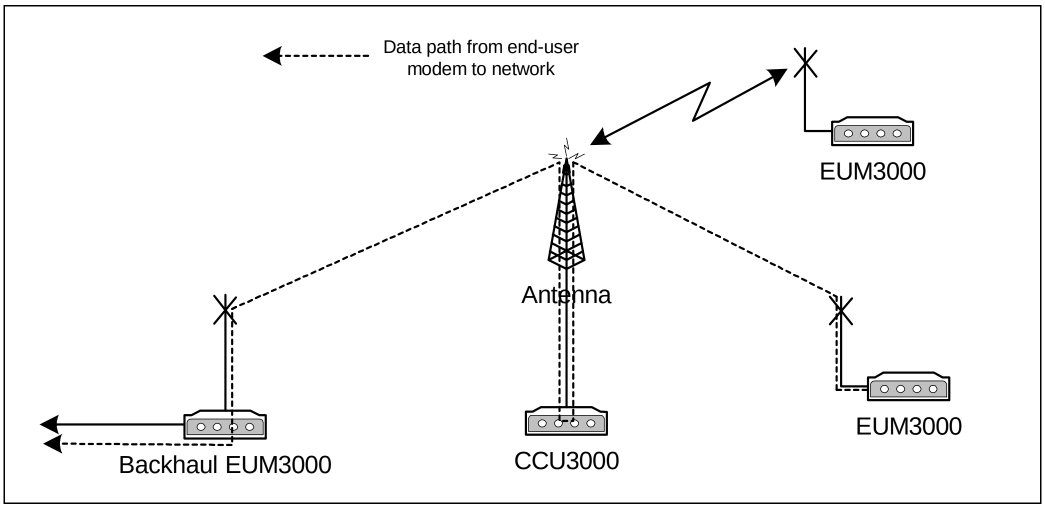

Figure 50 Using an EUM for Backhaul

In the EUM backhaul case, nearly all traffic traverses two airlinks — the first from the users’ EUMs to the CCU then the second from the CCU to the backhaul EUM. This situation reduces the available throughput of the CCU by half. To ensure that the backhaul EUM gets half the polls and that no packets are dropped in the transmit queues, a special GOS class definition still need to be used for the backhaul EUM, and for no others. This special GOS class is available, as an option, from WaveRider.

Appendix A Specifications

This appendix lists the following specifications for the LMS4000 900 MHz Radio Network, specifically the technical specifications for the CCU and EUM, configured for operation in the FCC/IC RF regulatory domain:

- *Radio Specifications* on page 157
- *Ethernet Interface Specifications* on page 158
- *Power Supply Specifications* on page 158
- *Environmental Specifications* on page 158

Table 38 Radio Specifications

Maximum Number of Operational CCUs and Orthogonal Channels	3
Maximum Number of EUMs per CCU	300 The maximum number of subscribers is limited by the terms of the user license purchased from WaveRider.
Minimum Channel Center Frequency	905 MHz
Maximum Channel Center Frequency	925 MHz
Channel Bandwidth	5.5 MHz
Center Frequency Spacing Increment	0.2 MHz (101 channels possible)
Minimum Separation Between Co-located Channels	6.6 MHz
Maximum Co-located Channels	3

Co-located Channel Set Center Frequencies (standard)	905 MHz, 915 MHz, 925 MHz Note: Other frequencies can be used, depending on site-specific considerations. Call WaveRider for more information.
Modulation Scheme	Based on DSSS (Direct-Sequence Spread Spectrum) signals, modulated with CCK (Complementary Code Keying), and Barker-coded BPSK (Binary Phase Shift Keying) and QPSK (Quaternary Phase Shift Keying)
Receiver Sensitivity for BER < 10^{-5}	Better than -86 dBm
Maximum Over-the-Air, Raw Data Rate	2.75 Mbps
Maximum Output Power	+26 dBm

Table 39 Ethernet Interface Specifications

CCU Physical Interface	10BaseT (Ethernet)
EUM Physical Interface	10BaseT (Ethernet)

Table 40 Power Supply Specifications

AC Input	110/230 ± 15% VAC, single phase
AC Input Frequency	50/60 ± 3 Hz
Maximum Input Current	0.2 A

Table 41 Environmental Specifications

Operating Temperature	0°C to +50°C, indoor CCU 10°C to +40°C, indoor EUM (10%-80% RH non-condensing)
Storage Temperature	-40°C to +70°C

Appendix B Factory Configuration

This appendix identifies the factory configuration settings for the CCU and EUM.

Table 42 CCU Factory Configuration

Parameter	Default Configuration
Console Prompt	The default console prompt is the station (CCU) ID.
Deregistration Count	8
DHCP Relay	Disabled
Ethernet IP Address	192.168.10.250
Ethernet Netmask	24
Gateway IP Address	192.168.10.1
GOS Definitions	BE (0 - 384 kbps) Bronze (0 - 1024 kbps) Silver (128 - 256 kbps) Gold (256 - 512 kbps) Denied (0 kbps) Note: The above data rates are based on FTP transfers from a single EUM, using maximum-sized packets)
GOS Default (Authorization Table)	BE (Best Effort)
Maximum Associations	75
Password	<cr>
Port Filters	137 (both) 138 (both) 139 (both) 1512 (both)
Radio Frequency	9050 (905.0 MHz)

Table 42 CCU Factory Configuration

Parameter	Default Configuration
Radio IP Address	192.168.11.1
Radio Netmask	24
Registration Server IP Address	0.0.0.0
Registration Server Netmask	0
SNMP Contact	WaveRider Communications Inc.
SNMP Location	www.waverider.com
SNMP Read Communities	public
SNMP Write Communities	private
SNMP Traps	None entered
SNTP Client Enabled	No
SNTP Client Resynchronization Period	3600 seconds
SNTP Client Retry Period	30 seconds
SNTP Relay Enabled	Yes
SNTP Relay Send Time on Boot	Yes
SNTP Relay Send Time on EUM Registration	Yes
SNTP Servers	132.246.168.148 (time.nrc.ca) 140.162.8.3 (ntp.cmr.gov) 136.159.2.1 (ntp.cpsc.ucalgary.ca) 192.5.5.250 (clock.isc.org) 127.0.0.1 (local host)
Transmit Power	HIGH

Table 43 EUM Factory Configuration

Parameter	Default Configuration
Console Prompt	The default console prompt is the station (EUM) ID.
Ethernet IP Address	192.168.10.250
Ethernet Netmask	24
Gateway IP Address	192.168.10.1
Maximum Bridge Table Size	256
Maximum Number of Customers	1
Password	<cr>

Table 43 EUM Factory Configuration

Parameter	Default Configuration
Port Filters	137 (both) 138 (both) 139 (both) 1512 (both)
Radio Frequency	9050 (905.0 MHz)
SNMP Contact	WaveRider Communications Ltd.
SNMP Location	www.waverider.com
SNMP Read Communities	public
SNMP Write Communities	private
SNMP Traps	None entered
SNTP Client (listen only) Enabled	Yes
Transmit Power	HIGH

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Appendix C   Command-Line Syntax

This appendix describes the various LMS4000 commands and syntax, and consists of the following sections:

- *Command-line Syntax Conventions and Shortcuts* on page 163
- *CCU Command-line Syntax* on page 165
- *EUM Command-line Syntax* on page 174

NOTE: The **help** command on the CCU or EUM may display additional commands that are not listed in the following tables. WaveRider recommends that you use only commands listed in this Appendix.

CAUTION: When entering IP addresses in the CCU or EUM, note that a leading '0' forces the CCU/EUM operating system to interpret the entry as octal rather than decimal. For example, pinging 10.0.2.010 actually pings 10.0.2.8

To Access the Command-line Interface

- In the WaveRider Configuration Utility, click the Windows menu and select Use Terminal Screen.

Command-line Syntax Conventions and Shortcuts

Table 44 shows the typographical conventions used to represent command-line syntax. Table 45 provides a list of shortcuts and methods to get help on commands. To execute a command, type the command and press **Enter**.

Table 44 Command-Line Syntax Conventions

Convention	Use	Examples
`monospaced font`	Indicates that you must type the text.	`ip route`
Enter	Bold face type indicates a keyboard key press. A plus sign (+) indicates key combinations. For example, for **Ctrl**+**U**, press and hold down the **Ctrl** key, then press the **U** key.	**Enter** **Esc** **Ctrl**+**U**
<variable>	Specifies a variable name or other information that you must replace with a real name or value.	`ip address ethernet <ip_address>`
bold **ch**aracters	Indicates the shortcut characters for a command.	**i**p **e**thernet can also be typed as **i e**
|	Separates two mutually exclusive choices in a command. Type one choice and do not type the vertical bar.	**e**xit|**q**uit
( )	Encloses a range of values from which you can choose a value.	**i**p **e**thernet <aaa.bbb.ccc.ddd> (0-32)

Table 45 Command-Line Shortcuts and Getting Help

Type	To do this...
?	To display the names of the root commands.
<command_name> ?	To display the syntax for a command.
help	To display all the commands, their subcommands and the parameters and options for each command.
help <command_name>	To display the parameters and options for the command.
!!	To repeat the last command that was executed.
ESC	To cancel the command you are typing.

CCU Command-line Syntax

Table 46 CCU Command-Line Syntax

Command Syntax (CCU)	Command Description
add	Displays the Address Table.
add **f**lush	Removes all entries from the Address Table.
add **r**em <eum id>	Removes an EUM ID from the Address Table, where: • <eum id> is the EUM ID, formatted in hexadecimal as XX:XX:XX.
air	Displays the Registration Table.
air **a**ssociations	Displays the maximum association count.
air **del**ete <eum id>	Deletes an EUM from the Registration Table, where: • <eum id> is the EUM ID, formatted in hexadecimal XX:XX:XX.
air **der**eg	Displays the deregistration count.
air **der**eg <value>	Changes the deregistration count, where: • <value> is the deregistration count, from 1 to 254.
air **fd**ereg <eum id>	Forces deregistration of an EUM, where: • <eum id> is the EUM ID, formatted in hexadecimal as XX:XX:XX.
air **fl**ush	Flushes the Registration Table.
arp	Displays the ARP Table.
arp **a**dd <aaa.bbb.ccc.ddd> <XX.XX.XX.XX.XX.XX> [flags]	Adds an entry to the ARP Table, where. • <aaa.bbb.ccc.ddd> is the IP address of the new entry. • <XX:XX:XX:XX:XX:XX> is the Ethernet address, in hexadecimal format. • [flags] is always set to 4, meaning the entry is *permanent* and doesn't time out, as long as the CCU or EUM is ON.
arp **d**el <aaa.bbb.ccc.ddd>	Deletes an entry from the ARP Table: • <aaa.bbb.ccc.ddd> is the IP address of the entry being deleted.
arp **f**lush	Clears the ARP Table.

Command Syntax (CCU)	Command Description
arp **m**ap	Displays the ARP Map Table.
arp **m**ap <aaa.bbb.ccc.ddd>	Maps MAC address to IP address <aaa.bbb.ccc.ddd>. The MAC address is obtained from the ARP Table, or by sending out an ARP request.
auth	Displays the Authorization Table.
auth **a**dd <eum id> <gos>	Adds an EUM to the Authorization Table, where: • <eum id> is the EUM ID, formatted in hexadecimal as XX:XX:XX. • <gos> is the EUM grade of service, for example, gold.
auth **def**ault <gos>	Sets the default GOS, which is the GOS assigned to an EUM on registration, where. • <gos> is the default grade of service, for example, bronze.
auth **del** <eum id>	Removes an EUM from the Authorization Table, where: • <eum id> is the EUM ID, formatted in hexadecimal as XX:XX:XX.
auth **g**os <gos>	Displays the GOS definitions, where: • <gos> is the grade of service, for example, bronze.
bcf	Displays the basic configuration file (BCF).
dhcp	Displays status of CCU DHCP Relay, either *enabled* or *disable*.
dhcp **d**isable	Disables DHCP relay.
dhcp **e**nable	Enables DHCP relay.
dhcp **r**elay	Displays the CCU DHCP relay status and contents of the DHCP Server Table.
dhcp **r**elay **a**dd <aaa.bbb.ccc.ddd> <net mask>	Adds the DHCP server IP address, where: • <aaa.bbb.ccc.ddd> is the IP address of the DHCP server. • <net mask> is the net mask of the DHCP server.
dhcp **r**elay **d**el <aaa.bbb.ccc.ddd>	Deletes the DHCP server IP address, where: • <aaa.bbb.ccc.ddd> is the IP address of the DHCP server.
dhcp **r**elay **f**lush	Flushes the DHCP server IP addresses.

Command Syntax (CCU)	Command Description
exit|**q**uit	Exits the current console session and returns to the password prompt.
file ?	Lists the file system utilities.
file **co**py|**cp** <source> <destination>	Copies a file. Use this command only when upgrading the firmware. • <source> is the name of the source file. • <destination> is the name of the destination file.
file **de**lete <filename>	Deletes a file, where. • <filename> is the name of the file you want to delete.
file **di**r|**l**s	Lists the file directory.
file **g**et <aaa.bbb.ccc.ddd> <username> <password> <source> <destination>	Retrieves a file from a remote location, where. • <aaa.bbb.ccc.ddd> is the IP address or hostname of the computer from which you are retrieving the file. • <username> is the user name required to log on to the remote computer. (If there is no username, as with an EUM, then use the password in place of the username.) • <password> is the password required to log on to the remote computer • <source> is the path and filename of the file that is being retrieved from the remote computer. • <destination> is the path and filename to which the file will be copied.
file **m**kboot|makeboot <filename>	Makes a new boot file, where: • <filename> is the name of the new boot file.
file **re**name|**rn** <old file name> <new file name>	Renames a file, where: • <old file name> is the old file name • <new file name> is the new file name.
help	Displays the console command structure.
ip	Displays the CCU IP address assignments.
ip **e**thernet	Displays the Ethernet IP address of the CCU.

<table>
<tr><th>Command Syntax (CCU)</th><th>Command Description</th></tr>
<tr><td>ip ethernet <aaa.bbb.ccc.ddd> (0-32)</td><td>Changes the Ethernet IP address of the CCU, where:
• <aaa.bbb.ccc.ddd> is the new Ethernet IP address of the CCU.
• (0-32) is the netmask.</td></tr>
<tr><td>ip gateway</td><td>Displays the IP address of the router through which the CCU connects to the Internet.</td></tr>
<tr><td>ip gateway <aaa.bbb.ccc.ddd></td><td>Defines the router through which the CCU connects to the Internet, where:
• <aaa.bbb.ccc.ddd> is the new Ethernet IP address of the router.</td></tr>
<tr><td>ip radio</td><td>Displays the radio IP address of the CCU.</td></tr>
<tr><td>ip radio <aaa.bbb.ccc.ddd> (0-32)</td><td>Changes the radio IP address of the CCU, where:
• <aaa.bbb.ccc.ddd> is the new IP address of the CCU radio.
• (0-32) is the netmask.</td></tr>
<tr><td>password</td><td>Initiates the process for changing the system password.</td></tr>
<tr><td>pcf</td><td>Displays the permanent configuration file (PCF).</td></tr>
<tr><td>ping <aaa.bbb.ccc.ddd></td><td>Sends ICMP echo requests to a remote host, where:
• <aaa.bbb.ccc.ddd> is the Ethernet IP address of the remote host.
Press any key to halt.</td></tr>
<tr><td>port</td><td>Displays the TCP/UDP port filters.</td></tr>
<tr><td>port add <port number> tcp|udp|both</td><td>Adds or modifies a port filter, where:
• <port number> is the number of the port to be filtered.
• One of tcp|udp|both is selected to filter TCP or UDP messages, or both.</td></tr>
<tr><td>port delete <port number></td><td>Deletes a port filter, where:
• <port number> is the port to be deleted.</td></tr>
<tr><td>port flush</td><td>Deletes all port filters.</td></tr>
<tr><td>port print</td><td>Prints port filters.</td></tr>
<tr><td>radio</td><td>Displays the radio attributes of the CCU.</td></tr>
</table>

<table>
<tr><th>Command Syntax (CCU)</th><th>Command Description</th></tr>
<tr><td>radio frequency</td><td>Displays the CCU radio frequency in tenths of a MHz; for example, 905.0 MHz is displayed as 9050.</td></tr>
<tr><td>radio frequency <frequency></td><td>Changes the CCU radio frequency, where.
• <frequency> is the new radio frequency, in tenths of a MHz; for example, 905.0 MHz is entered as 9050.</td></tr>
<tr><td>radio meter</td><td>Displays the current Polling MAC load. This information is displayed for each GOS.</td></tr>
<tr><td>radio rc</td><td>Clears the CCU RSSI and transmit power level history.</td></tr>
<tr><td>radio rf high|low</td><td>Displays or sets the power of the CCU radio. Note: The CCU RF level should always be set to high.</td></tr>
<tr><td>radio rh</td><td>Displays the RSSI and transmit power level history.</td></tr>
<tr><td>radio rssi</td><td>Displays continuous RSSI readings. Press any key to halt.</td></tr>
<tr><td>rcf</td><td>Displays the contents of the route configuration file (RCF).</td></tr>
<tr><td>reset|reboot</td><td>Reboots the CCU.</td></tr>
<tr><td>route</td><td>Displays the routing table for the CCU.</td></tr>
<tr><td>route add <aaa.bbb.ccc.ddd> <eee.fff.ggg.hhh> (0-32)</td><td>Adds a route to the routing table. This command applies only to the CCU.
• <aaa.bbb.ccc.ddd> is the Ethernet IP address of the network being added to the routing table.
• <eee.fff.ggg.hhh> is the Ethernet IP address of the gateway through which the destination is reached.
• (0-32) is the netmask for the destination network.</td></tr>
</table>

Command Syntax (CCU)	Command Description
route **d**elete <aaa.bbb.ccc.ddd> <eee.fff.ggg.hhh> (0-32)	Deletes a route from the routing table. • <aaa.bbb.ccc.ddd> is the Ethernet IP address of the network being removed from the routing table. • <eee.fff.ggg.hhh> is the Ethernet IP address of the gateway through which the destination device is reached. • (0-32) is the netmask for the destination network.
route **s**tats	Displays the routing statistics.
save|**com**mit	Saves configuration changes.
snmp	Displays the CCU SNMP information.
snmp **com**munity	Displays the SNMP communities.
snmp **com**munity **a**dd <community> <**r**ead|**w**rite>	Adds an SNMP community, where. • <community> is the name of the SNMP community being added, from 1-32 characters in length. • Enter <read> or <write> to indicate the type of the community being added.
snmp **com**munity **d**elete <community>	Deletes an SNMP community, where: • <community> is the name of the SNMP community being deleted.
snmp **con**tact	Displays the SNMP system contact.
snmp **con**tact <contact>	Changes the SNMP system contact, where: • <contact> is the name of the contact (WISP, for example), from 1-80 characters in length.
snmp **i**nterface	Displays the SNMP interface MIBs.
snmp **l**ocation	Displays the SNMP system location.
snmp **l**ocation <location>	Changes the SNMP system location, where: • <location> is the location of the CCU, from 1-80 characters in length.
snmp **t**rap	Displays the SNMP Trap Server Table.
snmp **t**rap **a**dd <aaa.bbb.ccc.ddd> <community>	Adds a trap server community, where: • <aaa.bbb.ccc.ddd> is the Ethernet IP address of the trap server. • <community> is the community name for the trap server, from 1-64 characters in length.

Command Syntax (CCU)	Command Description
snmp **t**rap **d**elete <aaa.bbb.ccc.ddd> <community>	Deletes a trap server community, where: • <aaa.bbb.ccc.ddd> is the Ethernet IP address of the trap server. • <community> is the community name for the trap server being deleted.
stats	Displays the statistics for all drivers and network protocols. Do not use this command in a Telnet session since doing so will display only a partial set of stats.
stats **c**lear	Clears the statistics for all drivers.
stats **e**thernet	Displays Ethernet statistics.
stats **m**ac	Displays MAC driver statistics.
stats **n**et	Displays network protocol statistics.
stats **n**et **ic**mp	Displays ICMP statistics.
stats **n**et **ip**	Displays IP statistics.
stats **n**et **t**cp	Displays TCP statistics.
stats **n**et **u**dp	Displays UDP statistics.
stats **ra**dio	Displays radio driver statistics.
stats **rp**	Displays routing protocol statistics.
stats **s**ummary	Displays a summary of the Atmel MAC statistics.
sys ?	Displays system information commands.
sys **l**og <number> <offset>	Displays the modem log file, where: • <number> is the number of characters to print from the log file. • <offset> is the character offset, default is 0.
sys **ma**c	Displays the MAC log.
sys **me**mory	Displays memory allocation information.
sys **p**rompt <new prompt>	Changes the system prompt, where: • <new prompt> is the new prompt, from 1-20 characters in length.
sys **s**s	Displays the system status file.
sys **t**ask	Displays the task list.
sys **u**ptime	Displays system uptime.
sys **v**ersion	Displays software version information.

Command Syntax (CCU)	Command Description
sys **w**log <text>	Writes text to the log file. This command is useful for adding information to the log for subsequent analysis: • <text> may be from 1-80 characters in length.
time	Displays the system calendar clock time.
time **a**dd <aaa.bbb.ccc.ddd>	Adds an NTP server, where: • <aaa.bbb.ccc.ddd> is the NTP server address.
time **c**lient	Manages the SNTP client and displays a list of NTP servers.
time **c**lient **d**isable	Disables the SNTP client.
time **c**lient **e**nable	Enables the SNTP client.
time **c**lient **p**ort <port>	Changes the SNTP client port number: • <port> is the port number. The default port number is 123.
time **c**lient **res**ync <seconds>	Sets the client resync period, where: • <seconds> is the resync period in seconds,
time **c**lient **ret**ry <seconds>	Sets the client retry period, where: • <seconds> is the retry period in seconds.
time **d**elete <aaa.bbb.ccc.ddd>	Deletes an NTP server, where: • <aaa.bbb.ccc.ddd> is the NTP server address.
time **f**lush	Deletes all NTP servers.
time **f**lush **d**efault	Deletes all NTP servers and restores defaults.
time **g**et	Displays the system time.
time **p**rint	Prints the SNTP configuration and NTP server list.
time **ref**resh|**u**pdate	Forces an NTP time update.
time **rel**ay ?	Lists SNTP relay commands.
time **rel**ay **e**nable	Enables SNTP relay over the radio interface.
time **rel**ay **d**isable	Disables SNTP relay over the radio interface.

Command Syntax (CCU)	Command Description
time **rel**ay **i**p|**d**estination <aaa.bbb.ccc.ddd>**|br**oadcast	Sends NTP messages to a single EUM, where: • <aaa.bbb.ccc.ddd> is the IP address of the EUM. or sends NTP messages to all EUMs if broadcast is entered.
time **ser**ver ?	Displays NTP server utilities.
time **ser**ver **p**ort <port>	Changes the SNTP server port, where: • <port> is the port number.
time **ser**ver stratum <value>	Sets NTP stratum or relative stratum offset, where: • <value> is the NTP offset, from 1-5 when sync, and 6-15 when unsync.
time **set** <time>.	Sets the system time (Greenwich Mean Time), where: • <time> is formatted [dy-mon-year hh:mm:ss] or [mm-dd-yy hh:mm:ss}. This command overwrites the local time obtained from the NTP server. The local time will be updated on the next refresh from the NTP server.
time **st**ats	Displays time statistics.

EUM Command-line Syntax

Table 47 EUM Command-Line Syntax

Command Syntax (EUM)	Command Description
arp	Displays the ARP Table.
arp **a**dd <aaa.bbb.ccc.ddd> <XX:XX:XX:XX:XX:XX> [flags]	Adds an entry to the ARP table, where. • <aaa.bbb.ccc.ddd> is the IP address. • <XX:XX:XX:XX:XX:XX> is the Ethernet address, in hexadecimal format. • [flags] is always set to 4, meaning the entry is *permanent* and doesn't time out, as long as the CCU or EUM is ON.
arp **d**el <aaa.bbb.ccc.ddd>	Deletes an entry from the ARP table, where. • <aaa.bbb.ccc.ddd> is the IP address of the entry.
arp **f**lush	Clears the ARP table.
arp **m**ap	Displays the ARP Map Table.
arp **m**ap <aaa.bbb.ccc.ddd>	Maps MAC address to IP address <aaa.bbb.ccc.ddd>. The MAC address is obtained from the ARP Table, or by sending out an ARP request.
bcf	Displays the basic configuration file (BCF).
cust	Displays the Customer Table.
cust **f**lush	Removes all entries from the Customer Table.
cust **m**ax	Displays the maximum number of customers.
cust **m**ax <value>	Sets the maximum number of customers, where: • <value> is the maximum number of customers, from 1-50.
exit|**q**uit	Exits the current console session and returns to the password prompt.
file ?	Lists the file system utilities.

Command Syntax (EUM)	Command Description
file **co**py|**cp** <source> <destination>	Copies a file. Use this command only when upgrading the firmware. • <source> is the name of the source file. • <destination> is the name of the destination file.
file **del**ete <filename>	Deletes a file, where: • <filename> is the name of the file you want to delete.
file **di**r|**l**s	Lists the file directory.
file **g**et <aaa.bbb.ccc.ddd> <username> <password> <source> <destination>	Retrieves a file from a remote location, where. • <aaa.bbb.ccc.ddd> is the IP address or hostname of the computer from which you are retrieving the file. • <username> is the user name required to log on to the remote computer. (If there is no username, as with an EUM, then use the password in place of the username.) • <password> is the password required to log on to the remote computer • <source> is the path and filename of the file that is being retrieved from the remote computer. • <destination> is the path and filename to which the file will be copied.
file **m**kboot|makeboot <filename>	Makes a new boot file, where: • <filename> is the name of the new boot file.
file **re**name|**rn** <old file name> <new file name>	Renames a file, where: • <old file name> is the old file name. • <new file name> is the new file name.
help	Displays the console command structure.
ip	Displays the EUM IP address assignments.
ip **e**thernet	Displays the EUM IP address and netmask, the same for both the radio and Ethernet port.

<table>
<tr><th>Command Syntax (EUM)</th><th>Command Description</th></tr>
<tr><td>ip ethernet <aaa.bbb.ccc.ddd> (0-32)</td><td>Changes the Ethernet IP address of the EUM, where:
<aaa.bbb.ccc.ddd> is the new Ethernet IP address of the EUM.
(0-32) is the netmask.</td></tr>
<tr><td>ip gateway</td><td>Displays the IP address of the CCU through which the EUM connects to the Internet.</td></tr>
<tr><td>ip gateway <aaa.bbb.ccc.ddd></td><td>Changes the CCU through which the EUM connects to the Internet, where:
<aaa.bbb.ccc.ddd> is the radio IP address of the new CCU.</td></tr>
<tr><td>password</td><td>Initiates the process for changing the system password.</td></tr>
<tr><td>pcf</td><td>Displays the permanent configuration file (PCF).</td></tr>
<tr><td>ping aaa.bbb.ccc.ddd</td><td>Sends ICMP echo requests to remote host, where:
<aaa.bbb.ccc.ddd> is the Ethernet IP address of the remote host.
Press any key to halt.</td></tr>
<tr><td>port</td><td>Displays the TCP/UDP port filters.</td></tr>
<tr><td>port add <port number> tcp|udp|both</td><td>Adds or modifies a port filter, where: <port number> is the number of the port to be filtered. One of tcp|udp|both is selected to filter TCP or UDP messages, or both.</td></tr>
<tr><td>port delete <port number></td><td>Deletes a port filter, where:
<port number> is the port to be deleted.</td></tr>
<tr><td>port flush</td><td>Deletes all port filters.</td></tr>
<tr><td>port print</td><td>Prints port filters.</td></tr>
<tr><td>radio</td><td>Displays the radio attributes of the EUM.</td></tr>
<tr><td>radio frequency</td><td>Displays the EUM radio frequency in tenths of a MHz; for example, 905.0 MHz would be displayed as 9050.</td></tr>
<tr><td>radio frequency <frequency></td><td>Changes the EUM radio frequency.
<frequency> is the radio frequency in tenths of a MHz; for example, 905.0 MHz would be entered as 9050.</td></tr>
</table>

Command Syntax (EUM)	Command Description
radio **rc**	Clears the CCU RSSI and transmit power level history.
radio **rf** high|low	Displays or sets the power of the EUM radio. Note: The EUM RF level should always be set to high.
radio **rh**	Displays the RSSI and transmit power level history.
radio **rs**si	Displays continuous RSSI readings. Press any key to halt.
reg eum	Forces the EUM to request registration.
reset|**reb**oot	Reboots the EUM.
save|**com**mit	Saves configuration changes.
snmp	Displays the EUM SNMP information.
snmp **co**mmunity	Displays the SNMP communities.
snmp **com**munity **a**dd <community> <**r**ead|**w**rite>	Adds an SNMP community, where. • <community> is the name of the SNMP community being added, from 1-32 characters in length. • Enter <read> or <write> to indicate the type of the community being added.
snmp **co**mmunity **d**elete <community>	Deletes an SNMP community, where. • <community> is the name of the SNMP community being deleted.
snmp **con**tact	Displays the SNMP system contact.
snmp **con**tact <contact>	Changes the SNMP system contact, where: • <contact> is name of the EUM SNMP system contact (subscriber, for example), from 1-80 characters in length.
snmp **i**nterface	Displays the interface MIBs.
snmp **l**ocation	Displays the SNMP system location.
snmp **l**ocation <location>	Changes the SNMP system location, where: • <location> is the location of the EUM, from 1-80 characters in length.
snmp **t**rap	Displays the SNMP Trap Server Table.

Command Syntax (EUM)	Command Description
snmp **t**rap **a**dd <aaa.bbb.ccc.ddd> <community>	Adds a trap server community, where: • <aaa.bbb.ccc.ddd> is the Ethernet IP address of the EUM. • <community> is the community name for the trap server, from 1-64 characters in length.
snmp **t**rap **d**elete <aaa.bbb.ccc.ddd> <community>	Deletes a trap server community, where: • <aaa.bbb.ccc.ddd> is the Ethernet IP address of the EUM. • <community> is the community name for the trap server being deleted, from 1-64 characters in length.
stats	Displays the statistics for all drivers and network protocols. Do not use this command in a Telnet session since doing so will display only a partial set of stats.
stats **c**lear	Clears the statistics for all drivers.
stats **e**thernet	Displays Ethernet statistics.
stats **ma**c	Displays MAC driver statistics.
stats **n**et	Displays network protocol statistics.
stats **n**et **ic**mp	Displays ICMP statistics.
stats **n**et **ip**	Displays IP statistics.
stats **n**et **t**cp	Displays TCP statistics.
stats **n**et **u**dp	Displays UDP statistics.
stats **ra**dio	Displays radio driver statistics.
stats **rp**	Displays routing protocol statistics.
stats **s**ummary	Displays a summary of the Atmel MAC statistics.
sys ?	Displays system information commands.
sys **l**og <number> <offset>	Displays the modem log file, where: • <number> is the number of characters to print from the log file. • <offset> is the character offset, default is 0.
sys **ma**c	Displays the MAC log.
sys **me**mory	Displays memory allocation information.

Command Syntax (EUM)	Command Description
sys **p**rompt <new prompt>	Changes the system prompt, where: • <new prompt> is the new prompt, from 1-20 characters in length.
sys **s**s	Displays the system status file.
sys **t**ask	Displays the task list.
sys **u**ptime	Displays system uptime.
sys **v**ersion	Displays software version information.
sys **w**log <text>	Writes text to the log file. This feature is useful for adding information to the log for subsequent analysis. • <text> may be from 1-80 characters in length.
time	Displays the system calendar clock time.
time **a**dd <aaa.bbb.ccc.ddd>	Adds an NTP server, where: • <aaa.bbb.ccc.ddd> is the NTP server address.
time **c**lient	Manages the SNTP client and displays a list of NTP servers.
time **c**lient **d**isable	Disables the SNTP client.
time **c**lient **e**nable	Enables the SNTP client.
time **c**lient **p**ort <port>	Changes the SNTP client port number, where: • <port> is the port number. The default port number is 123.
time **d**elete <aaa.bbb.ccc.ddd>	Deletes an NTP server, where: • <aaa.bbb.ccc.ddd> is the address of the NTP server being deleted.
time **g**et	Displays the system time.
time **p**rint	Prints the SNTP configuration and NTP server list.
time **s**et <time>	Set the system time (Greenwich Mean Time), where: • is formatted [dy-mon-year hh:mm:ss] or [mm-dd-yy hh:mm:ss}. This command overwrites the local time obtained from the NTP server. The local time will be updated on the next refresh from the NTP server.
time **st**ats	Displays time statistics.

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Appendix D   Antenna Guidelines

WARNING!

Antennas and associated transmission cable must be installed by qualified personnel, and external antennas must be properly grounded. Failure to terminate the antenna port correctly can permanently damage the EUM. WaveRider assumes no liability for failure to adhere to this recommendation or to recognized general safety precautions.

The CCU and EUM have been certified for use with Omni, Disc, Patch, Yagi, and Dipole Reflector antenna types. Table 48 includes examples of each of the recommended antenna types, as well as their associated maximum antenna system gain.

Table 48   CCU, EUM Supported Antennas

Antenna Type	Maximum Antenna System Gain
Omni	5.1dBi
Disc	3.0dBi
Patch	8.5dBi
Yagi	9.1dBi
Dipole Reflector	10.4dBi

Antenna system gain is the net gain of the system. In other words, it is the antenna gain minus the insertion loss due to cabling, connectors, filters, surge protectors, and other hardware components. During installation, you must verify that the antenna system does not exceed the maximum allowable antenna system gain for that specific antenna type.

Calculate the antenna system gain by adding the value of the insertion loss for each component of the antenna system, excluding the antenna, and subtracting the total of that sum from the antenna gain. You can measure the insertion loss of the components, and the antenna gain, at the frequency of interest, or obtain it by referencing the manufacturer's supplied literature.

For example, with a Yagi antenna system, 10 m of cable, a surge protector, and a bandpass filter, you would calculate the following antenna system gain:

- Antenna Gain: 9.1 dBi
- Insertion loss:
    - Cable/connectors: - 4.0 dB
    - Surge Protector: - 0.2 dB
    - Filter: - 1.1 dB

- Antenna System Gain: 3.8 dBi

The antenna gain (9.1 dBi) minus the total insertion loss (5.3 dBi), yields an antenna system gain of 3.8 dBi, which is a valid antenna configuration, because the antenna system gain is lower than the maximum permissible value of 9.1 dBi for a yagi antenna type.

WARNING!

To prevent equipment damage, you must use the WaveRider proprietary WCM connector to connect transmission line and antennas to the EUM2000.

WARNING!

Use of an outdoor antenna with the EUM requires professional installation, in accordance with FCC guidelines.

WARNING!

Antennas used with the EUM must not present a short to ground at the EUM antenna port. Contact the WaveRider Customer Support Centre for more information.

Appendix E CCU/EUM Data Tables

The CCU and EUM firmware is structured around a set of tables and files, which are discussed in the following sections in the logical order that they are actively involved in the transmission of packets from the Internet to the end-user's PC:

Port Filter Table (CCU and EUM)

The Port Filter Table provides a list of all port filters that have been enabled. Any IP packet with one of these port numbers will be discarded.

The contents of the Port Filter Table are:

Table 49 Port Filter Table Entries

Table Entry	Description
Port	The number of the port which is to be filtered.
Filter	For each port listed, the CCU or EUM can be set to filter UDP, TCP, or both UDP and TCP packets.

To access the Port Filter Table:

```
Console> port
PORT FILTERS
    Port                   Filter
---------------------------------
      137                   both
      138                   both
      139                   both
     1512                   both
----------------------------------
Console>
```

Routing Table (CCU and EUM)

The Routing Table is used by the CCU to determine the routing of IP packets. The routes in the Routing Table are either entered by the system operator as static routes, or automatically generated by the CCU. The CCU does not support dynamic routing. As a minimum, the Routing Table contains the following three routes:

Table 50 Basic CCU Routes

Default Route	Any packet with a destination which is not listed in the Routing Table is forwarded to the gateway address defined in the default route. Normally, this is be the IP address of the NAP router. The default route is generated automatically by the CCU when you enter the gateway IP address.
Radio Subnet Route	Any packet with a destination in the radio subnet (EUMs, end-user PCs) is forwarded to the CCU radio port. This route is automatically generated by the CCU, using the CCU radio subnet IP address, entered by the system operator.
Loopback Route	The loopback interface exists (among other reasons) so the CCU operating system can talk to itself without handing the packet to a hardware driver. This route keeps unneeded traffic off the network. This loopback route is automatically generated by the CCU.

In addition to these standard routes, the system operator may add other routes; for example, routes to support direct CCU-to-CCU communications, without going back to the NAP router.

Each route in the Routing Table has the following entries:

Table 51 Routing Table Entries

Entry	Description
Destination	The IP address for the destination network.
Mask	The subnet mask for the destination network.
TOS	Type of service, for example: • 0000 Default • 0001 Minimize monetary cost • 0010 Maximize reliability • 0100 Maximize throughput • 1000 Minimize delay RFC1700 and RFC1349 recommend TOS settings for various protocols, including Telnet, FTP, TFTP, ICMP and SNMP.
Gateway	The IP address of the gateway through which to access the destination network.
Flags	Refer to Table 52.
RefCnt	Number of processes currently referencing the route. If a process requires a route, it looks it up in the Routing Table. When the route is being referenced by a process, *refcnt* will be incremented by one. When the process is done with the route, *refcnt* will be decremented by one.
Use	Initialized to 0 and incremented every time an IP datagram uses this route.
Interface	The CCU interface through which to send packets to the gateway and destination, one of: • esmc0: CCU Ethernet interface • rdr1: CCU radio interface • lo0: Loopback
Proto	This entry is an operating system parameter that has no meaning for CCU configuration and operation.

To view the Routing Table:

```
WaveRider Communications, Inc. LMS3000
Password:
Console> route
Destination     Mask      TOS   Gateway        Flags RefCnt  Use     Interface Proto
0.0.0.0         0          0    10.0.0.1        803    0     196587   esmc0     1
10.5.0.0        ffff0000   0    10.5.0.1        101    0     0        rdr1      0
127.0.0.1       0          0    127.0.0.1       5      0     24       lo0       0
Console>
```

In the above example, the default route is defined by:

```
Destination      Mask      TOS   Gateway        Flags RefCnt  Use     Interface Proto
0.0.0.0          0          0    10.0.0.1        803   0      196587   esmc0     1
```

Any IP packet with a destination which is not listed in the Routing Table will be forwarded through the Ethernet port (IP address 10.0.0.1) and on to the NAP router.

The radio subnet route is defined by:

```
Destination      Mask      TOS   Gateway        Flags RefCnt  Use     Interface Proto
10.5.0.0         ffff0000   0    10.5.0.1        101   0      0        rdr1      0
```

Any IP packet destined for the radio subnet (any IP address starting with 10.5.xx.xx) will be forwarded through the CCU radio port (IP address 10.5.0.1) and over the radio link to the EUMs and end-user's computers.

The loopback route is defined by:

```
Destination      Mask      TOS   Gateway        Flags RefCnt  Use     Interface Proto
127.0.0.1        0          0    127.0.0.1       5     0      24       lo0       0
```

Any IP packet destined for 127.0.0.1, which is an IP address reserved for loopback, will be looped back to the CCU operating system.

The Routing Table flags are summarized in Table 52.

Table 52 Routing Table Flags.

Flag Mask	Description
0x1	Route usable
0x2	Destination is a gateway
0x4	Host entry (net otherwise)
0x8	Host or net unreachable
0x10	Created dynamically (by redirect)
0x20	Modified dynamically (by redirect)
0x40	Message confirmed
0x80	Subnet mask present
0x100	Generate new routes on use
0x200	External daemon resolves name
0x400	Generated by ARP or ESIS
0x800	Manually added
0x1000	Just discard packets (during updates)
0x2000	Protocol specific routing flag
0x4000	Protocol specific routing flag
0x8000	Modified by management protocol

To use Table 52, consider the flag associated with the default route, 803, which is equal to (800 + 2 +1). Referring to Table 52, this route was manually added, the destination is a gateway, and the route is usable.

ARP Table (CCU and EUM)

For each host (EUM or PC) in the system, the ARP (Address Resolution Protocol) Table displays the following information:

Table 53 ARP Table Entries

Table Entry	Description
destination	Host IP Address
gateway	Host Ethernet MAC Address
flags	Refer to *Routing Table (CCU and EUM)* on page 184 for a description of these flags.
Refcnt	Number of processes currently referencing this ARP entry. If a process requires a MAC address, it looks it up in the ARP Table. When the ARP entry is referenced by a process, *refcnt* will be incremented by one. When the process is done with the ARP entry, *refcnt* will be decremented by one.
Use	Number of times the ARP Table has been accessed for this network element.
Interface	The type of interface, one of the following: • esmc0: Ethernet • rdr1: Radio • lo0: Loopback

The ARP Table is automatically built by the CCU or EUM based on traffic passing between the Ethernet and Radio ports. This table displays the host IP and MAC addresses. After the CCU or EUM recovers the destination IP address from an IP packet sent to the router layer, it looks in the ARP Table to find the destination Ethernet MAC address. If the IP address does not appear in the ARP Table, the CCU or EUM obtains the MAC address through an ARP request/reply and adds it to the ARP Table. The only time a host IP address appears in the ARP Table, is if the host has recently (in the past ten minutes or so) sent or received data. This can be forced using a ping, Telnet, SNMP request, or by entering:

```
arp map <aaa.bbb.ccc.ddd>
```

where `<aaa.bbb.ccc.ddd>` is the host IP address.

To view the CCU ARP table:

```
Console> arp

LINK LEVEL ARP TABLE
destination      gateway            flags  Refcnt  Use           Interface
--------------------------------------------------------------------------
10.0.0.1         00:30:80:4a:08:a1    405    1       5             esmc0
10.0.0.2         00:10:4b:6c:fa:54    405    0       4610          esmc0
```

```
10.0.0.3         00:90:27:33:c7:e8    405    0       507           esmc0
10.0.0.10        00:a0:98:00:9b:26    405    0       1             esmc0
10.0.0.15        00:10:83:fd:61:a     405    0       781           esmc0
10.0.0.16        00:10:83:fd:e1:4e    405    0       1839          esmc0
10.0.0.17        00:b0:d0:e1:04:c0    405    0       155           esmc0
10.0.1.68        00:00:e8:4d:62:3     405    1       19054         esmc0
10.5.1.17        00:50:da:bb:d1:de    405    0       135           rdr1
10.5.2.50        00:50:ba:b3:97:cd    405    0       12            rdr1
10.5.2.54        00:50:da:b7:25:2f    405    0       8823          rdr1
---------------------------------------------------------------------------
Console>
```

Address Translation Table (CCU only)

The Address Translation Table lists the MAC addresses for:

- End-user PC's that have been granted air access, if the CCU has sent traffic to, or received traffic from, the PC
- EUMs, if the CCU has sent traffic to, or received traffic from, the network element.

If no traffic has been sent traffic to, or received traffic from, an end-user PC or EUM host for a 12-hour period, they will be removed from the Address Translation Table.

The CCU uses the Address Translation Table, which is built automatically by the CCU, to look up the EUM ID for a particular MAC address. The MAC addresses associated with the EUM, are:

- EUM Radio MAC Address
- EUM Ethernet Address
- End-user PC MAC Address (one or more)

To view the Address Translation Table:

```
Console> add

EUM ID         MAC Address
-----------------------------------
60:0a:33       00:90:c8:60:0a:33
60:0a:33       00:01:03:04:f7:d8
60:0a:33       00:90:c8:e0:0a:33
60:00:46       00:90:c8:60:00:46
60:00:4a       00:50:da:bb:d1:de
60:00:4a       00:90:c8:60:00:4a
60:03:75       00:90:c8:60:03:75
60:02:79       00:90:c8:60:02:79
60:02:79       00:50:ba:b3:97:cd
60:04:a3       00:90:c8:60:04:a3
60:00:a9       00:90:c8:60:00:a9
60:00:ef       00:01:02:2b:b2:99
60:00:f5       00:02:44:10:a6:6f
Total of 13 entries
Console>
```

In the above view, the following MAC addresses are associated with EUM ID 60:0a:33:

- `00:90:c8:60:0a:33`EUM Radio MAC Address

- `00:01:03:04:f7:d8`End-user PC MAC Address
- `00:50:c8:e0:0a:33`EUM Ethernet MAC Address

Authorization Table (CCU only)

The Authorization Table controls the EUMs' access to the LMS4000 900 MHz Radio Network. The Authorization Table contains the grade of service class for each EUM in the system, whether the EUM is *active* or not.

The contents of the Authorization Table are used by the Polling MAC algorithm, and also by the CCU, to automatically build the Registration Table.

The entries in the Authorization Table can be entered directly by the system operator, or the complete table can be modified remotely and downloaded to the CCU using FTP. The GOS class entry will either be a grade of service class, or "denied" (service).

The Default entry in the Authorization Table is assigned on registration to any EUM that has not been assigned a grade of service class. The Default entry can be a grade of service class, or *denied*, meaning any EUM that has not been assigned a grade of service class will be denied service. This rule applies only to newly registered EUMs, and not to EUMs that have been previously registered. Once you have changed the default, if you want the default changed for all EUMs, regardless of when they registered, then you must flush the Registration Table. The new default then takes effect as the EUMs re-register.

There are two approaches to managing the Authorization Table:

- Approach 1: If the default is set to *denied*, then EUMs will be denied service unless they are explicitly entered in the Authorization Table, with a grade of service.
- Approach 2: If the default is set to a grade of service, such as *best effort*, then EUMs will be authorized and given a *best effort* grade of service unless they are explicitly denied service in the Authorization Table.

To view the Authorization Table:

```
Console> auth

EUM ID       GOS CLASS
----------------------
60:02:79     silver
60:00:a9     bronze
60:03:77     gold
60:04:a3     silver
60:0a:33     silver
Default      gold
Total of 5 entries

Console>
```

Registration Table (CCU only)

The Registration Table contains a list of all *registered* EUMs. The CCU automatically builds and adds to this table as EUMs communicate with the CCU. Every EUM that registers with the CCU appears in this table. The EUM will be removed from the Registration Table if the:

- EUM has not communicated with the CCU for more than 12 hours because:
  - the EUM has been turned off for more than 12 hr., or
  - the EUM has had no traffic to send for more than 12 hr., or
  - the EUM has lost its RF connection to the CCU for more than 12 hr.
- EUM does not respond to traffic from the CCU. In this case, the EUM will be removed immediately from the Registration Table.

The Registration Table contains the following entries:

Table 54 Registration Table Entries

Table Entry	Description
EUM ID	EUM ID
GOS Level	Grade of Service Class
Time (s)	Time since the last payload was received from the EUM.
Maximum Associations	The maximum number of EUMs that can be *associated* at any one instant in time.
Deregistration Count	An EUM will be de-registered if it does not respond after the CCU has sent it this many consecutive polls.

To view the Registration Table:

```
Console> air

Maximum Associations : 75
Deregistration Count : 8


REGISTERED EUMs
EUM ID         GOS Level Time[s]
--------------------------------
60:03:75          gold    22
60:0a:33        silver    2
60:00:ef          gold    29
60:00:46          gold    1
60:00:4a          gold    0
60:00:f5          gold    1522
60:02:79        silver    1
60:03:f6          gold    1
60:04:a3        silver    27
60:00:a9        bronze    0
--------------------------------
```

```
Console>
```

NOTE: The `air` command has been used to view the Registration Table, because `reg` is too close to `reb` (reboot).

ARP Map Table (CCU and EUM)

For each host (EUM or PC) in the system, the ARP Map Table displays the following entries:

Table 55 ARP MAP Table Entries

Table Entry	Description
IP Address	Host IP address
Ethernet	Host Ethernet MAC address
EUMID	EUM ID
GOS	EUM Grade of Service
Last Rx	Number of seconds since the last payload was received from the EUM.

The ARP MAP Table is built automatically by the CCU, from information contained in the Address, ARP and Registration Tables. Its primary use is to summarize the information in these tables in a user-friendly format, for presentation to the system operator.

To view the ARP MAP Table:

```
Console> arp map
ARP MAP TABLE
IP Address       Ethernet           EUMID    GOS        Last Rx
10.5.0.10        00:90:c8:60:02:79  60:02:79 silver     24
10.5.0.11        00:90:c8:60:04:a3  60:04:a3 silver     19
10.5.0.12        00:90:c8:60:03:f6  60:03:f6 gold       23
10.5.0.13        00:90:c8:60:00:a9  60:00:a9 bronze     0
10.5.0.14        00:90:c8:60:0a:33  60:0a:33 silver     24
10.5.0.16        00:90:c8:60:00:ef  60:00:ef gold       21
10.5.0.17        00:90:c8:60:00:4a  60:00:4a gold       20
10.5.0.18        00:90:c8:60:00:46  60:00:46 gold       23
10.5.0.31        00:90:c8:60:03:75  60:03:75 gold       14
10.5.1.14        00:01:03:04:f7:d8  60:0a:33 silver     24
10.5.1.16        00:01:02:2b:b2:99  60:00:ef gold       21
10.5.1.17        00:50:da:bb:d1:de  60:00:4a gold       20
10.5.2.50        00:50:ba:b3:97:cd  60:02:79 silver     24
10.5.2.54        00:50:da:b7:25:2f  60:00:a9 bronze     0
Console>
```

Customer Table (EUM only)

The purpose of the Customer Table is to give the system operator control over the number of PCs that can access the Internet through the EUM. The Customer Table is optimized for the case where multiple hosts are connected to the EUM, but only one accesses the Internet at any given time. The Customer Table also acts as a bridging table, ensuring local traffic is kept local.

The Customer Table presents a list of the end-user computers that are connected to the EUM. If *customer_max* is set to “1”, only one of the computers in the table will have air access. If *customer_max* is set to “n”, up to “n” computers in the Customer Table will have air access.

Air access is assigned on a “first come, first served” basis. If n=1, the first computer to transmit packets will be granted air access. All other computers will be denied air access. If the computer that has been granted air access, does not transmit traffic for 10 minutes, then his air access will be removed and the next computer that transmits a packet will be granted air access.

More generally, for any “n”, up to *customer_max*, the first n computers transmitting packets will be granted air access and, if any of them fails to transmit traffic for 10 minutes, their air access will be removed, allowing the next computer without air access to be granted air access as soon as they transmit data.

The contents of the Customer Table are:

Table 56 Customer Table Entries

Table Entry	Description
MAC Address	Computer’s MAC address
Air Access	Y - computer has been granted air access. N - computer has not been granted air access
Time (s)	Time, in seconds, since the last packet was received from a particular end-user computer or device.

NOTE: If *customer max* is set to 1, and you want to connect a different PC to the EUM, for maintenance purposes, for example, you must clear the Customer Table, reset the EUM, or wait for 10 minutes.

To display the Customer Table:

```
Console> cust

  MAC Address          Air Access   Time[s]
-------------------------------------------
   00:50:da:b7:34:f3    Y            100
   00:50:da:bb:d1:de    N            100

Total of: 2 entries
Console>
```

Basic Configuration File (CCU and EUM)

The Basic Configuration File (BCF) presents a summary of CCU and EUM configurable parameters, which are either the factory default settings, or those entered by the system operator.

To view the BCF for an EUM, for example:

```
Console> bcf

Basic Cfg File:

File ID        : basic.cfg
File Time Stamp:
File Version   : 3
File Notes     : Operator updated
File CRC       : 0xC3

Ethernet/USB IP Address: 10.5.0.31
Ethernet/USB Net Mask  : ffff0000

Gateway IP Address: 10.5.0.1

Contact: WaveRider Communications Inc.
Location: www.waverider.com
Name: LMS3000

SNMP Read Communities:
        public

SNMP Write Communities:
        private

SNMP Traps:

Radio Frequency: 9170
RF Power: HIGH
Customer Connection: Ethernet
Maximum Number of Customers : 50
Maximum bridge table size : 256

Console>
```

The CCU BCF is similar to the EUM BCF.

Permanent Configuration File (CCU and EUM)

The Permanent Configuration File (PCF) is a record of device parameters that are permanently programmed during manufacturing.

To view the PCF:

```
Console> pcf


Permanent Cfg File:

File ID        : perm.cfg
File Time Stamp: 17May2001
File Version   : 002
```

```
File Notes     : Based on TN040

Customer Port MAC Address: 00:90:c8:e0:03:75

Hardware ID: 4B

Airlink MAC Address: 00:90:c8:60:03:75

Serial Number: E00375

Modem Type: EUM

RF level              +27 dbm       +15 dbm
Lo   - 905.0 Mhz        -14        20
Med  - 915.0 Mhz        -22        16
High - 925.0 Mhz        -22        16

RSSI level             -76 dbm      -70 dbm      -46 dbm
Lo   - 905.0 Mhz           45           51           77
Med  - 915.0 Mhz           46           51           78
High - 925.0 Mhz           46           51           78

POT Settings: Wiper1: 131 Wiper2: 152


Console>
```

An RSSI level that falls outside the range of the calibration, or between the calibration points, can be converted to a received signal strength (RSS) reading in dBm, using the following simple rules:

- If the measured RSSI is 'x' below the RSSI level at the lower calibration point, then the received signal strength can be calculated as -76dBm - x. Using the above unit as an example, if you are measuring an RSSI of 42 at a frequency of 915MHz, then the received signal strength is -76dBm - (46 - 42) = -80dBm.
- Similarly, if the measured RSSI is 'y' above the RSSI level at the higher calibration point, then the received signal strength can be calculated as -46dBm + y. Using the above unit as an example, if you are measuring an RSSI of 80 at a frequency of 905MHz, then the received signal strength is -46dBm + (80 - 77) = -43dBm.
- For RSSI measurements that fall between two calibration points, you must interpolate up (1dBm for every unit step in RSSI value) from the lower of the two calibration points if the RSSI falls below the midpoint of the two calibration points. Likewise, you must interpolate down from the higher of the two calibration points if the RSSI falls above the midpoint.

Using these simple rules, the following RSSI-RSS cross-reference table for the above sample unit, at 915MHz, can be produced:

Table 57 RSSI/RSS Cross-reference for Sample Unit (at 915 MHz)

RSSI	RSS	RSSI	RSS	RSSI	RSS	RSSI	RSS	RSSI	RSS
39	-83dBm	48	-74dBm	57	-64dBm	66	-58dBm	75	-49dBm
40	-82dBm	49	-72dBm	58	-63dBm	67	-57dBm	76	-48dBm
41	-81dBm	50	-71dBm	59	-62dBm	68	-56dBm	77	-47dBm
42	-80dBm	51	-70dBm	60	-61dBm	69	-55dBm	78	-46dBm
43	-79dBm	52	-69dBm	61	-60dBm	70	-54dBm	79	-45dBm
44	-78dBm	53	-68dBm	62	-59dBm	71	-53dBm	80	-44dBm
45	-77dBm	54	-67dBm	63	-58dBm	72	-52dBm	81	-43dBm
46	-76dBm	55	-66dBm	64	-57dBm	73	-51dBm	82	-42dBm
47	-75dBm	56	-65dBm	65	-59dBm	74	-50dBm	83	-41dBm

As shown in Table 57, using these simple rules means that the RSS values midway between the calibration points may not exactly line up, but the results will be within the accuracy of the measurement. The Configuration Utility automatically calculates and displays the current received signal strength, and a histogram of the received signal strength.

System Status File (CCU and EUM)

The System Status File is a record of the results of the CCU and EUM POST (Power On Self Test).

To view the System Status File:

```
Console> sys ss
POST Results:
-----------------------
Registers......Passed
Timers.........Passed
SDRAM..........Passed
Watchdog.......Passed
TFFS...........Passed
PCMCIA.........Not run
Ethernet.......Passed
MAC............Passed
Radio..........Not run
USB............Not run
RS232_1........Not run
RS232_2........Not run

File Status:
-----------------------
perm.cfg........Opened-OK
basic.cfg.......Opened-OK
route.cfg.......Test Not Run
sa1110.exe......Opened-OK
netdb.cfg.......Test Not Run
```

```
IO Connections:
-----------------------
USB Detected           True
Ethernet Detected      True
RS232_1 Detected       True
RS232_2 Detected       False

System State:
-----------------------
System         Operational

Console>
```

Appendix F Ping Commands

The following table lists the options available for use with a Windows Ping test. This information was obtained from *Microsoft Windows 2000 TCP/IP Protocols and Services Technical Reference, pp. 184-185.*

Table 58 Windows Ping Test Command Options

Option	Use	Default
-t	Sends Echoes until interrupted.	Not set
-a	Performs a Domain Name System (DNS) reverse query to resolve the DNS hose name of the specified IP address	Not set
-n *count*	The number of Echoes to send	4
-l *size*	The size of the Optional Data field up to a maximum of 65,500	32
-f	Sets the Don’t Fragment (DF) flag to 1	Not set
-I *TTL*	Sets the value of the TTL field in the IP header	32
-v *TOS*	Sets the value of the Type of Service field in the IP header. The TOS value is in decimal	0
-r *count*	Sends the ICMP Echoes using the IP Record Route option and sets the value of the number of slots. Count has a maximum value of 9.	Not set
-s *count*	Sends the ICMP Echoes using the IP Internet Timestamp option and sets the value of the number of slots. Count has a maximum value of 4. Windows 2000 PING uses the Internet Timestamp FLAG set to 1 (records both the IP addresses of each hop and the timestamp.	Not set

Option	Use	Default
-j *host-list*	Sends the ICMP Echoes using the Loose Source Route option and sets the next hop addresses to the IP addresses in the host list. The host list is made up of IP addresses separated by spaces corresponding to the loose source route. There can be up to nine IP addresses in the lost list.	Not set
-k *host-list*	Sends the ICMP Echoes using the Strict Source Route option and sets the next hop addresses to the IP addresses in the host list. The host list is made of IP addresses in the host list. The host list is made of IP addresses separated by spaces corresponding to the loose source route. There can be up to 9 IP addresses in the host list.	Not set
-w *timeout*	Waits the specified amount of time, in milliseconds, for the corresponding Echo Reply before displaying a Request Timed Out message.	1000

Appendix G SNMP MIB Definitions

This appendix defines the MIBs used in the CCU and EUM. These MIBs are organized under the following headings:

MIB-II Elements Supported from RFC-1213

The CCU and EUM support the following MIB-II groups, which are defined in detail in RFC1213.

Groups in MIB-II

MIB-II is divided into the following MIBs. All values in Table 59 are prefixed by 1.3.6.1.2.1.

Table 59 Groups in MIB-II

MIB Name	OID	Type	Status	Description
system	1	MIB	R	This group provides information on the general system, such as system description, contact, system up time.
interfaces	2	MIB	R	This group has one set of values for each interface on the modem. The CCU/EUM has 3 interfaces: 1= loopback, 2 = esmc0 (ethernet) and 2 = mdr1 (radio).

MIB Name	OID	Type	Status	Description
at	3	MIB	R	This group shows the address translation table, mapping Ethernet addresses to IP addresses. This group is only for MIB-I compatibility.
ip	4	MIB	R	This group provides all of the statistics on IP traffic that is routed through the modem. For EUMs, all traffic from the end-user to the CCU bypass the IP stack in the EUM so these numbers are only for the EUM applications. For the CCU, all IP traffic through the CCU router application, including CCU application traffic.
icmp	5	MIB	R	This groups provides statistics on all ICMP packets processed by the IP stack.
tcp	6	MIB	R	This provides counters for all TCP packets processed by the modem. Only TCP packets sent or received by the modem applications are counted (e.g. FTP or Telnet sessions directly to the modem) since any packets for other hosts are routed by the IP protocol and never reach the TCP protocol.
udp	7	MIB	R	Counters for all UDP packets processed by the modem's applications. Only UDP packets sent or received by the modem applications are counted (e.g. FTP or Telnet sessions directly to the modem) since any packets for other hosts are routed by the IP protocol and never reach the UDP protocol.
snmp	11	MIB	R	Counters for all SNMP packets process by the modem's applications.

Interfaces Group MIB

Table 60 provides the details of the Interfaces group MIB mentioned above. All values in the following table are prefixed with 1. 3. 6.1. 2.1. 2.

Table 60 MIB-II Interface List Header MIB

MIB Name	OID	Type	Status	Description
ifIndex	1	Integer	R	The number of entries in ifTable.
ifTable	2	MIB		The list of interfaces.

All values in Table 61 are prefixed with 1.3.6.1.2.1.2.2.1, as defined in RFC1213, and are read only.

Table 61 MIB-II Interface List Table MIB

MIB Name	OID	Value Type	Accepted Values	Description
ifIndex	1	Integer		A unique value for each interface. Its value ranges between 1 and the value of ifNumber. The value for each interface must remain constant at least from one re-initialization of the entity's network management system to the next re-initialization.

MIB Name	OID	Value Type	Accepted Values	Description
ifDescr	2	String	lo0: loopback esmc0: ethernet mdr1: radio	A textual string containing information about the interface. This string should include the name of the manufacturer, the product name and the version of the hardware interface.
ifType	3	Integer	6:ethernet-csmacd 6: radio interface 24: softwareLoopback	The type of interface, distinguished according to the physical/link protocol(s) immediately `below' the network layer in the protocol stack. The radio interface and ethernet-csmacd return the same value since they are both viewed as Ethernet ports by the CCU routing application.
ifMtu	4	Integer		The size of the largest datagram which can be sent/received on the interface, specified in octets. For interfaces that are used for transmitting network datagrams, this is the size of the largest network datagram that can be sent on the interface.
ifSpeed	5	Gauge		An estimate of the interface's current bandwidth in bits per second. For interfaces which do not vary in bandwidth or for those where no accurate estimation can be made, this object should contain the nominal bandwidth.
ifPhysAddress	6	Phys Address		The interface's address at the protocol layer immediately `below' the network layer in the protocol stack. For interfaces which do not have such an address (e.g., a serial line), this object should contain an octet string of zero length.
ifAdminStatus	7	Integer	1: up 2: down 3: testing	The desired state of the interface. The testing(3) state indicates that no operational packets can be passed.
ifOperStatus	8	Integer	1: up 2: down 3: testing	The current operational state of the interface. The testing(3) state indicates that no operational packets can be passed.
ifLastChange	9	TimeTicks		The value of sysUpTime at the time the interface entered its current operational state. If the current state was entered prior to the last re-initialization of the local network management subsystem, then this object contains a zero value.
ifInOctets	10	Counter		The total number of octets received on the interface, including framing characters.
ifInUcastPkts	11	Counter		The number of subnetwork-unicast packets delivered to a higher-layer protocol.
ifInNUcastPkts	12	Counter		The number of non-unicast (i.e., subnetwork-broadcast or subnetwork-multicast) packets delivered to a higher-layer protocol.

MIB Name	OID	Value Type	Accepted Values	Description
ifInDiscards	13	Counter		The number of inbound packets which were chosen to be discarded even though no errors had been detected to prevent their being deliverable to a higher-layer protocol. One possible reason for discarding such a packet could be to free up buffer space.
ifInErrors	14	Counter		The number of inbound packets that contained errors preventing them from being deliverable to a higher-layer protocol.
ifInUnknownProtos	15	Counter		The number of packets received via the interface which were discarded because of an unknown or unsupported protocol.
ifOutOctets	16	Counter		The total number of octets transmitted out of the interface, including framing characters.
ifOutUcastPkts	17	Counter		The total number of packets that higher-level protocols requested be transmitted to a subnetwork-unicast address, including those that were discarded or not sent.
ifOutNUcastPkts	18	Counter		The total number of packets that higher-level protocols requested be transmitted to a non-unicast (i.e., a subnetwork-broadcast or subnetwork-multicast) address, including those that were discarded or not sent.
ifOutDiscards	19	Counter		The number of outbound packets which were chosen to be discarded even though no errors had been detected to prevent their being transmitted. One possible reason for discarding such a packet could be to free up buffer space.
ifOutErrors	20	Counter		The number of outbound packets that could not be transmitted because of errors.
ifOutQLen	21	Gauge		The length of the output packet queue (in packets).
ifSpecific	22	object		Not used

WaveRider CCU Enterprise MIBs

The structure of the CCU MIBs is illustrated in Figure 51.

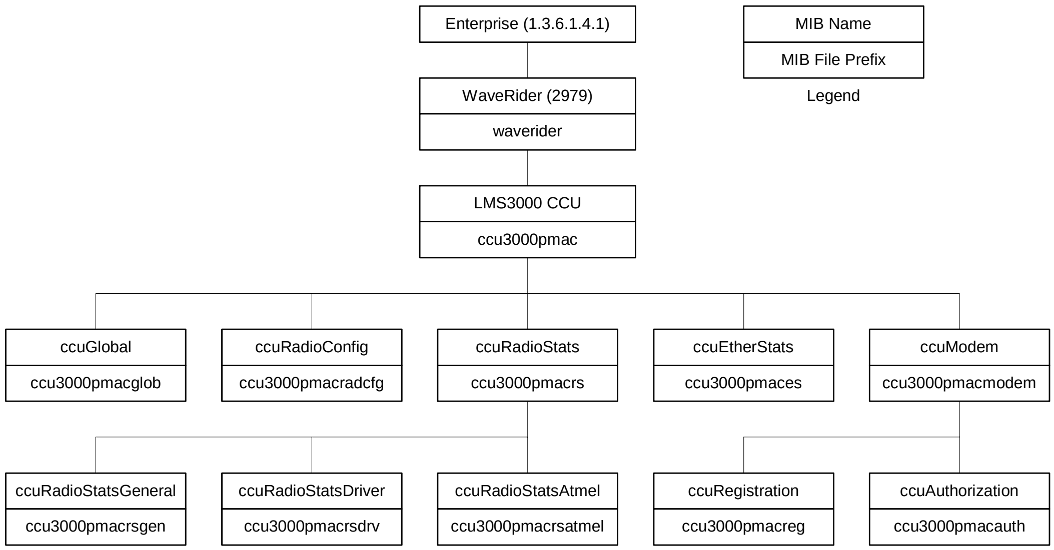

Figure 51 CCU MIBs

Each of the MIBs in Figure 51 is discussed in the following sections.

CCU Base MIB

All values in Table 62, which are read only, are prefixed with 1. 3. 6.1.4.1. 2979.11.

Table 62 WaveRider CCU Base MIB

MIB Name	OID	Value Type	Description
ccuGlobal	1	MIB	CCU general data.
ccuRadioConfig	2	MIB	CCU configuration and setup data.
ccuRadioStats	3	MIB	CCU radio statistics.
ccuEtherStats	4	MIB	CCU Ethernet statistics
ccuModems	5	MIB	CCU registration and authorization information.

CCU General Information Group

All values in Table 63 are prefixed with 1.3.6.1.4.1.2979.11.1.

Table 63 WaveRider CCU General Information Enterprise MIBs

MIB Name	OID	Value Type	Status	Accepted Values	Description
ccuSerialNumber	1	String	R		CCU hardware serial number
ccuSoftwareVersion	2	String	R		CCU firmware version.
ccuHardwareVersion	3	String	R		CCU hardware version.
ccuExtraFunctions	4	Integer	R	0	A mask for extra functionality that may be added at a later date. For now, it returns ‘0’.
ccuGlobalStatus	5	Integer	R	1: startup 2: dead 3: ok 4: suspect	Current status of the radio interface. For now, this field returns ‘ok’.
ccuGlobalSaveCounter	6	Counter	R		A count of the number of times the configuration is saved. Initially, this field always returns ‘0’.
ccuGlobalConfigFiles	7	String	R		A list of configuration files for the CCU. The list is delimited with a semicolon; i.e., “basic.cfg;route.cfg, ...”
ccuGlobalReset	8	Integer	W	1: reset	Not functional at this time.
ccuGlobalReload	9	Integer	W	1: reload	Not functional at this time.

CCU Radio Configuration Group

All CCU Radio Configuration Group MIB values are read only. All values in Table 64 are prefixed with 1.3.6.1.4.1.2979.11.2.

Table 64 WaveRider CCU Radio Configuration Enterprise MIBs

MIB Name	OID	Value Type	Accepted Values	Description
ccuRadioConfigVersion	1	String		Radio firmware version.
ccuRadioConfigMacAirlinkAddr	2	Phys Address	MAC address	Radio MAC address.
ccuRadioConfigFrequency	3	Integer		Radio frequency in use (in 1/10ths of a MHz)
ccuRadioConfigDomain	4	Integer	0: IEEE 1: FCC or IC/ Canada	Current regulatory domain for which the radio is configured.
ccuRadioHardwareRevision	5	String		Radio hardware revision.

CCU Radio Statistics Group

All CCU Radio Statistics Group MIB values are read only. All values in Table 65 are prefixed with 1.3.6.1.4.1.2979.11.3.

Table 65 WaveRider CCU Radio Statistics MIB

MIB Name	OID	Value Type	Description
ccuRadioStatsGeneral	1	MIB	General radio statistics.
ccuRadioStatsDriver	2	MIB	Radio driver statistics
ccuRadioStatsMAC	3	MIB	Radio MAC statistics.

CCU Radio General Statistics Group

All CCU Radio General Statistics Group MIB values are read only. All values in Table 66 are prefixed with 1.3.6.1.4.1.2979.11.3.1.

Table 66 WaveRider CCU Radio General Statistics Group MIB

MIB Name	OID	Value Type	Description
ccuRadioGenRSSI	1	Integer	Not used.
ccuRadioGenTPI	2	Integer	Radio transmit power indicator.

CCU Radio Driver Statistics Group

All CCU Radio Driver Statistics Group MIB values are read only. All values in Table 67 are prefixed with 1.3.6.1.4.1.2979.11.3.2.

Table 67 WaveRider CCU Radio Driver Statistics Group MIB

MIB Name	OID	Value Type	Description
ccuRadioDrvEvents	1	Counter	Number of interrupts received (any interrupt) in the radio driver ISR (Interrupt Service Routine)
ccuRadioDrvRxComplete	2	Counter	Number of *receive complete* interrupts received by the radio driver ISR.
ccuRadioDrvTxComplete	3	Counter	Number of *transmit complete* interrupts received by the radio driver ISR.
ccuRadioDrvCmdComplete	4	Counter	Number of *command complete* interrupts received by the radio driver ISR.
ccuRadioDrvFatalEvent	5	Counter	Number of *fatal error* interrupts received by the radio driver ISR.
ccuRadioDrvTxPowerRailEvent	6	Counter	Number of *Tx Power alarm* interrupts received by the radio driver ISR.

MIB Name	OID	Value Type	Description
ccuRadioDrvUnknownEvent	7	Counter	Number of *received an unknown/no event* interrupts received by the radio driver ISR.
ccuRadioDrvSend	8	Counter	Number of packets sent successfully by the radio driver transmit queue.
ccuRadioDrvSendQFull	9	Counter	Number of packets not sent because the radio driver transmit queue was full.
ccuRadioDrvSendUnavailable	10	Counter	Number of times invalid (null) mblks were sent to the radio driver for transmission.
ccuRadioDrvSendNotEnabled	11	Counter	Number of times tried to send packets before the radio driver was started; i.e., before the device was up and working.
ccuRadioDrvAMMPut	12	Counter	Number of times a packet was successfully sent to the MAC-layer shared memory for transmission over the air.
ccuRadioDrvAMMQFull	13	Counter	Number of times a packet could not be sent to the MAC-layer shared memory because there were no transmit descriptors left. Radio driver tries 5 more times to send the packet.
ccuRadioDrvAMMQFullDiscard	14	Counter	Number of times, after 5 attempts, a packet could not be sent to the MAC-layer shared memory because there were no transmit descriptors left. Packet is discarded.
ccuRadioDrvGet	15	Counter	Number of packets received from the MAC-layer shared memory.
ccuRadioDrvQEmpty	16	Counter	Number of times there was a receive interrupt, but nothing available to read out of the MAC-layer shared memory.
ccuRadioDrvRx	17	Counter	Number of successfully received packets.
ccuRadioDrvRxNotAvailable	18	Counter	Number of times the radio driver could not allocate an mblk (memory block) for storing a packet retrieved from the MAC-layer shared memory.
ccuRadioDrvRxNotEnabled	19	Counter	Number of times the radio driver received a receive interrupt, but the radio driver was not yet up and running. The received packet is ignored in this case.

CCU Radio MAC Statistics Group

All CCU Radio MAC Statistics Group MIB values are read only. All values in Table 68 are prefixed with 1.3.6.1.4.1.2979.11.3.3.

Table 68 WaveRider CCU Radio MAC Statistics Group MIB

MIB Name	OID	Value Type	Description
ccuRadioMACRxDataPayloads	1	Counter	Number of Ethernet frames received correctly from the air interface.
ccuRadioMACRxCtrlPayloads	2	Counter	Number of control payloads received correctly from the air interface.

MIB Name	OID	Value Type	Description
ccuRadioMACRxPayloadFailInvalidType	3	Counter	Number of times an unknown type of payload was received from the air interface.
ccuRadioMACRxPayloadFailGiant	4	Counter	Number of times a payload that was too long was received from the air interface, and therefore discarded.
CCURadioMACNullRxDesc	5	Counter	Number of times the internal MAC receive interface was corrupted.
ccuRadioMACTxDataPayloads	6	Counter	Number of Ethernet frames transmitted to the air interface.
ccuRadioMACTxCtrlPayloads	7	Counter	Number of control payloads transmitted to the air interface.
ccuRadioMACTxPayloadFailInvalidType	8	Counter	Number of times a payload of an unknown type was discarded.
ccuRadioMACTxPayloadFailGiant	9	Counter	Number of times a payload that was too long was discarded.
ccRadioMACTxPayloadFailInvalidDesc	10	Counter	Number of times the internal MAC transmit interface was corrupted.
ccuRadioMACTxBufferFullOnArrival	11	Counter	Number of transmit packets that were queued for delivery.
ccuRadioMACCmdTimeOuts	12	Counter	Number of times the MAC-layer management message was incomplete.
ccuRadioMACCmdMissedIRQs	13	Counter	Number of times there was no response to the MAC-layer management message.
ccuRadioMACFalseCmdIRQs	14	Counter	Number of times a hardware IRQ was detected with no message associated. This MIB parameter is used primarily by software development.
ccuRadioMACCmdStatusErrors	15	Counter	Number of times the MAC-layer management message was rejected.
ccuRadioMACFatalError	16	Counter	Number of nonrecoverable MAC-layer errors, each causing a CCU reboot.
	17		Reserved.
ccuRadioMACRxPacketsRedirected	18	Counter	Number of times a reply from the EUM is received with the correct HCRC (header cyclic redundancy check). Note: The name of this MIB is an error and should be *ccuRadioMACRxPacketsDirected.*
ccuRadioMACRxPktsBroadcast	19	Counter	Number of times an EUM succeeds in a random access.
ccuRadioMACRxPktsNoMatch	20	Counter	Number of packets correctly received, but not directed to, this station.
ccuRadioMACRxPktsDuplicate	21	Counter	Number of duplicate payloads (see note 1) received and discarded. Indicates that a MAC layer acknowledgement was lost.

MIB Name	OID	Value Type	Description
ccuRadioMACRxPktsRuntFail	22	Counter	Number of packets received that were shorter than the minimum size.
ccuRadioMACRxPktsLongFail	23	Counter	Number of packets received that were longer than the maximum size.
ccuRadioMACRxPktsHCRCFail	24	Counter	Number of packets received with a MAC header CRC failure (header corrupted).
ccuRadioMACRxPktsICVFail	25	Counter	Number of packets received with an encryption (WEP, wireless equivalent privacy) key mismatch (see note 3).
ccuRadioMACRxPktsFCSFail	26	Counter	Number of packets received with a Frame Check Sequence failure (payload corrupted).
ccuRadioMACRxPktsAssocFail	27	Counter	Number of times a received packet had to be discarded because too many EUMs were already *associated*.
ccuRadioMACRxPktsIncomplete	28	Counter	Number of times the receive DMA for a payload does not complete (internal error).
ccuRadioMACRxPayloadsFailFull	29	Counter	Number of times a received payload has to be discarded because either no receive descriptor was available, or there was not enough buffer space.
ccuRadioMACRxPayloadsDelivered	30	Counter	Number of payloads that this station received correctly.
ccuRadioMACRxPktsEmpty	31	Counter	Number of packets received with no payload.
ccuRadioMACTxPkts	32	Counter	Number of packets transmitted.
ccuRadioMACTxPktsEmpty	33	Counter	Number of packets transmitted with no payload.
ccuRadioMACTxPayloads	34	Counter	Number of payloads transmitted.
ccuRadioMACTxPayloadsBroadcast	35	Counter	Number of broadcast payloads transmitted.
ccuRadioMACTxPayloads1Ok	36	Counter	Number of payloads acknowledged after the first transmission.
ccuRadioMACTxPayloads2Ok	37	Counter	Number of payloads acknowledged after the second transmission.
ccuRadioMACTxPayloads3Ok	38	Counter	Number of payloads acknowledged after the third transmission.
ccuRadioMACTxPayloads4Ok	39	Counter	Number of payloads acknowledged after the fourth transmission.
ccuRadioMACTxPayloadsFailRetry	40	Counter	Number of payloads that failed to transmit due to the retry limit.
ccuRadioMACTxPayloadsFailDeleted	41	Counter	Number of payloads discarded from a queue that was emptied when an EUM was deregistered due to non-response or deauthorization.
ccuRadioMACTxPayloadsBadParam	42	Counter	Number of payloads returned to the host because they are improperly formed (internal error).
ccuRadioMACTxPayloadsVnetInactive	43	Counter	Number of payloads returned to the host because the virtual net was not active (internal error).

MIB Name	OID	Value Type	Description
ccuRadioMACTxPayloadsAssocFail	44	Counter	Number of payloads returned to the host because too many other EUMs were already *associated*.
ccuRadioMACTxPayloadsTimeout	45	Counter	Number of payloads returned to the host because of timeout.
ccuRadioMACTxPayloadQueueTooLong	46	Counter	Number of payloads returned to the host because the transmit queue for the EUM was too long (see note 4).
	47	Counter	Not used.
ccuRadioMACReplyOrRssiTimeout	48	Counter	Number of times that no response was received to a directed poll.
ccuRadioMACRestarts	49	Counter	Number of times that the MAC layer recovered from an internal error or unexpected event.
ccuRadioMACRegRequests	50	Counter	Number of registration requests received (see note 5).
ccuRadioMACRegResponse	51	Counter	Number of registration responses transmitted (see note 5).
ccuRadioMACDeregRequests	52	Counter	Number of deregistration requests transmitted (see note 5).
ccuRadioMACDeregInits	53	Counter	Number of times no response was received from an EUM, after multiple polls (see note 5). This statistic indicates a poor radio link to one or more EUMs.
ccuRadioMACDisassociationRequests	54	Counter	Number of disassociation requests transmitted (see note 6).
ccuRadioMACDisassociationInits	55	Counter	Number of times the CCU has determined than an EUM should be *disassociated* (see note 6).

Notes:

- A *packet* is the basic unit of transmission. A *packet* may or may not contain a *payload*. A *payload* is user data, which may be an Ethernet frame or a logical link layer control message.
- WEP is not supported in this release.
- The CCU maintains a transmit queue for each EUM. The length of this queue is limited, to prevent one EUM from consuming all the resources and impacting service to other EUMs. Discards indicate excessive load by one EUM, possibly due to large TCP windows.
- Registration occurs once per EUM and/or CCU boot time. Deregistration may occur if an EUM is not authorized (a registration/deregistration request pair occurs periodically while that EUM is powered ON) or if the EUM does not respond to multiple consecutive polls, such as when it is powered OFF.
- Association occurs when there is traffic to send to or from an EUM. Disassociation occurs if there is no traffic to or from an EUM for a short period of time.

CCU Ethernet Statistics Group

All CCU Ethernet Statistics Group MIB values are read only. All values in Table 69 are prefixed with 1.3.6.1.4.1.2979.11.4.

Table 69 WaveRider CCU Ethernet Statistics Group MIB

MIB Name	OID	Value Type	Description
ccuEtherInterrupts	1	Counter	Total number of interrupts received by the Ethernet driver ISR, interrupt service routine.
ccuEtherRxInterrupt	2	Counter	Number of *receive complete* interrupts received by the Ethernet driver ISR.
ccuEtherRxOverrunInterrupt	3	Counter	Number of *overrun* interrupts received by the Ethernet driver ISR. An overrun occurs when a received packet has exceeded the packet size, or the processor has missed one or more packets.
ccuEtherRxInProgressInterrupt	4	Counter	Number of times a *receive complete* interrupt was received by the Ethernet driver ISR before the current packet was finished.
ccuEtherTxCompleteInterrupt	5	Counter	Number of normal transmit interrupts received by the Ethernet driver ISR.
ccuEtherTxErrorInterrupt	6	Counter	Number of *transmit error* interrupts received by the Ethernet driver ISR.
ccuEtherTxCarrierLostInterrupt	7	Counter	Number of *transmit carrier lost* interrupts received by the Ethernet driver ISR.
ccuEtherTxAllocInterrupt	8	Counter	Number of *transmit allocation complete* interrupts received by the Ethernet driver ISR.
ccuEtherTxEPHInterrupt	9	Counter	Number of *transmit EPH* interrupts (Ethernet protocol handler interrupts) received by the Ethernet driver ISR.
ccuEtherTxERCVInterrupts	10	Counter	Number of *transmit ERCV* interrupts (early receive interrupts) received by the Ethernet driver ISR..
ccuEtherRxData	11	Counter	Number of packets received and accepted by the IP stack.
ccuEtherRxDataError	12	Counter	Number of packets received and rejected by the IP stack because of errors.
ccuEtherRxDataMblkAllocError	13	Counter	Number of packets lost due to insufficient memory resources.
ccuEtherRxDataLenghtError	14	Counter	Number of packets received that violate Ethernet packet length rules.
ccuEtherRxDiscards	15	Counter	Number of packets discarded because the unit was not ready to receive data.
ccuEtherTxData	16	Counter	Number of packets received and placed on the transmit queue.
ccuEtherTxDataQFull	17	Counter	Number of packets discarded because the transmit queue was full.

MIB Name	OID	Value Type	Description
ccuEtherTxOk	18	Counter	Number of packets sent correctly.
ccuEtherTxTimeout	19	Counter	Number of times the packet transmit has timed out.
ccuEtherTxSemWait	20	Counter	Number of times a transmit semaphore could not be taken in the timeout period.

CCU Modem Information MIB

All values in Table 70 are prefixed with 1.3.6.1.4.1.2979.11.5.

Table 70 WaveRider CCU Modem Information MIB

MIB Name	OID	Value Type	Description
ccuRegistration	1	MIB	Registration Table.
ccuAuthorization	2	MIB	Authorization Table.

CCU Registration Information MIB

All CCU Registration MIB values are read only. All values in Table 71 are prefixed with 1.3.6.1.4.1.2979.11.5.1

Table 71 WaveRider CCU Registration Information MIB

MIB Name	OID	Value Type	Description
ccuRegistrationCount	1	Integer	Number of connections in the Registration Table.
ccuRegistrationTable	2	MIB	

CCU Registration Table

All CCU Registration Table Group MIB values are read only. All values in Table 72 are prefixed with 1.3.6.1.4.1.2979.11.5.1.2.

Table 72 WaveRider CCU Registration Table MIB

MIB Name	OID	Value Type	Accepted Values	Description
ccuRegistrationIndex	1	Integer		Index of entry in Registration Table.
ccuRegistrationId	2	Integer	000000-FFFFFF	Integer representation of the EUM ID, normally displayed in hexadecimal.

CCU Authorization Information MIB

All CCU Authorization MIB values are read only. All values in Table 73 are prefixed with 1.3.6.1.4.1.2979.11.5.2.

Table 73 WaveRider CCU Authorization Table MIB

MIB Name	OID	Value Type	Description
ccuAuthorizationCount	1	Integer	Number of authorized EUMs.
ccuAuthorizationTable	2	MIB	

CCU Authorization Table

All CCU Authorization Table Group MIB values are read only. All values in Table 74 are prefixed with 1.3.6.1.4.1.2979.11.5.2.2.

Table 74 WaveRider CCU Authorization Table MIB

MIB Name	OID	Type	Accepted Values	Description
ccuAuthorizationIndex	1	Integer		Index of entry in Authorization Table.
ccuAuthorizationId	2	Integer	000000-FFFFFF	Integer representation of the EUM ID, normally displayed in hexadecimal.
ccuAuthorizationGosClass	3	Integer	1: Best Effort 2: Bronze 3: Silver 4: Gold 5: Denied	The grade of service associated with the EUM.

CCU RFC MIB-II Traps

RFC MIB-II Traps

Table 75 CCU RFC MIB-II Traps

MIB Name	OID	Description
coldStart	1.3.6.1.2.1.11.0.0	Power Cycle or Power On.
authenticationFailure	1.3.6.1.2.1.11.0.4	An SNMP request has failed due to improper authentication.

WaveRider EUM Enterprise MIBs

The structure of the EUM MIBs is illustrated in Figure 52.

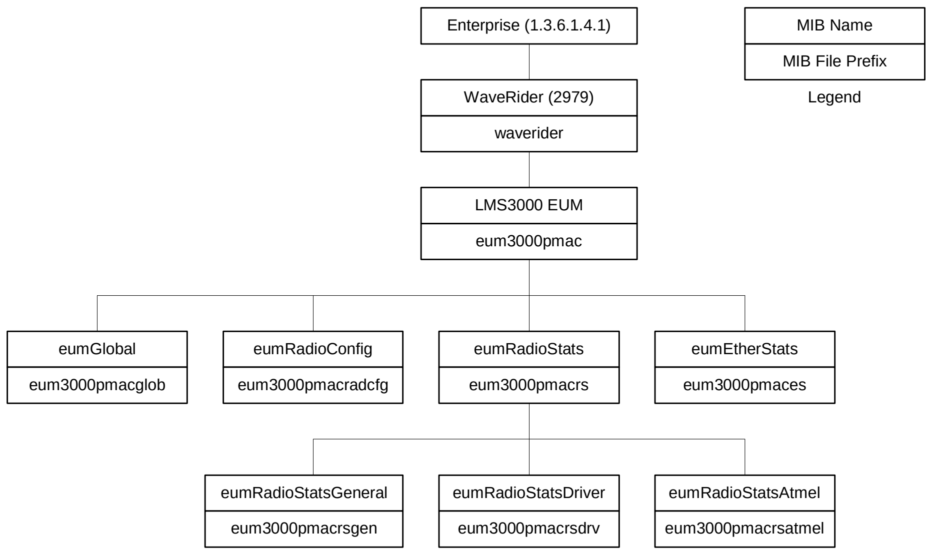

Figure 52 EUM MIBs

Each of the MIBs in Figure 52 is discussed in the following sections.

EUM Base MIB

All values in Table 76, which are read only, are prefixed with 1. 3. 6.1.4.1. 2979.12.

Table 76 WaveRider EUM Base MIB

MIB Name	OID	Value Type	Description
eumGlobal	1	MIB	EUM general data.
eumRadioConfig	2	MIB	EUM configuration and setup data.
eumRadioStats	3	MIB	EUM radio statistics.
eumEtherStats	4	MIB	EUM Ethernet statistics
eumModems	5	MIB	EUM registration and authorization information.

EUM General Information Group

All values in Table 77 are prefixed with 1.3.6.1.4.1.2979.12.1.

Table 77 WaveRider EUM General Information Enterprise MIBs

MIB Name	OID	Value Type	Status	Accepted Values	Description
eumSerialNumber	1	String	R		EUM hardware serial number
eumSoftwareVersion	2	String	R		EUM firmware version.
eumHardwareVersion	3	String	R		EUM hardware version.
eumExtraFunctions	4	Integer	R	0	A mask for extra functionality that may be added at a later date. For now, it returns '0'.
eumGlobalStatus	5	Integer	R	1: startup 2: dead 3: ok 4: suspect	Current status of the radio interface. For now, this field returns 'ok'.
eumGlobalSaveCounter	6	Counter	R		A count of the number of times the configuration is saved. Initially, this field always returns '0'.
eumGlobalConfigFiles	7	String	R		A list of configuration files for the EUM. The list is delimited with a semicolon; i.e., "basic.cfg;route.cfg, ..."
eumGlobalReset	8	Integer	W	1: reset	Not functional at this time.
eumGlobalReload	9	Integer	W	1: reload	Not functional at this time.

EUM Radio Configuration Group

All EUM Radio Configuration Group MIB values are read only. All values in Table 78 are prefixed with 1.3.6.1.4.1.2979.12.2.

Table 78 WaveRider EUM Radio Configuration Enterprise MIBs

MIB Name	OID	Value Type	Accepted Values	Description
eumRadioConfigVersion	1	String		Radio firmware version.
eumRadioConfigMacAirlinkAddr	2	Phys Address	MAC address	Radio MAC address.
eumRadioConfigFrequency	3	Integer		Radio frequency in use (in 1/10ths of a MHz)
eumRadioConfigDomain	4	Integer	0: IEEE 1: FCC or IC/ Canada	Current regulatory domain for which the radio is configured.
eumRadioHardwareRevision	5	String		Radio hardware revision.

EUM Radio Statistics Group

All EUM Radio Statistics Group MIB values are read only. All values in Table 79 are prefixed with 1.3.6.1.4.1.2979.12.3.

Table 79 WaveRider EUM Radio Statistics MIB

MIB Name	OID	Value Type	Description
eumRadioStatsGeneral	1	MIB	General radio statistics.
eumRadioStatsDriver	2	MIB	Radio driver statistics
eumRadioStatsMAC	3	MIB	Radio MAC statistics.

EUM Radio General Statistics Group

All EUM Radio General Statistics Group MIB values are read only. All values in Table 80 are prefixed with 1.3.6.1.4.1.2979.12.3.1.

Table 80 WaveRider EUM Radio General Statistics Group MIB

MIB Name	OID	Value Type	Description
eumRadioGenRSSI	1	Integer	Radio receive signal strength indicator, in dBm. ‘0’ indicates no signal present.

EUM Radio Driver Statistics Group

All EUM Radio Driver Statistics Group MIB values are read only. All values in Table 81 are prefixed with 1.3.6.1.4.1.2979.12.3.2.

Table 81 WaveRider EUM Radio Driver Statistics Group MIB

MIB Name	OID	Value Type	Description
eumRadioDrvEvents	1	Counter	Number of interrupts received (any interrupt) in the radio driver ISR (Interrupt Service Routine)
eumRadioDrvRxComplete	2	Counter	Number of *receive complete* interrupts received by the radio driver ISR.
eumRadioDrvTxComplete	3	Counter	Number of *transmit complete* interrupts received by the radio driver ISR.
eumRadioDrvCmdComplete	4	Counter	Number of *command complete* interrupts received by the radio driver ISR.
eumRadioDrvFatalEvent	5	Counter	Number of *fatal error* interrupts received by the radio driver ISR.
eumRadioDrvTxPowerRailEvent	6	Counter	Number of *Tx Power alarm* interrupts received by the radio driver ISR.

MIB Name	OID	Value Type	Description
eumRadioDrvUnknownEvent	7	Counter	Number of *received an unknown/no event* interrupts received by the radio driver ISR.
eumRadioDrvSend	8	Counter	Number of packets sent successfully by the radio driver transmit queue.
eumRadioDrvSendQFull	9	Counter	Number of packets not sent because the radio driver transmit queue was full.
eumRadioDrvSendUnavailable	10	Counter	Number of times invalid (null) mblks were sent to the radio driver for transmission.
eumRadioDrvSendNotEnabled	11	Counter	Number of times tried to send packets before the radio driver was started; i.e., before the device was up and working.
eumRadioDrvAMMPut	12	Counter	Number of times a packet was successfully sent to the MAC-layer shared memory for transmission over the air.
eumRadioDrvAMMQFull	13	Counter	Number of times a packet could not be sent to the MAC-layer shared memory because there were no transmit descriptors left. Radio driver tries 5 more times to send the packet.
eumRadioDrvAMMQFullDiscard	14	Counter	Number of times, after 5 attempts, a packet could not be sent to the MAC-layer shared memory because there were no transmit descriptors left. Packet is discarded.
eumRadioDrvGet	15	Counter	Number of packets received from the MAC-layer shared memory.
eumRadioDrvQEmpty	16	Counter	Number of times there was a receive interrupt, but nothing available to read out of the MAC-layer shared memory.
eumRadioDrvRx	17	Counter	Number of successfully received packets.
eumRadioDrvRxNotAvailable	18	Counter	Number of times the radio driver could not allocate an mblk (memory block) for storing a packet retrieved from the MAC-layer shared memory.
eumRadioDrvRxNotEnabled	19	Counter	Number of times the radio driver received a receive interrupt, but the radio driver was not yet up and running. The received packet is ignored in this case.

EUM Radio MAC Statistics Group

All EUM Radio MAC Statistics Group MIB values are read only. All values in Table 82 are prefixed with 1.3.6.1.4.1.2979.12.3.3.

Table 82 WaveRider EUM Radio MAC Statistics Group MIB

MIB Name	OID	Value Type	Description
eumRadioMACRxDataPayloads	1	Counter	Number of Ethernet frames received correctly from the air interface.
eumRadioMACRxCtrlPayloads	2	Counter	Number of control payloads received correctly from the air interface.

MIB Name	OID	Value Type	Description
eumRadioMACRxPayloadFailInvalidType	3	Counter	Number of times an unknown type of payload was received from the air interface.
eumRadioMACRxPayloadFailGiant	4	Counter	Number of times a payload that was too long was received from the air interface, and therefore discarded.
eumRadioMACNullRxDesc	5	Counter	Number of times the internal MAC receive interface was corrupted.
eumRadioMACTxDataPayloads	6	Counter	Number of Ethernet frames transmitted to the air interface.
eumRadioMACTxCtrlPayloads	7	Counter	Number of control payloads transmitted to the air interface.
eumRadioMACTxPayloadFailInvalidType	8	Counter	Number of times a payload of an unknown type was discarded.
eumRadioMACTxPayloadFailGiant	9	Counter	Number of times a payload that was too long was discarded.
ccRadioMACTxPayloadFailInvalidDesc	10	Counter	Number of times the internal MAC transmit interface was corrupted.
eumRadioMACTxBufferFullOnArrival	11	Counter	Number of transmit packets that were queued for delivery.
eumRadioMACCmdTimeOuts	12	Counter	Number of times the MAC-layer management message was incomplete.
eumRadioMACCmdMissedIRQs	13	Counter	Number of times there was no response to the MAC-layer management message.
eumRadioMACFalseCmdIRQs	14	Counter	Number of times a hardware IRQ was detected with no message associated. This MIB parameter is used primarily by software development.
eumRadioMACCmdStatusErrors	15	Counter	Number of times the MAC-layer management message was rejected.
eumRadioMACFatalError	16	Counter	Number of nonrecoverable MAC-layer errors, each requiring an EUM reboot.
	17		Reserved.
eumRadioMACRxPacketsRedirected	18	Counter	Number of times a poll for the EUM is received from the CCU with the correct HCRC.
eumRadioMACRxPktsBroadcast	19	Counter	Number of broadcast packets (see note 1) received with the correct HCRC.
eumRadioMACRxPktsNoMatch	20	Counter	Number of packets correctly received, but not directed to, this station.
eumRadioMACRxPktsDuplicate	21	Counter	Number of duplicate payloads (see note 1) received and discarded. Indicates that a MAC layer acknowledgement was lost.
eumRadioMACRxPktsRuntFail	22	Counter	Number of packets received that were shorter than the minimum size.
eumRadioMACRxPktsLongFail	23	Counter	Number of packets received that were longer than the maximum size.

MIB Name	OID	Value Type	Description
eumRadioMACRxPktsHCRCFail	24	Counter	Number of packets received with a MAC header CRC failure (header corrupted).
eumRadioMACRxPktsICVFail	25	Counter	Number of packets received with an encryption (WEP, wireless equivalent privacy) key mismatch (see note 3).
eumRadioMACRxPktsFCSFail	26	Counter	Number of packets received with a Frame Check Sequence failure (payload corrupted).
	27		Not used. Returns a value of ‘0’.
eumRadioMACRxPktsIncomplete	28	Counter	Number of times the receive DMA for a payload does not complete (internal error).
eumRadioMACRxPayloadsFailFull	29	Counter	Number of times a received payload has to be discarded because either no receive descriptor was available, or there was not enough buffer space.
eumRadioMACRxPayloadsDelivered	30	Counter	Number of payloads that this station received correctly.
eumRadioMACRxPktsEmpty	31	Counter	Number of packets received with no payload.
eumRadioMACTxPkts	32	Counter	Number of packets transmitted.
eumRadioMACTxPktsEmpty	33	Counter	Number of packets transmitted with no payload.
eumRadioMACTxPayloads	34	Counter	Number of payloads transmitted.
	35		Not used. Returns a value of ‘0’.
eumRadioMACTxPayloads1Ok	36	Counter	Number of payloads acknowledged after the first transmission.
eumRadioMACTxPayloads2Ok	37	Counter	Number of payloads acknowledged after the second transmission.
eumRadioMACTxPayloads3Ok	38	Counter	Number of payloads acknowledged after the third transmission.
eumRadioMACTxPayloads4Ok	39	Counter	Number of payloads acknowledged after the fourth transmission.
eumRadioMACTxPayloadsFailRetry	40	Counter	Number of payloads that failed to transmit due to the retry limit.
	41		Not used. Returns a value of ‘0’.
eumRadioMACTxPayloadsBadParam	42	Counter	Number of payloads returned to the host because they are improperly formed (internal error).
	43		Not used. Returns a value of ‘0’.
	44		Not used. Returns a value of ‘0’.
eumRadioMACTxPayloadsTimeout	45	Counter	Number of payloads returned to the host because of timeout.
	46		Not used. Returns a value of ‘0’.
	47		Not used. Returns a value of ‘0’

MIB Name	OID	Value Type	Description
eumRadioMACReplyOrRssiTimeout	48	Counter	Number of times the RSSI timer expired because the EUM had not received anything from the CCU for more than 0.5s.
eumRadioMACRestarts	49	Counter	Number of times that the MAC layer recovered from an internal error or unexpected event.
eumRadioMACRegRequests	50	Counter	Number of registration requests transmitted (see note 4).
eumRadioMACRegResponse	51	Counter	Number of registration responses received (see note 4).
eumRadioMACDeregRequests	52	Counter	Number of deregistration requests received (see note 4).
	53		Not used. Returns a value of ‘0’.
eumRadioMACDisassociationRequests	54	Counter	Number of disassociation requests received (see note 5).
	55	r	Not used. Returns a value of ‘0’.

Notes:

- A *packet* is the basic unit of transmission. A *packet* may or may not contain a *payload*. A *payload* is user data, which may be an Ethernet frame or a logical link layer control message.
- WEP is not supported in this release.
- Registration occurs once per EUM and/or CCU boot time. Deregistration may occur if an EUM is not authorized (a registration/deregistration request pair occurs periodically while that EUM is powered ON) or if the EUM does not respond to multiple consecutive polls, such as when it is powered OFF.
- Association occurs when there is traffic to send to or from an EUM. Disassociation occurs if there is no traffic to or from an EUM for a short period of time.

EUM Ethernet Statistics Group

All EUM Ethernet Statistics Group MIB values are read only. All values in Table 83 are prefixed with 1.3.6.1.4.1.2979.12.4.

Table 83 WaveRider CCU Ethernet Statistics Group MIB

MIB Name	OID	Value Type	Description
eumEtherInterrupts	1	Counter	Total number of interrupts received by the Ethernet driver ISR, interrupt service routine.
eumEtherRxInterrupt	2	Counter	Number of *receive complete* interrupts received by the Ethernet driver ISR.

MIB Name	OID	Value Type	Description
eumEtherRxOverrunInterrupt	3	Counter	Number of *overrun* interrupts received by the Ethernet driver ISR. An overrun occurs when a received packet has exceeded the packet size, or the processor has missed one or more packets.
eumEtherRxInProgressInterrupt	4	Counter	Number of times a *receive complete* interrupt was received by the Ethernet driver ISR before the current packet was finished.
eumEtherTxCompleteInterrupt	5	Counter	Number of normal transmit interrupts received by the Ethernet driver ISR.
eumEtherTxErrorInterrupt	6	Counter	Number of *transmit error* interrupts received by the Ethernet driver ISR.
eumEtherTxCarrierLostInterrupt	7	Counter	Number of *transmit carrier lost* interrupts received by the Ethernet driver ISR.
eumEtherTxAllocInterrupt	8	Counter	Number of *transmit allocation complete* interrupts received by the Ethernet driver ISR.
eumEtherTxEPHInterrupt	9	Counter	Number of *transmit EPH* interrupts (Ethernet protocol handler interrupts) received by the Ethernet driver ISR.
eumEtherTxERCVInterrupts	10	Counter	Number of *transmit ERCV* interrupts (early receive interrupts) received by the Ethernet driver ISR..
eumEtherRxData	11	Counter	Number of packets received and accepted by the IP stack.
eumEtherRxDataError	12	Counter	Number of packets received and rejected by the IP stack because of errors.
eumEtherRxDataMblkAllocError	13	Counter	Number of packets lost due to insufficient memory resources.
eumEtherRxDataLenghtError	14	Counter	Number of packets received that violate Ethernet packet length rules.
eumEtherRxDiscards	15	Counter	Number of packets discarded because the unit was not ready to receive data.
eumEtherTxData	16	Counter	Number of packets received and placed on the transmit queue.
eumEtherTxDataQFull	17	Counter	Number of packets discarded because the transmit queue was full.
eumEtherTxOk	18	Counter	Number of packets sent correctly.
eumEtherTxTimeout	19	Counter	Number of times the packet transmit has timed out.
eumEtherTxSemWait	20	Counter	Number of times a transmit semaphore could not be taken in the timeout period.

EUM RFC MIB-II Traps

RFC MIB-II Traps

Table 84 EUM RFC MIB-II Traps

MIB Name	OID	Description
coldStart	1.3.6.1.2.1.11.0.0	Power Cycle or Power On
authenticationFailure	1.3.6.1.2.1.11.0.4	An SNMP request has failed due to improper authentication

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Appendix H Operating Statistics

The CCU and EUM provide a comprehensive set of operating statistics for each of the following:

- Ethernet Port
- Radio Driver
- MAC Interface
- Routing/Bridging Protocol
- Network Interface
- System Load (Radio Meter)

These statistics can be used as a diagnostic and troubleshooting tool when system performance is being impaired by interference, radio link degradation, network problems, atypical end-user applications, capacity issues, and so on.

All of these statistics are available through the command-line interface. Most of the statistics are also available in the CCU and EUM MIBs, if you want to monitor the LMS4000 900 MHz radio network from an SNMP manager.

CAUTION: Each CCU and EUM statistic is a maximum 32-bit number (maximum 4,294,967,296). If a statistics counter exceeds its maximum value, the counter resets to zero and begins again. When this occurs, you must either take the rollover into account, or reset the statistics to re-synchronize the counters. To reset statistics, type **stats clear** at the command prompt and press **Enter**.

As a result of the above, the system uptime rolls over about every 8 days. By checking the system log file, you can calculate the actual up time, after the unit has been up for more than 8 days.

To Display (all) Statistics from the CLI

- At the command prompt, type stats and press Enter.

The following sections describe each of the statistics in detail and the procedure for obtaining specific sets of statistics (Ethernet, Radio, and so on).

Ethernet Statistics

Ethernet Statistics present operational information about data passing through the CCU and EUM Ethernet ports. These statistics are described in Table 85.

As indicated in Table 85, all of the Ethernet statistics are available in a WaveRider MIB.

Table 85 Ethernet Statistics

Statistic	Available in MIB	Description
`Interrupts`	✓	Total number of interrupts received by the Ethernet driver ISR, interrupt service routine.
`RX Interrupts`	✓	Number of *receive complete* interrupts received by the Ethernet driver ISR.
`RX Overrun Interrupts`	✓	Number of *overrun* interrupts received by the Ethernet driver ISR. An overrun occurs when a received packet has exceeded the packet size, or the processor has missed one or more packets.
`RX In Progress Interrupts`	✓	Number of times a *receive complete* interrupt was received by the Ethernet driver ISR before the current packet was finished.
`TX Complete Interrupts`	✓	Number of normal transmit interrupts received by the Ethernet driver ISR.
`TX Error Interrupts`	✓	Number of *transmit error* interrupts received by the Ethernet driver ISR.
`TX Carrier Lost Interrupts`	✓	Number of *transmit carrier lost* interrupts received by the Ethernet driver ISR.
`TX Alloc Interrupts`	✓	Number of *transmit allocation complete* interrupts received by the Ethernet driver ISR.
`TX EPH Interrupts`	✓	Number of *transmit EPH* interrupts (Ethernet protocol handler interrupts) received by the Ethernet driver ISR.
`TX ERCV Interrupts`	✓	Number of *transmit ERCV* interrupts (early receive interrupts) received by the Ethernet driver ISR.

Statistic	Available in MIB	Description
`RX Data`	✓	Number of packets received and accepted by the IP stack.
`RX Data Error`	✓	Number of packets received and rejected by the IP stack because of errors.
`RX Data Mblk Error`	✓	Number of packets lost due to insufficient memory resources.
`RX Data Length Error`	✓	Number of packets received that violate Ethernet packet length rules.
`RX Discards`	✓	Number of packets discarded because the unit was not ready to receive data.
`TX Data`	✓	Number of packets received and placed on the transmit queue.
`TX Data Q Full`	✓	Number of packets discarded because the transmit queue was full.
`TX'D OK`	✓	Number of packets sent correctly.
`TX Timeout`	✓	Number of times the packet transmit has timed out.
`TX Sem Wait`	✓	Number of times a transmit semaphore could not be taken in the timeout period.

To view the Ethernet statistics:

```
CCU> stats ethernet
-------------------- Ethernet Statistics -----------------------
Interrupts                       : 288647
RX Interrupts                    : 151103
RX Overrun Interrupts            : 0
RX In Progress Interrupts        : 4676
TX Complete Interrupts           : 133189
TX Error Interrupts              : 0
TX Carrier Lost Interrupts       : 0
TX Alloc Interrupts              : 0
TX EPH Interrupts                : 0
TX ERCV Interrupts               : 0

RX Data                          : 158095
RX Data Error                    : 0
RX Data Mblk Alloc Error         : 0
RX Data Length Error             : 0
RX Discards (No Space Available) : 18

TX Data                          : 133189
TX Data Q Full                   : 0
TX'D OK                          : 133189
TX Timeout                       : 0
TX Sem Wait                      : 0

CCU>
```

Radio Driver Statistics

Radio Driver Statistics present operational information about data passing through the CCU and EUM radio driver and ports. These statistics are described in Table 86.

As indicated in Table 86, all of the Radio Driver statistics are available in a WaveRider MIB.

Table 86 Radio Driver Statistics

Statistic	Available in MIB	Description
`Events`	✓	Number of interrupts received (any interrupt) in the radio driver ISR (Interrupt Service Routine)
`Rx Complete Event`	✓	Number of *receive complete* interrupts received by the radio driver ISR.
`Tx Complete Event`	✓	Number of *transmit complete* interrupts received by the radio driver ISR.
`Cmd Complete Event`	✓	Number of *command complete* interrupts received by the radio driver ISR.
`Fatal Error Event`	✓	Number of *fatal error* interrupts received by the radio driver ISR.
`Tx Power Rail Event`	✓	Number of *Tx Power alarm* interrupts received by the radio driver ISR.
`Unknown Event`	✓	Number of *received an unknown/no event* interrupts received by the radio driver ISR.
`Send`	✓	Number of packets sent successfully by the radio driver transmit queue.
`Send Q Full`	✓	Number of packets not sent because the radio driver transmit queue was full.
`Send End MBlk Unavailable`	✓	Number of times invalid (null) mblks (memory blocks) were sent to the radio driver for transmission.
`Send Not Enabled`	✓	Number of times tried to send packets before the radio driver was started; i.e., before the device was up and working.
`AMM Put`	✓	Number of times a packet was successfully sent to the MAC-layer shared memory for transmission over the air.
`AMM Q Full`	✓	Number of times a packet was delayed before being placed in the MAC-layer shared memory due to a full transmit queue.

Statistic	Available in MIB	Description
`AMM Q Full Discard`	✓	Number of times a packet was discarded due to the MAC-layer shared memory transmit queue not draining.
`AMM Get`	✓	Number of packets received from the MAC-layer shared memory.
`AMM Q Empty`	✓	Number of times there was a receive interrupt, but nothing available to read out of the MAC-layer shared memory.
`Receive`	✓	Number of successfully received packets.
`Receive MBlk Unavailable`	✓	Number of times the radio driver could not allocate an mblk (memory block) for storing a packet retrieved from the MAC-layer shared memory.
`Receive Not Enabled`	✓	Number of times the radio driver received a receive interrupt, but the radio driver was not yet up and running. The received packet is ignored in this case.

To view the radio driver statistics:

```
CCU> stats ra
------------------- Radio Driver Statistics --------------------

Events                          : 376194
Rx Complete Event               : 184886
Tx Complete Event               : 189052
Cmd Complete Event              : 0
FATAL ERROR Event               : 0
Tx Power Rail Event             : 0
Unknown Event                   : 2348
Send                            : 189143
Send Q Full                     : 0
Send MBlk Unavailable           : 0
Send Not Enabled                : 0
AMM Put                         : 189143
AMM Q Full                      : 0
AMM Q Full Discard              : 0
AMM get                         : 184886
AMM Q Empty                     : 99
Receive                         : 184886
Receive MBlk Unavailable        : 0
Receive Not Enabled             : 0

CCU>
```

MAC Interface Statistics

MAC Interface Statistics present operational information about data which is processed by the CCU and EUM MAC layer. These statistics are described in Table 87.

As noted in Table 87, most of the MAC interface statistics are available in a WaveRider MIB.

Table 87 MAC Interface Statistics

Statistic	Available in MIB	Description (see note 2)
`Rx Data Payloads`	✓	Number of data payloads received correctly from the air interface.
`Rx Ctrl Payloads`	✓	Number of control payloads received correctly from the air interface.
`Rx Payload Fail Invalid Type`	✓	Number of times an unknown type of payload was received from the air interface.
`Rx Payload Fail Giant`	✓	Number of times a payload that was too long was received from the air interface, and therefore discarded.
`Null Rx Descriptors`	✓	Number of times the internal MAC receive interface was corrupted.
`Tx Data Payloads`	✓	Number of data payloads transmitted to the air interface.
`Tx Ctrl Payloads`	✓	Number of control payloads transmitted to the air interface.
`Tx Payload Fail Invalid Type`	✓	Number of times a payload of an unknown type was discarded.
`Tx Payload Fail Giant`	✓	Number of times a payload that was too long was discarded.
`Tx Payload Fail Invalid Desc`	✓	Number of times the internal MAC transmit interface was corrupted.
`Atmel Tx Buffer full on arrival`	✓	Number of transmit packets that were queued for delivery.
`Command Time Outs`	✓	Number of times the MAC-layer management message was incomplete.
`Command Missed IRQs`	✓	Number of times there was no response to the MAC-layer management message.
`False Command IRQs`	✓	Number of times a command failed because the previous command was still being processed.
`Command Status Errors`	✓	Number of times the MAC-layer management message was rejected.

Statistic	Available in MIB	Description (see note 2)
`Atmel Fatal Error`		Not used.
`Unused Statistic`		Not used.
`rxPktsDirected`	✓	At the CCU, the number of times a reply from the EUM is received with the correct HCRC (header cyclic redundancy check). In the EUM, the number of times a poll for the EUM is received from the CCU with the correct HCRC.
`rxPktsBroadcast`	✓	At the CCU, the number of times an EUM succeeds in a random access. Note that all EUM packets are directed to the CCU, not broadcast. At the EUM, the number of broadcast packets (see note 1) received with the correct HCRC. These are also random access opportunities.
`rxPktsNoMatch`	✓	Number of packets correctly received, but not directed to, this station.
`rxPktsDuplicate`	✓	Number of duplicate payloads (see note 1) received and discarded. Indicates that a MAC layer acknowledgement was lost.
`rxPktsRuntFail`	✓	Number of packets received that were shorter than the minimum size.
`rxPktsLongFail`	✓	Number of packets received that were longer than the maximum size.
`rxPktsHCRCFail`	✓	Number of packets received with a MAC header CRC failure (header corrupted).
`rxPktsICVFail`	✓	Number of packets received with an encryption (WEP, wireless equivalent privacy) key mismatch (see note 3).
`rxPktsFCSFail`	✓	Number of packets received with a Frame Check Sequence failure (payload corrupted).
`rxPktsAssocFail`	✓	Number of times a received packet had to be discarded because too many EUMs were already *associated*. [CCU only]
`rxPktsIncomplete`	✓	Number of times the receive DMA for a payload does not complete (internal error).
`rxPayloadsFailFull`	✓	Number of times a received payload has to be discarded because either no receive descriptor was available, or there was not enough buffer space.
`rxPayloadsDelivered`	✓	Number of payloads that this station received correctly.

Statistic	Available in MIB	Description (see note 2)
`rxPktsEmpty`	✓	Number of packets received that are directed to this station, but that did not contain a payload.
`txPkts`	✓	Number of packets transmitted.
`txPktsEmpty`	✓	Number of packets transmitted with no payload.
`txPayloads`	✓	Number of payloads transmitted.
`txPayloadsBCast`	✓	Number of broadcast payloads transmitted. [CCU only]
`txPayloads1Ok`	✓	Number of payloads acknowledged after the first transmission.
`txPayloads2Ok`	✓	Number of payloads acknowledged after the second transmission.
`txPayloads3Ok`	✓	Number of payloads acknowledged after the third transmission.
`txPayloads4Ok`	✓	Number of payloads acknowledged after the fourth transmission.
`txPayloadsFailRetry`	✓	Number of payloads that failed to transmit due to the retry limit.
`txPayloadsFailAssocDeleted`	✓	Number of payloads that were discarded because the EUM was unreachable or deauthorized. [CCU only]
`txPayloadsFailBadParam`	✓	Number of payloads returned to the host because they are improperly formed (internal error).
`txPayloadsFailVnetInactive`	✓	Number of payloads returned to the host because the virtual net was not active (internal error). [CCU only]
`txPayloadsFailAssocFail`	✓	Number of payloads returned to the host because too many other EUMs were already *associated*. [CCU only]
`txPayloadsFailTimeout`	✓	Number of payloads returned to the host because of timeout.
`txPayloadsFailQueueTooLong`	✓	Number of payloads returned to the host because the transmit queue for the EUM was too long (see note 4). [CCU only]
`txPayloadsEmpty`		Not used.

Statistic	Available in MIB	Description (see note 2)
`replyOrRssiTimeouts`	✓	At the CCU, the number of times that no response was received to a directed poll. At the EUM, the number of times the RSSI timer expired because the EUM had not received anything from the CCU for more than 0.5s.
`restarts`	✓	Number of times that a PAI (physical attachment interface) state machine restart occurred (internal error).
`registrationRequests`	✓	At the CCU, the number of registration requests received (see note 5). At the EUM, the number of registration requests transmitted (see note 5).
`registrationResponses`	✓	At the CCU, the number of registration responses transmitted (see note 5). At the EUM, the number of registration responses received (see note 5).
`deregistrationRequests`	✓	At the CCU, the number of deregistration requests transmitted (see note 5). At the EUM, the number of deregistration requests received (see note 5).
`deregistrationInits`	✓	Number of times no response was received from an EUM, after multiple polls (see note 5). [CCU only]
`disassociationRequests`	✓	At the CCU, the number of disassociation requests transmitted (see note 6). At the EUM, the number of disassociation requests received (see note 6).
`disassociationInits`	✓	Number of times the CCU has determined than an EUM should be *disassociated* (see note 6). [CCU only]
`newAssociations`	✓	At the CCU, the number of times a new association is created (see note 6). At the EUM, the number of transitions to *associated* state (see note 6).
`currentAssociations`	✓	Number of EUMs currently associated + 1 (see note 6). The one additional association is for “broadcast”. [CCU only]
`unexpectedEvents`	✓	Number of internal unexpected events.

Notes:

- A *packet* is the basic unit of transmission. A *packet* may or may not contain a *payload*. A *payload* is user data, which may be an Ethernet frame or a logical link layer control message.
- WEP is not supported in this release.

- The CCU maintains a transmit queue for each EUM. The length of this queue is limited, to keep one EUM from consuming all the resources and impacting other EUMs. Discards indicate excessive load by one EUM, possibly due to large TCP windows.
- Registration occurs once per EUM and/or CCU boot time. Deregistration may occur if an EUM is not authorized (a registration/deregistration request pair occurs periodically while that EUM is powered ON) or if the EUM does not respond to multiple consecutive polls, such as when it is powered OFF.
- Association occurs when there is traffic to send to or from an EUM. Disassociation occurs if there is no traffic to or from an EUM for a short period of time.

To view the MAC Interface Statistics:

```
CCU> stats mac
----------------- MAC Interface Statistics --------------------

Rx Data Payloads                : 132323
Rx Ctrl Payloads                : 5702
Rx Payload Fail Invalid Type    : 0
Rx Payload Fail Giant           : 0
Null Rx Descriptors             : 0
Tx Data Payloads                : 138245
Tx Ctrl Payloads                : 5702
Tx Payload Fail Invalid Type    : 0
Tx Payload Fail Giant           : 0
Tx Payload Fail Invalid Desc    : 0
Atmel Tx Buffer full on arrival : 0
Command time outs               : 0
Command missed IRQs             : 0
False Command IRQs              : 1766
Command Status Errors           : 0
Atmel Fatal Errors              : 0
Unused statistic                : 0
                rxPktsDirected:  2765984
               rxPktsBroadcast:  2163
                 rxPktsNoMatch:  0
               rxPktsDuplicate:  733
                rxPktsRuntFail:  0
                rxPktsLongFail:  0
                rxPktsHCRCFail:  151
                 rxPktsICVFail:  0
                 rxPktsFCSFail:  23
               rxPktsAssocFail:  0
              rxPktsIncomplete:  0
            rxPayloadsFailFull:  0
           rxPayloadsDelivered:  138025
                  rxPktsEmpty:  2635068
                       txPkts:  16960762
                  txPktsEmpty:  16804869
                   txPayloads:  155893
              txPayloadsBCast:  2040
                txPayloads1Ok:  131286
                txPayloads2Ok:  9423
                txPayloads3Ok:  1027
                txPayloads4Ok:  133
          txPayloadsFailRetry:  27
   txPayloadsFailAssocDeleted:  11
       txPayloadsFailBadParam:  0
   txPayloadsFailVnetInactive:  0
      txPayloadsFailAssocFail:  0
        txPayloadsFailTimeout:  0
```

```
        txPayloadsFailQueueTooLong:  0
                 txPayloadsEmpty:  0
            replyOrRssiTimeouts:  232598
                        restarts:  0
           registrationRequests:  0
          registrationResponses:  0
        deregistrationRequests:  0
           deregistrationInits:  0
        disassociationRequests:  5671
           disassociationInits:  5702
               newAssociations:  5671
           currentAssociations:  3
              unexpectedEvents:  0
                      latestTx:  187
                    latestProg:  9881
               latestTxPayload:  212
                   latestReply:  9912
                  lateReplyEum:  6294067
                 longestSearch:  127
                   txDescAvail:  74
CCU>
```

Routing/Bridging Protocol Statistics

Routing/Bridging Protocol Statistics present operational information about data which is processed by the EUM bridging or CCU routing layer. These statistics are described in Table 88.

The Routing/Bridging Protocol Statistics are not available in the WaveRider MIBs.

Table 88 Routing/Bridging Protocol Statistics

Statistic	Description
`Rx Eth Dst - App`	Number of received Ethernet frames transferred from the Ethernet port to the EUM application. [EUM only]
`Rx Eth Dst - Radio`	Number of received Ethernet frames bridged from the Ethernet port to the radio port. [EUM only]
`Rx Eth Dst - To Router`	Number of received Ethernet frames transferred from the Ethernet port to the CCU router application. [CCU only]
`Rx Eth Err - Mblk`	Number of Ethernet frames from the Ethernet port that were discarded because of a specific type of memory allocation error.
`Rx Eth Err - Msg Buffer`	Number of Ethernet frames from the Ethernet port that were discarded because of a specific type of memory allocation error.

Statistic	Description
`Rx Eth Err - Pkt Size`	Number of Ethernet frames from the Ethernet port that were discarded because the frame was too large or too small to decode.
`Rx Eth Err - Unknown Ether Type`	Number of Ethernet frames from the Ethernet port that were discarded because they were neither IP nor ARP frames (example, IPX frame).
`Rx Eth Err - Customer Table Error`	Number of Ethernet frames from the Ethernet port that were discarded because the host was not allowed air access. [EUM only]
`Rx Eth Err - Invalid NetPool`	Number of Ethernet frames from the Ethernet port that were discarded because of a specific type of memory allocation error. [EUM only]
`Rx Eth Dst - Unknown`	Number of Ethernet frames from the Ethernet port that were discarded because the host is known to be on the EUM's Ethernet side. [EUM only]
`Rx Eth Err - Could not Duplicate`	Number of Ethernet frames from the Ethernet port that were discarded because of a specific type of memory allocation error. [EUM only]
`Rx Eth Err - IP Filter`	Number of port-filtered Ethernet frames from the Ethernet port.
`Rx Radio Dst - App`	Number of Ethernet frames that were transferred from the radio to the application layer.
`Rx Radio Dst - Radio`	Number of Ethernet frames that were received from the radio and transmitted back out through the radio (i.e., "switched"). [CCU only]
`Rx Radio Dst - To Router`	Number of Ethernet frames that were received from the radio port and forwarded to the CCU router application (i.e., destined for the CCU application or gateway). [CCU only]
`Rx Radio Dst - Eth`	Number of Ethernet frames from the radio port that were bridged from the radio port to the Ethernet port. [EUM only]
`Rx Radio Err - Mblk`	Number of Ethernet frames from the radio port that were discarded because of a specific type of memory allocation error.
`Rx Radio Err - Msg Buffer`	Number of Ethernet frames from the radio port that were discarded because of a specific type of memory allocation error.
`Rx Radio Err - Pkt Size`	Number of Ethernet frames from the radio port that were discarded because the frame was too large or too small to decode.
`Rx Radio Err - Unknown Ether Type`	Number of Ethernet frames from the radio port that were discarded because they were neither IP nor ARP frames (example, IPX frame).

Statistic	Description
`Rx Radio Err - Unknown Msg Type`	Number of Ethernet frames from the radio port that were discarded because of an internal routing error.
`Rx Radio Err - Unreg Request`	Number of Ethernet frames received from the radio port that were discarded because they came from an *unregistered* EUM. [CCU only]
`Rx Radio Err - Invalid NetPool`	Number of Ethernet frames received from the radio port that were discarded because of a specific type of memory allocation error.
`Rx Radio Err - Could not Duplicate`	Number of Ethernet frames received from the radio port that were discarded because of a specific type of memory allocation error.
`Rx Radio Err - Reflection`	Number of Ethernet frames received from the radio port that were discarded because the source address was on the EUM (split-horizon rule). [EUM only]
`Rx Radio Err - IP Filter`	Number of port-filtered Ethernet frames from the radio port.
`Tx Dst - Eth`	Number of Ethernet frames that were transmitted through the Ethernet port.
`Tx Dst - Radio`	Number of Ethernet frames that were transmitted through the radio port.
`Tx Err - Mblk`	Number of transmit Ethernet frames that had to be discarded because of a specific type of memory allocation error.
`Tx Err - Msg Buffer`	Number of transmit Ethernet frames that had to be discarded because of a specific type of memory allocation error.
`Tx Err - Pkt Size`	Number of transmit Ethernet frames that had to be discarded because the frame was too large or too small to decode.
`Tx Dst - Unregistered`	Number of transmit Ethernet frames that had to be discarded because they were for an unregistered EUM. [CCU only]
`Tx Dst - Unknown`	Number of transmit Ethernet frames that had to be discarded because the Ethernet address did not appear in the Address Table.
`Tx Err - Invalid NetPool`	Number of transmit Ethernet frames that had to be discarded because of a specific type of memory allocation error. [EUM only]
`Tx Err - Could not Duplicate`	Number of transmit Ethernet frames that had to be discarded because of a specific type of memory allocation error. [EUM only]

To view the Routing Protocol Statistics:

```
CCU> stats rp

----------------Routing Protocol Statistics -----------------

Rx Eth Dst - Radio                                : 0
Rx Eth Dst - To Router                            : 154396
Rx Eth Err - Mblk                       (Discard) : 0
Rx Eth Err - Msg Buffer                 (Discard) : 0
Rx Eth Err - Pkt Size                   (Discard) : 0
Rx Eth Err - Unknown Ether Type         (Discard) : 554
Rx Eth Err - IP Filter                  (Discard) : 0

Rx Radio Dst - App                                : 340
Rx Radio Dst - Radio                              : 1268
Rx Radio Dst - To Router                          : 129025
Rx Radio Dst - Eth                                : 0
Rx Radio Err - Mblk                     (Discard) : 0
Rx Radio Err - Msg Buffer               (Discard) : 0
Rx Radio Err - Pkt Size                 (Discard) : 0
Rx Radio Err - Unknown Ether Type       (Discard) : 0
Rx Radio Err - Unknown Msg Type         (Discard) : 0
Rx Radio Err - Unreg Request            (Discard) : 0
Rx Radio Err - Invalid NetPool          (Discard) : 0
Rx Radio Err - Could not Duplicate      (Discard) : 0
Rx Radio Err - IP Filter                (Discard) : 0

Tx Dst - Eth                                      : 131288
Tx Dst - Radio                                    : 136286
Tx Err - Mblk                           (Discard) : 0
Tx Err - Msg Buffer                     (Discard) : 0
Tx Err - Pkt Size                       (Discard) : 0
Tx Dst - Unregistered                   (Discard) : 0
Tx Dst - Unknown                        (Discard) : 0

CCU>
```

Network Interface Statistics

Network Interface Statistics, described in Table 88, are generated by the IP-protocol suite resident on the CCU and EUM.

Network Interface Statistics are not available in the WaveRider MIBs.

Table 89 Network Interface Statistics

Statistic	Description
ICMP	For information on ICMP, and ICMP-related statistics, refer to RFC729.
IP	For information on IP, and IP-related statistics, refer to RFC791.
TCP	For information on TCP, and TCP-related statistics, refer to RFC793.
UDP	For information on UDP, and UDP-related statistics, refer to RFC768.

To view all network interface statistics:

```
CCU> stats net
```

To view network interface ICMP statistics:

```
CCU> stats net icmp
ICMP:
        3133 calls to icmp_error
        0 error not generated because old message was icmp
        Output histogram:
                destination unreachable: 3133
        0 message with bad code fields
        0 message < minimum length
        0 bad checksum
        0 message with bad length
        Input histogram:
                destination unreachable: 20
        0 message response generated
CCU>
```

To view network interface IP statistics:

```
CCU> stats net ip
               total 2181354
              badsum    0
            tooshort    0
            toosmall    0
             badhlen    0
              badlen    0
         infragments    0
         fragdropped    0
         fragtimeout    0
             forward 1925975
         cantforward 96917
        redirectsent    0
     unknownprotocol   20
           nobuffers    0
         reassembled    0
        outfragments    0
             noroute    2


Active Internet connections (including servers)
PCB      Proto Recv-Q Send-Q  Local Address      Foreign Address    (state)
-------- ----- ------ ------  ------------------ ------------------ -------
56d500   TCP        1      0  10.5.0.1.23        10.0.1.50.2687     ESTABLISHE
56c8d0   TCP        0      0  0.0.0.0.23         0.0.0.0.0          LISTEN
56c6c8   TCP        0      0  0.0.0.0.21         0.0.0.0.0          LISTEN
56cad8   UDP        0      0  0.0.0.0.123        0.0.0.0.0
56cbdc   UDP        0      0  0.0.0.0.20001      0.0.0.0.0
56bb9c   UDP        0      0  0.0.0.0.161        0.0.0.0.0
CCU>
```

In the above example, the active internet connections were:

Port 21	FTP
Port 23	Telnet (two sessions open)
Port 123	NTP
Port 161	SNMP
Port 20001	WaveRider private CCU load meter server

To view network interface TCP statistics;

```
CCU> stats net tcp
TCP:
        536 packets sent
                304 data packets (23557 bytes)
                0 data packet (0 byte) retransmitted
                222 ack-only packets (7 delayed)
                0 URG only packet
                0 window probe packet
                0 window update packet
                10 control packets
        527 packets received
                310 acks (for 23571 bytes)
                7 duplicate acks
                0 ack for unsent data
                283 packets (485 bytes) received in-sequence
                0 completely duplicate packet (0 byte)
                0 packet with some dup. data (0 byte duped)
                7 out-of-order packets (0 byte)
                0 packet (0 byte) of data after window
                0 window probe
                0 window update packet
                0 packet received after close
                2 discarded for bad checksums
                0 discarded for bad header offset field
                0 discarded because packet too short
        1 connection request
        7 connection accepts
        8 connections established (including accepts)
        7 connections closed (including 0 drop)
        0 embryonic connection dropped
        309 segments updated rtt (of 311 attempts)
        2 retransmit timeouts
                0 connection dropped by rexmit timeout
        0 persist timeout
        0 keepalive timeout
                0 keepalive probe sent
                0 connection dropped by keepalive
        0 pcb cache lookup failed
CCU>
```

To view the network interface UDP statistics

```
CCU> stats net udp
UDP:
        247539 total packets
        158004 input packets
        89535 output packets
        0 incomplete header
        0 bad data length field
        0 bad checksum
        81429 broadcasts received with no ports
        0 full socket
        50202 pcb cache lookups failed
        57 pcb hash lookups failed
UDP>
```

System Load Statistics (Radio Meter)

The radio meter command prints out a table of measurements that indicate the current load on the system. These statistics are only available at the CCU. The load statistics are summarized in Table 90. System Load Statistics are not available through the WaveRider MIBs.

Table 90 Load Statistics (Radio Meter)

Statistic	Description
`Time`	Value of the CCU's internal 32-bit microsecond timer at the instant the messages were taken. `Time` rolls over to "0" about every hour and eleven minutes.
`Fw Pyls`	Number of payloads transmitted from the CCU to EUMs in this class/level, including retries.
`Fw Bytes`	Number of bytes of payload transmitted from the CCU to EUMs in this class/level, including retries.
`Rev Pyls`	Number of payloads transmitted from EUMs in this class/level that are correctly received by the CCU.
`Rev Bytes`	Number of bytes of payload transmitted from EUMs in this class/level that are correctly received by the CCU.
`Max Vio`	MaxIPS Violations - Number of times the CCU has not polled an EUM in this class/level within the inter-poll space defined by the EUM's grade of service.
`Ideal Vio`	IdealIPS Violations - Number of times the average inter-poll space for EUMs in this class/level has been more than 25% higher than the ideal inter-poll space defined by the grade of service.
`#EUMs`	Number of EUMs in the class/level at the instant in time the load statistics were collected. The broadcast channel counts as one.
`Avg IPS`	Current low-pass average inter-poll space, in microseconds, for the class/level at that instant in time, which corresponds to the current polling rate for EUMs in that class. If no EUMs are currently in the class, it is the average taken at the time the last EUM exited the class.
`Total Polls`	Number of times the CCU has polled an EUM in the class/level.
`Empty Polls`	Number of times the CCU has polled an EUM in the class/level and did not either transmit or receive a payload.

Notes:

- All counters are continuous; that is, they are never zeroed, except if the unit is reset or power cycled.
- Payload and poll counters can roll over after a minimum of 50 days.
- Byte counters can roll over after a minimum of 4 hours.

- Violation counters could roll over after 70 seconds if the corresponding parameter was set too small. A steeply climbing violation counter indicates serious problems with either the settings or the system load.

To view the load statistics:

```
Console> radio meter
CCU Load Meter    Time (us): 2388125184
                   Fw Pyls   Fw Bytes   Rev Pyls  Rev Bytes Max Vio Ideal Vio
    Gold Active     261996  117413346     233592   45583692       1         0
  Gold Inactive      65145    3614618       3038     356335       0         0
  Silver Active     885135  299817354     795036  131774471       0         2
Silver Inactive      50164    2246125       1283     172947       0         0
  Bronze Active      20847   13538244      17727    2242378       0         0
Bronze Inactive       4098     178357        191      25156       0         0
      BE Active      34294    2380443       3395     356844       0        97
    BE Inactive      21443     708668      15808     688558       0         0
      Broadcast      51436    2697875      48070    6848739       0         0
        Overall    1394558  442595030    1118140  188049120       1        99

                  #EUMs     Avg IPS  Total Polls  Empty Polls
    Gold Active       0       21507      3017826      2577645
  Gold Inactive       1       45867      2351419      2283292
  Silver Active       0        1268     30527206     28936895
Silver Inactive       0       49800      1549140      1497712
  Bronze Active       0       11906       257261       224260
Bronze Inactive       1       48111       125211       120926
      BE Active       0       29463       707972       670633
    BE Inactive       1       50472      1100549      1063487
      Broadcast       1        1197    376559248    376459966
Console>
```

Each row on the above table, except for `Overall`, corresponds to a grade of service/activity level combination. The last row is the overall totals, which in all cases except IPS, are the sum of the entries in the column. *Active* refers to EUMs that have had traffic within the last *activePollTimeout*, and *Inactive* refers to EUMs that have not had traffic within the last *activePollTimeout* and have not timed out on *disassociationTime*. Therefore payload counts for *inactive* EUMs indicate transitions from *inactive* to *active*.

NOTE: Broadcast traffic is carried with random access polls. Therefore, forward traffic (CCU-to-EUM) in the broadcast row is broadcast traffic, while reverse traffic is random access traffic. The reverse packet rate should be less than 15% of the total poll rate for the broadcast traffic, since random access attempts can collide. Assuming uncorrelated arrivals, this should ensure that 99.7% of random access attempts succeed (in four retries or less).

Appendix I IP Plan — Example

The following tables provide an example of an IP plan for an LMS4000 system equipped with fifteen 900 MHz CAPs.

NAP IP Addressing Plan

Table 91 Example - CCU Ethernet Subnet Data

Subnet	192.168.10.0
Subnet Mask Bits	24
Subnet Mask	255.255.255.0 (ff.ff.ff.00)

Table 92 Example - NAP IP Addressing Plan

NAP Element	IP Address
Gateway (NAP) Router	192.168.10.1 /24
NAP Switch	192.168.10.5 /24
NAP UPS	192.168.10.6 /24
SNMP Manager	192.168.10.7 /24

CCU Ethernet IP Addressing Plan

Table 93 Example - CCU Ethernet IP Addressing Plan

Site	CCU	CCU Ethernet Address	Site	CCU	CCU Ethernet Address
CAP01	CCU01	192.168.10.11	CAP09	CCU01	192.168.10.139
	CCU02	192.168.10.12		CCU02	192.168.10.140
	CCU03	192.168.10.13		CCU03	192.168.10.141
CAP02	CCU01	192.168.10.27	CAP10	CCU01	192.168.10.155
	CCU02	192.168.10.28		CCU02	192.168.10.156
	CCU03	192.168.10.29		CCU03	192.168.10.157
CAP03	CCU01	192.168.10.43	CAP11	CCU01	192.168.10.171
	CCU02	192.168.10.44		CCU02	192.168.10.172
	CCU03	192.168.10.45		CCU03	192.168.10.173
CAP04	CCU01	192.168.10.59	CAP12	CCU01	192.168.10.187
	CCU02	192.168.10.60		CCU02	192.168.10.188
	CCU03	192.168.10.61		CCU03	192.168.10.189
CAP05	CCU01	192.168.10.75	CAP13	CCU01	192.168.10.203
	CCU02	192.168.10.76		CCU02	192.168.10.204
	CCU03	192.168.10.77		CCU03	192.168.10.205
CAP06	CCU01	192.168.10.91	CAP14	CCU01	192.168.10.219
	CCU02	192.168.10.92		CCU02	192.168.10.220
	CCU03	192.168.10.93		CCU03	192.168.10.221
CAP07	CCU01	192.168.10.107	CAP15	CCU01	192.168.10.235
	CCU02	192.168.10.108		CCU02	192.168.10.236
	CCU03	192.168.10.109		CCU03	192.168.10.237
CAP08	CCU01	192.168.10.123			
	CCU02	192.168.10.124			
	CCU03	192.168.10.125			

CCU Radio IP Addressing Plan

Table 94 Example - CCU Radio Subnet Data

Subnet	172.16.0.0
Subnet Mask Bits	22
Subnet Mask	255.255.252.0 (ff.ff.fc.00)

Table 95 Example - CCU Radio IP Addressing Plan

Site	CCU	Subnet	CCU Radio IP Address	CCU Radio Subnet Range	Broadcast
CAP01	CCU01	172.16.4.0	172.16.4.1	172.16.4.1 - 172.16.7.254	172.16.7.255
	CCU02	172.16.8.0	172.16.8.1	172.16.8.1 - 172.16.11.254	172.16.11.255
	CCU03	172.16.12.0	172.16.12.1	172.16.12.1 - 172.16.15.254	172.16.15.255
CAP02	CCU01	172.16.16.0	172.16.16.1	172.16.16.1 - 172.16.19.254	172.16.19.255
	CCU02	172.16.20.0	172.16.20.1	172.16.20.1 - 172.16.23.254	172.16.23.255
	CCU03	172.16.24.0	172.16.24.1	172.16.24.1 - 172.16.27.254	172.16.27.255
CAP03	CCU01	172.16.28.0	172.16.28.1	172.16.28.1 - 172.16.31.254	172.16.31.255
	CCU02	172.16.32.0	172.16.32.1	172.16.32.1 - 172.16.35.254	172.16.35.255
	CCU03	172.16.36.0	172.16.36.1	172.16.36.1 - 172.16.39.254	172.16.39.255
CAP04	CCU01	172.16.40.0	172.16.40.1	172.16.40.1 - 172.16.43.254	172.16.43.255
	CCU02	172.16.44.0	172.16.44.1	172.16.44.1 - 172.16.47.254	172.16.47.255
	CCU03	172.16.48.0	172.16.48.1	172.16.48.1 - 172.16.51.254	172.16.51.255
CAP05	CCU01	172.16.52.0	172.16.52.1	172.16.52.1 - 172.16.55.254	172.16.55.255
	CCU02	172.16.56.0	172.16.56.1	172.16.56.1 - 172.16.59.254	172.16.59.255
	CCU03	172.16.60.0	172.16.60.1	172.16.60.1 - 172.16.63.254	172.16.63.255
CAP06	CCU01	172.16.64.0	172.16.64.1	172.16.64.1 - 172.16.67.254	172.16.67.255
	CCU02	172.16.68.0	172.16.68.1	172.16.68.1 - 172.16.71.254	172.16.71.255
	CCU03	172.16.72.0	172.16.72.1	172.16.72.1 - 172.16.75.254	172.16.75.255
CAP07	CCU01	172.16.76.0	172.16.76.1	172.16.76.1 - 172.16.79.254	172.16.79.255
	CCU02	172.16.80.0	172.16.80.1	172.16.80.1 - 172.16.83.254	172.16.83.255
	CCU03	172.16.84.0	172.16.84.1	172.16.84.1 - 172.16.87.254	172.16.87.255
CAP08	CCU01	172.16.88.0	172.16.88.1	172.16.88.1 - 172.16.91.254	172.16.91.255
	CCU02	172.16.92.0	172.16.92.1	172.16.92.1 - 172.16.95.254	172.16.95.255
	CCU03	172.16.96.0	172.16.96.1	172.16.96.1 - 172.16.99.254	172.16.99.255

Site	CCU	Subnet	CCU Radio IP Address	CCU Radio Subnet Range	Broadcast
CAP09	CCU01	172.16.100.0	172.16.100.1	172.16.100.1 - 172.16.103.254	172.16.103.255
	CCU02	172.16.104.0	172.16.104.1	172.16.104.1 - 172.16.107.254	172.16.107.255
	CCU03	172.16.108.0	172.16.108.1	172.16.108.1 - 172.16.111.254	172.16.111.255
CAP10	CCU01	172.16.112.0	172.16.112.1	172.16.112.1 - 172.16.115.254	172.16.115.255
	CCU02	172.16.116.0	172.16.116.1	172.16.116.1 - 172.16.119.254	172.16.119.255
	CCU03	172.16.120.0	172.16.120.1	172.16.120.1 - 172.16.123.254	172.16.123.255
CAP11	CCU01	172.16.124.0	172.16.124.1	172.16.124.1 - 172.16.127.254	172.16.127.255
	CCU02	172.16.128.0	172.16.128.1	172.16.128.1 - 172.16.131.254	172.16.131.255
	CCU03	172.16.132.0	172.16.132.1	172.16.132.1 - 172.16.135.254	172.16.135.255
CAP12	CCU01	172.16.136.0	172.16.136.1	172.16.136.1 - 172.16.139.254	172.16.139.255
	CCU02	172.16.140.0	172.16.140.1	172.16.140.1 - 172.16.143.254	172.16.143.255
	CCU03	172.16.144.0	172.16.144.1	172.16.144.1 - 172.16.147.254	172.16.147.255
CAP13	CCU01	172.16.148.0	172.16.148.1	172.16.148.1 - 172.16.151.254	172.16.151.255
	CCU02	172.16.152.0	172.16.152.1	172.16.152.1 - 172.16.155.254	172.16.155.255
	CCU03	172.16.156.0	172.16.156.1	172.16.156.1 - 172.16.159.254	172.16.159.255
CAP14	CCU01	172.16.160.0	172.16.160.1	172.16.160.1 - 172.16.163.254	172.16.163.255
	CCU02	172.16.164.0	172.16.164.1	172.16.164.1 - 172.16.167.254	172.16.167.255
	CCU03	172.16.168.0	172.16.168.1	172.16.168.1 - 172.16.171.254	172.16.171.255
CAP15	CCU01	172.16.172.0	172.16.172.1	172.16.172.1 - 172.16.175.254	172.16.175.255
	CCU02	172.16.176.0	172.16.176.1	172.16.176.1 - 172.16.179.254	172.16.179.255
	CCU03	172.16.180.0	172.16.180.1	172.16.180.1 - 172.16.183.254	172.16.183.255

EUM IP Addressing Plan

Table 96 Example - EUM Subnet Data

Subnet	172.16.0.0
Subnet Mask Bits	22
Subnet Mask	255.255.252.0 (ff.ff.fc.00)

Table 97 Example - EUM IP Addressing Plan

Site	CCU	Subnet ID	EUM IP Address Range
CAP01	CCU01	EUM001-253	172.16.4.2 - 172.16.4.254
		EUM254-300	172.16.5.1 - 172.16.5.47
	CCU02	EUM001-253	172.16.8.2 - 172.16.8.254
		EUM254-300	172.16.9.1 - 172.16.9.47
	CCU03	EUM001-253	172.16.12.2 - 172.16.12.254
		EUM254-300	172.16.13.1 - 172.16.13.47
CAP02	CCU01	EUM001-253	172.16.16.2 - 172.16.16.254
		EUM254-300	172.16.17.1 - 172.16.17.47
	CCU02	EUM001-253	172.16.20.2 - 172.16.20.254
		EUM254-300	172.16.21.1 - 172.16.21.47
	CCU03	EUM001-253	172.16.24.2 - 172.16.24.254
		EUM254-300	172.16.25.1 - 172.16.25.47
CAP03	CCU01	EUM001-253	172.16.28.2 - 172.16.28.254
		EUM254-300	172.16.29.1 - 172.16.29.47
	CCU02	EUM001-253	172.16.32.2 - 172.16.32.254
		EUM254-300	172.16.33.1 - 172.16.33.47
	CCU03	EUM001-253	172.16.36.2 - 172.16.36.254
		EUM254-300	172.16.37.1 - 172.16.37.47
CAP04	CCU01	EUM001-253	172.16.40.2 - 172.16.40.254
		EUM254-300	172.16.41.1 - 172.16.41.47
	CCU02	EUM001-253	172.16.44.2 - 172.16.44.254
		EUM254-300	172.16.45.1 - 172.16.45.47
	CCU03	EUM001-253	172.16.48.2 - 172.16.48.254
		EUM254-300	172.16.49.1 - 172.16.49.47

Site	CCU	Subnet ID	EUM IP Address Range
CAP05	CCU01	EUM001-253	172.16.52.2 - 172.16.52.254
		EUM254-300	172.16.53.1 - 172.16.53.47
	CCU02	EUM001-253	172.16.56.2 - 172.16.56.254
		EUM254-300	172.16.57.1 - 172.16.57.47
	CCU03	EUM001-253	172.16.60.2 - 172.16.60.254
		EUM254-300	172.16.61.1 - 172.16.61.47
CAP06	CCU01	EUM001-253	172.16.64.2 - 172.16.64.254
		EUM254-300	172.16.65.1 - 172.16.65.47
	CCU02	EUM001-253	172.16.68.2 - 172.16.68.254
		EUM254-300	172.16.69.1 - 172.16.69.47
	CCU03	EUM001-253	172.16.72.2 - 172.16.72.254
		EUM254-300	172.16.73.1 - 172.16.73.47
CAP07	CCU01	EUM001-253	172.16.76.2 - 172.16.76.254
		EUM254-300	172.16.77.1 - 172.16.77.47
	CCU02	EUM001-253	172.16.80.2 - 172.16.80.254
		EUM254-300	172.16.81.1 - 172.16.81.47
	CCU03	EUM001-253	172.16.84.2 - 172.16.84.254
		EUM254-300	172.16.85.1 - 172.16.85.47
CAP08	CCU01	EUM001-253	172.16.88.2 - 172.16.88.254
		EUM254-300	172.16.89.1 - 172.16.89.47
	CCU02	EUM001-253	172.16.92.2 - 172.16.92.254
		EUM254-300	172.16.93.1 - 172.16.93.47
	CCU03	EUM001-253	172.16.96.2 - 172.16.96.254
		EUM254-300	172.16.97.1 - 172.16.97.47
CAP09	CCU01	EUM001-253	172.16.100.2 - 172.16.100.254
		EUM254-300	172.16.101.1 - 172.16.101.47
	CCU02	EUM001-253	172.16.104.2 - 172.16.104.254
		EUM254-300	172.16.105.1 - 172.16.105.47
	CCU03	EUM001-253	172.16.108.2 - 172.16.108.254
		EUM254-300	172.16.109.1 - 172.16.109.47

Site	CCU	Subnet ID	EUM IP Address Range
CAP10	CCU01	EUM001-253	172.16.112.2 - 172.16.112.254
		EUM254-300	172.16.113.1 - 172.16.113.47
	CCU02	EUM001-253	172.16.116.2 - 172.16.116.254
		EUM254-300	172.16.117.1 - 172.16.117.47
	CCU03	EUM001-253	172.16.120.2 - 172.16.120.254
		EUM254-300	172.16.121.1 - 172.16.121.47
CAP11	CCU01	EUM001-253	172.16.124.2 - 172.16.124.254
		EUM254-300	172.16.125.1 - 172.16.125.47
	CCU02	EUM001-253	172.16.128.2 - 172.16.128.254
		EUM254-300	172.16.129.1 - 172.16.129.47
	CCU03	EUM001-253	172.16.132.2 - 172.16.132.254
		EUM254-300	172.16.133.1 - 172.16.133.47
CAP12	CCU01	EUM001-253	172.16.136.2 - 172.16.136.254
		EUM254-300	172.16.137.1 - 172.16.137.47
	CCU02	EUM001-253	172.16.140.2 - 172.16.140.254
		EUM254-300	172.16.141.1 - 172.16.141.47
	CCU03	EUM001-253	172.16.144.2 - 172.16.144.254
		EUM254-300	172.16.145.1 - 172.16.145.47
CAP13	CCU01	EUM001-253	172.16.148.2 - 172.16.148.254
		EUM254-300	172.16.149.1 - 172.16.149.47
	CCU02	EUM001-253	172.16.152.2 - 172.16.152.254
		EUM254-300	172.16.153.1 - 172.16.153.47
	CCU03	EUM001-253	172.16.156.2 - 172.16.156.254
		EUM254-300	172.16.157.1 - 172.16.157.47
CAP14	CCU01	EUM001-253	172.16.160.2 - 172.16.160.254
		EUM254-300	172.16.161.1 - 172.16.161.47
	CCU02	EUM001-253	172.16.164.2 - 172.16.164.254
		EUM254-300	172.16.165.1 - 172.16.165.47
	CCU03	EUM001-253	172.16.168.2 - 172.16.168.254
		EUM254-300	172.16.169.1 - 172.16.169.47

Site	CCU	Subnet ID	EUM IP Address Range
CAP15	CCU01	EUM001-253	172.16.172.2 - 172.16.172.254
		EUM254-300	172.16.173.1 - 172.16.173.47
	CCU02	EUM001-253	172.16.176.2 - 172.16.176.254
		EUM254-300	172.16.177.1 - 172.16.177.47
	CCU03	EUM001-253	172.16.180.2 - 172.16.180.254
		EUM254-300	172.16.181.1 - 172.16.181.47

Subscriber IP Addressing Plan

Table 98 Example - Subscriber Subnet Data

Subnet	172.16.0.0
Subnet Mask Bits	22
Subnet Mask	255.255.252.0 (ff.ff.fc.00)

Table 99 Example - Subscriber IP Addressing Plan

Site	CCU	Subnet ID	Subscriber IP Address Range
CAP01	CCU01	SUB001-253	172.16.6.1 - 172.16.6.254
		SUB254-300	172.16.7.1 - 172.16.7.46
	CCU02	SUB001-253	172.16.10.1 - 172.16.10.254
		SUB254-300	172.16.11.1 - 172.16.11.46
	CCU03	SUB001-253	172.16.14.1 - 172.16.14.254
		SUB254-300	172.16.15.1 - 172.16.15.46
CAP02	CCU01	SUB001-253	172.16.18.1 - 172.16.18.254
		SUB254-300	172.16.19.1 - 172.16.19.46
	CCU02	SUB001-253	172.16.22.1 - 172.16.22.254
		SUB254-300	172.16.23.1 - 172.16.23.46
	CCU03	SUB001-253	172.16.26.1 - 172.16.26.254
		SUB254-300	172.16.27.1 - 172.16.27.46

Site	CCU	Subnet ID	Subscriber IP Address Range
CAP03	CCU01	SUB001-253	172.16.30.1 - 172.16.30.254
		SUB254-300	172.16.31.1 - 172.16.31.46
	CCU02	SUB001-253	172.16.34.1 - 172.16.34.254
		SUB254-300	172.16.35.1 - 172.16.35.46
	CCU03	SUB001-253	172.16.38.1 - 172.16.38.254
		SUB254-300	172.16.39.1 - 172.16.39.46
CAP04	CCU01	SUB001-253	172.16.42.1 - 172.16.42.254
		SUB254-300	172.16.43.1 - 172.16.43.46
	CCU02	SUB001-253	172.16.46.1 - 172.16.46.254
		SUB254-300	172.16.47.1 - 172.16.47.46
	CCU03	SUB001-253	172.16.50.1 - 172.16.50.254
		SUB254-300	172.16.51.1 - 172.16.51.46
CAP05	CCU01	SUB001-253	172.16.54.1 - 172.16.54.254
		SUB254-300	172.16.55.1 - 172.16.55.46
	CCU02	SUB001-253	172.16.58.1 - 172.16.58.254
		SUB254-300	172.16.59.1 - 172.16.59.46
	CCU03	SUB001-253	172.16.62.1 - 172.16.62.254
		SUB254-300	172.16.63.1 - 172.16.63.46
CAP06	CCU01	SUB001-253	172.16.66.1 - 172.16.66.254
		SUB254-300	172.16.67.1 - 172.16.67.46
	CCU02	SUB001-253	172.16.70.1 - 172.16.70.254
		SUB254-300	172.16.71.1 - 172.16.71.46
	CCU03	SUB001-253	172.16.74.1 - 172.16.74.254
		SUB254-300	172.16.75.1 - 172.16.75.46
CAP07	CCU01	SUB001-253	172.16.78.1 - 172.16.78.254
		SUB254-300	172.16.79.1 - 172.16.79.46
	CCU02	SUB001-253	172.16.82.1 - 172.16.82.254
		SUB254-300	172.16.83.1 - 172.16.83.46
	CCU03	SUB001-253	172.16.86.1 - 172.16.86.254
		SUB254-300	172.16.87.1 - 172.16.87.46

Site	CCU	Subnet ID	Subscriber IP Address Range
CAP08	CCU01	SUB001-253	172.16.90.1 - 172.16.90.254
		SUB254-300	172.16.91.1 - 172.16.91.46
	CCU02	SUB001-253	172.16.94.1 - 172.16.94.254
		SUB254-300	172.16.95.1 - 172.16.95.46
	CCU03	SUB001-253	172.16.98.1 - 172.16.98.254
		SUB254-300	172.16.99.1 - 172.16.99.97
CAP09	CCU01	SUB001-253	172.16.102.1 - 172.16.102.254
		SUB254-300	172.16.103.1 - 172.16.103.46
	CCU02	SUB001-253	172.16.106.1 - 172.16.106.254
		SUB254-300	172.16.107.1 - 172.16.107.46
	CCU03	SUB001-253	172.16.110.1 - 172.16.110.254
		SUB254-300	172.16.111.1 - 172.16.111.46
CAP10	CCU01	SUB001-253	172.16.114.1 - 172.16.114.254
		SUB254-300	172.16.115.1 - 172.16.115.46
	CCU02	SUB001-253	172.16.118.1 - 172.16.118.254
		SUB254-300	172.16.119.1 - 172.16.119.46
	CCU03	SUB001-253	172.16.122.1 - 172.16.122.254
		SUB254-300	172.16.123.1 - 172.16.123.46
CAP11	CCU01	SUB001-253	172.16.126.1 - 172.16.126.254
		SUB254-300	172.16.127.1 - 172.16.127.46
	CCU02	SUB001-253	172.16.130.1 - 172.16.130.254
		SUB254-300	172.16.131.1 - 172.16.131.46
	CCU03	SUB001-253	172.16.134.1 - 172.16.134.254
		SUB254-300	172.16.135.1 - 172.16.135.46
CAP12	CCU01	SUB001-253	172.16.138.1 - 172.16.138.254
		SUB254-300	172.16.139.1 - 172.16.139.46
	CCU02	SUB001-253	172.16.142.1 - 172.16.142.254
		SUB254-300	172.16.143.1 - 172.16.143.46
	CCU03	SUB001-253	172.16.146.1 - 172.16.146.254
		SUB254-300	172.16.147.1 - 172.16.147.46

Site	CCU	Subnet ID	Subscriber IP Address Range
CAP13	CCU01	SUB001-253	172.16.150.1 - 172.16.150.254
		SUB254-300	172.16.151.1 - 172.16.151.46
	CCU02	SUB001-253	172.16.154.1 - 172.16.154.254
		SUB254-300	172.16.155.1 - 172.16.155.46
	CCU03	SUB001-253	172.16.158.1 - 172.16.158.254
		SUB254-300	172.16.159.1 - 172.16.159.46
CAP14	CCU01	SUB001-253	172.16.162.1 - 172.16.162.254
		SUB254-300	172.16.163.1 - 172.16.163.46
	CCU02	SUB001-253	172.16.166.1 - 172.16.166.254
		SUB254-300	172.16.167.1 - 172.16.167.46
	CCU03	SUB001-253	172.16.170.1 - 172.16.170.254
		SUB254-300	172.16.171.1 - 172.16.170.46
CAP15	CCU01	SUB001-253	172.16.174.1 - 172.16.174.254
		SUB254-300	172.16.175.1 - 172.16.175.46
	CCU02	SUB001-253	172.16.178.1 - 172.16.178.254
		SUB254-300	172.16.179.1 - 172.16.179.46
	CCU03	SUB001-253	172.16.182.1 - 172.16.182.254
		SUB254-300	172.16.183.1 - 172.16.183.46

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Appendix J Acronyms and Glossary

Table 100 Acronyms and Abbreviations

Acronym or Abbreviation	Definition
ABWM	Advanced Bandwidth Manager
AC	Alternating Current
API	Application Programming Interface
ARP	Address Resolution Protocol
ARQ	Automatic Retry Request
ASCII	American Standard Code for Information Interchange
BCF	Basic Configuration File
CAP	Communications Access Point
CCU	CAP Channel Unit
CIR	Committed Information Rate
CLI	Command Line Interface
CPU	Central Processing Unit
CSA	Canadian Standards Association
CTS	Clear To Send
dB	decibel
dBi	decibel—with respect to an isotropic radiator
DCE	Data Communication Equipment
DES	Data Encryption Standard
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server, Domain Network Server
DRAM	Dynamic Random-access Memory

Acronym or Abbreviation	Definition
DSR	Data Set Ready
DSSS	Direct-sequence Spread Spectrum
DTE	Data Terminal Equipment
ESD	Electrostatic Discharge
ESN	Electronic Serial Number
ETSI	European Telecommunications Standards for Industry
EUM	End-user Modem
FCC	Federal Communications Commission (U.S.A.)
FRU	Field Replaceable Unit
FTP	File Transfer Protocol
GHz	GigaHertz
GMT	Greenwich Mean Time
GOS	Grade of Service
HTTP	HyperText Transfer Protocol
IC	Industry Canada
ICMP	Internet Control Message Protocol
ID	Identifier, Identification
IP	Internet Protocol
ISM	Industrial, Scientific, and Medical (Unlicensed Radio Band)
ISP	Internet Service Provider
LAN	Local Area Network
LED	Light-Emitting Diode
LMDS	Local Multipoint Distribution System
LMS	Last Mile Solution®
LOS	Line Of Sight
MAC	Media Access Control, Medium Access Controller
Mbps	Megabits per second
MBR	Maximum Burst Rate
MCF	MAC Configuration File
MHz	MegaHertz
MIB	Management Information Base
MTU	Maximum Transmission Unit
n/a	not applicable
NAP	Network Access Point

Acronym or Abbreviation	Definition
NAT	Network Address Translation
NCL	Network Communication Link
NTP	Network Time Protocol
OAM	Operations, Administration and Maintenance
OID	Object Identifier
OS	Operating System
PAT	Port Address Translation
PC	Personal Computer
PCF	Permanent Configuration File
PHY	Physical Layer
RADIUS	Remote Access Dial-in User Service
RCF	Route Configuration File
RF	Radio Frequency
RIP	Routing Information Protocol
RMA	Returned Merchandise Authorization
RSSI	Receive Signal Strength Indicator
RTS	Request To Send
Rx	Receive
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SNTP	Simple Network Time Protocol
SOHO	Small Office/Home Office
SRAM	Static Random Access Memory
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TDD	Time-Division Duplex (Modulation)
TDMA	Time-Division Multiple Access
Tx	Transmit
UDP	User Datagram Protocol
UL	Underwriters Laboratories
UPS	Uninterruptable Power Supply
UTC	Universal Time Coordination
WRAP	WaveRider Access Point

Table 101 LMS4000 Network Glossary

Term	Definition
LMS4000 RF Subsystem	The RF Equipment associated with an LMS4000, including CCUs, RFSM, antennas, and transmission lines.
Bandwidth Manager	The entity in the LMS4000 that uses various algorithms to manage end-user access to the network interface bandwidth, based on subscribed level of service.
Broadcast (Message)	A message sent by one network device to all other devices connected to the network.
Cell Size	The nominal radius of the geographic area served by a single CAP, within which EUMs can reliably receive service.
Channel	Generally, the medium though which information is communicated. In wireless communications, the channel is usually defined by the center frequency, modulation type, and occupied bandwidth.
CLI (Command Line Interface)	In contrast to a graphical user interface, a CLI is a configuration and control interface based on keyboard-entry commands and responses.
Console Port	Typically, the 9–pin RS-232 serial port on an LMS device to which a terminal or laptop computer is connected, for the purpose of configuring or controlling the device.
Configuration Terminal	The configuration terminal is provided for the purpose of configuring or controlling a device directly through its console port.
DNS (Domain Name System)	A database system that translates domain names into IP addresses. For example, waverider.com is converted into 207.23.187.242.
DSSS (Direct-Sequence Spread Spectrum)	A form of spread-spectrum communications that uses a high-speed code sequence, along with the information being sent, to modulate the RF carrier.
Ethernet Switch	In the context of LMS, the devices that provide data link layer Ethernet connection between the router, NMS, UPS, and back haul equipment at the LMS4000, and the CCUs, RFSM, back haul equipment and UPS at the CAP.
Host Name	The common name given to network devices to make them more easily identifiable by network operators and maintenance personnel.
Gateway	A device connecting two networks that use different communications technologies or protocols; for example, an IP/Telephony Gateway provides a connection between an IP network and a telephone network.

Term	Definition
GOS (Grade of Service)	A level of service associated with an EUM, which determines how often, and when, an EUM will be polled. Since an EUM can only send one packet each time it is polled, the data rate is related to the polling rate.
IP (Internet Protocol)	The network-layer protocol in the TCP/IP stack (defined by RFC 791).
Line of Sight	The radio link between a transmitter and receiver is said to be line of sight if the direct path between the two is relatively free from physical obstruction.
MAC (Medium Access Control)	The mechanism of managing access, by multiple users, to a common transmission medium.
Multicast (Message)	A message sent by a network device to a limited set of network devices.
Orthogonal Channels	Communications channels that can operate over a common transmission medium without significantly interfering with each other. In the context of LMS, radio frequencies on appropriately spaced frequencies are considered to be orthogonal.
OSPF (Open Shortest Path First)	A link-state, hierarchical interior gateway routing protocol that can provide least-cost routing, multipath routing, and load balancing.
NAT (Network Address Translation)	An Internet standard that enables a local area network to use one set of IP addresses for internal traffic and another set of addresses for external traffic.
PAT (Port Address Translation)	A feature that lets you number a LAN with inside local addresses and filter them through one globally routable IP address.
Point-to-Multipoint	A communications architecture in which a central station (CAP, for example) communicates with multiple remote stations (EUMs).
POTS (Plain Old Telephone Service)	The basic telephone service provided by the public switched telephone network (PSTN).
Radio Module	The device in the EUM (or CCU) that provides the wireless interface to the LMS network. The radio module performs signal spreading and modulation, channelization, up-conversion and amplification in the transmit direction, and signal amplification, down-conversion, channel selection, demodulation, de-spreading and data recovery in the receive direction.
Range	The maximum distance that a signal can be reliably transmitted between a CCU and EUM.

Term	Definition
RIP (Routing Information Protocol)	A routing protocol in which network routers periodically broadcast their entire current routing database.
Router	A network device that routes IP messages from one physical port to another based on a table of routes that are manually entered by a crafts person (static routes) or generated by the router using a routing protocol such as RIP or OSPF.
Routing	The process of finding a path to a destination host through an IP network.
Sectorization	An RF engineering technique whereby co-located transceivers are connected to separate antennas with different but geometrically arranged azimuths, for the purpose of optimizing radio frequency reuse, extending range, and reducing interference. 120° sectorization is commonly applied in LMS systems.
SNMP (Simple Network Management Protocol)	A protocol used to manage nodes in an IP network.
SNMP Agent	An agent resides on an SNMP-managed device, and performs operations when requested to do so by an SNMP manager.
SNMP Community	A grouping of SNMP agents that can be managed by an SNMP manager. An SNMP manager can manage more than one SNMP community. The community name is used to authenticate the SNMP manager before allowing it access to the agent.
SNMP MIB (Management Information Base)	The information that an SNMP manager, such as the NMS, can request from an SNMP agent.
SNMP Trap	A message sent by an SNMP agent to an NMS, console, or terminal to indicate the occurrence of a significant event, such as a specified condition, or a defined threshold that was reached.
SNMP Trap Server	The server to which SNMP trap messages are forwarded.
SNTP (Simple Network Time Protocol)	A feature that provides LMS4000 devices with an accurate time clock for time stamping events in a log file.
Spread Spectrum	A communication technology in which the transmitted signal occupies a much greater bandwidth than the information bandwidth. The benefits of spread spectrum are generally lower spectral power density, and immunity to noise, interference and jamming.
Static Route	A route that is manually entered into a routing table by a crafts person or network operator.
Subscriber	In the context of LMS, it is the individual or entity associated with an EUM.

Term	Definition
TCP (Transmission Control Protocol)	The connection-oriented transport layer protocol that provides reliable, full-duplex data transmission in TCP/IP networks.
Telnet	A terminal emulation program for TCP/IP networks.
UDP (User Datagram Protocol)	Part of the TCP/IP protocol suite, which provides a way for applications to access the connectionless features of IP. It provides for exchange of datagrams without acknowledgements or guaranteed delivery.
Unicast	A message sent by one network device to another network device.
User Authentication	In LMS, the secure mechanism through which a user identification is verified.
User Authorization	The secure mechanism by which a user is approved to use LMS services. To illustrate, an EUM may be authenticated but denied service because of the delinquent payment of a bill.
VoIP (Voice over IP)	The ability to carry normal telephony-style voice over an IP-based internet, with POTS-like functionality, reliability and voice quality.

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