LINKTROPY® WAN EMULATOR
USER'S GUIDE

Firmware Version 4.5

APPOSITE
TECHNOLOGIES

Linktropy® WAN Emulator User's Guide

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1 OVERVIEW

Thank you for purchasing the Apposite Technologies Linktropy WAN Emulator. This *User's Guide* describes the installation, configuration, and operation of the Linktropy functionality. A companion *Hardware Guide* describes the Linktropy hardware for each specific model. A separate *Quick Start Guide* provides a walk-through for first time configuration.

1.1 Linktropy Product Family

The two Linktropy lab models, the Linktropy 5510 and 8510 offer identical functionality, differing only in capacity and the number and type of network interfaces. Earlier Linktropy lab models, the 4500, 5500, 7500, 7500 PRO, 8500, and 10G have been superseded by newer models.

The functionality of the Linktropy Mini series differs substantially from the Linktropy lab models, and is described in a separate *Linktropy Mini2 & Mini-G User's Guide*.

1.2 Linktropy Operation

Linktropy WAN Emulators emulate the bandwidth, delay, loss, and other properties of the wide area network link between two local networks.

Depending on the model, the Linktropy product emulates either a single WAN link through one pair of Ethernet ports, or multiple WAN links through multiple pairs of Ethernet ports. Each link functions as a separate, independent emulator.

For each link, the Linktropy WAN Emulator is installed as either a bridge or router between the Ethernet segments connected to the LAN A and LAN B ports on the device. Frames received on one port are subjected to the emulated WAN conditions before being forwarded to the opposite port.

For each link, frames are processed by the Linktropy WAN Emulator in the following steps:

1. Ethernet frames arrive on the LAN A or LAN B interface.

2. The effective size of the frame is calculated as the data portion of the Ethernet frame (without the Ethernet header or FCS) plus the configured value for framing overhead.

3. Frames are subjected to random duplication at the configured duplication rate. Duplicated frames are added to the data stream immediately following the original frames.

4. Random frames are selected for reordering according to the configured reordering probability. Selected frames are held for the specified delay before being reinserted into the data stream.

5. Frames are throttled to the specified WAN bandwidth. Frames in excess of the specified WAN bandwidth are queued to the configured maximum queue depth. When the queue is full, newly-arriving frames are discarded.

6. Frames are subjected to random discard based on the configured packet loss and bit error parameters.

7. Frames remaining after the discard procedure are held for the specified link delay. Frames are not reordered in this step, even if subjected to differing delays.

8. Remaining frames are bridged or routed to the opposite LAN interface and transmitted to the destination address.

In addition to the Ethernet frames received on the LAN A and LAN B interfaces, the Linktropy WAN Emulator can internally generate background traffic that competes for link bandwidth according to a configured link utilization rate and burst size. These background traffic frames are subjected to the same emulation conditions as the traffic received from external sources.

Frames are subject to four separate delays:

1. Propagation delay: Delay caused by the distance the signal travels. This delay is emulated as the specified link delay.

2. Queuing delay: If frames arrive faster than they can be transmitted over the WAN link, they are held awaiting their slot for transmission. The actual queuing delay will vary depending on how quickly frames arrive compared to how quickly they can be transmitted. The maximum queuing delay is determined by the maximum queue depth, which can be set in milliseconds, bytes, or packets.

3. Transmission delay: The time to transmit the individual bits in each frame is an additional delay that can be significant for large frames over low speed links. For example, the transmission of a 1500 byte frame over a 9600 bps link adds 1.25 seconds of latency. The transmission delay is determined by the frame size and link bandwidth.

4. Reordering delay: If reordering delay is enabled, randomly selected frames are held for a specified amount of time before being reinserted into the data stream, increasing the total delay for the reordered frames.

Only the propagation delay and reordering delay are specified directly as emulation parameters. The end-to-end delay is the sum of the four individual delays.

Frames are subject to three separate types of loss:

1. Emulated packet loss: Frames are randomly discarded based on the specified packet loss rate. Since frame discard occurs after the frames have been rate throttled, discarded frames will consume link bandwidth.

2. Emulated bit errors: Frames are randomly discarded based on the specified bit error rate. Since this discard also occurs after the frames have been rate throttled, discarded frames will consume link bandwidth.

3. Queue drops: If frames arrive faster than they can be transmitted over the emulated link, excess frames will be queued to the specified maximum queue depth. Once the queue is full, additional frames are discarded. These dropped frames do not consume WAN bandwidth.

When installed as a bridge, the Linktropy WAN Emulator is not limited to emulating IP networks, but can emulate any type of network so long as the traffic is encapsulated in Ethernet. In addition to IP, the device can be used with IPv6, IPX, AppleTalk, SCPS, and proprietary network and transport layer protocols.

1.3 Linktropy Configuration

The Linktropy WAN Emulator is usually configured through the browser-based Linktropy GUI (Graphical User Interface). The GUI is accessible from any PC or other device with a standard web browser. The GUI is accessed through a dedicated Ethernet management port on the Linktropy device or in-band through the LAN A or LAN B interface. See Section 3 for more information on the Linktropy GUI.

In addition to the GUI, the Linktropy WAN Emulator includes a command line interface (CLI) that can be accessed via a dedicated console serial port on the Linktropy device or over the network using Telnet or SSH. The CLI can be used to set the IP address of the management interface if the GUI is not accessible over the network. The CLI can also be used for scripting and test automation to configure link emulation parameters, load stored emulation conditions, or turn emulation on or off. See Section 14 for details on the CLI.

2 GETTING STARTED:

INSTALLING THE LINKTROPY WAN EMULATOR

The Linktropy WAN Emulator is managed through a browser-based GUI over an Ethernet connection to a dedicated management interface. Prior to operation, this management interface must be configured with appropriate network settings, either through the Linktropy GUI or through the command-line interface accessed via the serial console. For convenience, the management interface comes preconfigured with an IP address of 10.0.0.10, and the GUI is accessible from a directly-connected host on the 10.0.0.0/255.0.0.0 subnet.

2.1 Preparation

Management of the Linktropy WAN Emulator requires a PC running a supported web browser (Internet Explorer, Firefox, Chrome, or Safari). JavaScript must be enabled.

Initial configuration of the management interface requires either:

▸ a PC running a supported web browser that can be configured and placed on the 10.0.0.0/255.0.0.0 network.

▸ a PC with an RS-232 serial port running terminal emulation software such as HyperTerminal or PuTTY.

2.2 Hardware Installation

Plug in a standard power cord (a U.S. power cord is supplied with the unit) into the socket on the back of the device and use the power switch to turn on the device. On some models, the power switch is a rocker that needs to be held in place for up to 5 seconds. When powered on, the Power LED on the front panel glows green. The system will be available for use within 90 seconds.

For additional hardware installation details, please see the *Hardware Guide* for your Linktropy model.

2.3 IP Address Configuration via the Linktropy GUI

To configure the management interface using the Linktropy GUI:

❶ Configure a PC running a supported web browser with the IP address 10.0.0.2 or other address on the 10.0.0.0/255.0.0.0 subnet.

❷ Connect an Ethernet cable between the PC and the MGMT port of the Linktropy WAN Emulator.

❸ Open the browser on the PC and enter http://10.0.0.10 (the preconfigured management address) in the address bar. Review the End User License Agreement.

❹ Linktropy units are shipped with a temporary license pre-installed for initial operation. Follow the instructions on the screen to download and install a regular license. This step may be skipped and the license installed later.

❺ The Linktropy GUI will open to the **Device Settings** tab. If desired, modify the IP address, netmask, and default gateway for the management interface. Click the *Apply Changes* button when done.

❻ After the managment interface has been configured, use the Ethernet cable to connect the MGMT port to the management network.

2.4 IP Address Configuration via the Serial Console

To configure the MGMT interface using the serial console:

❶ Using the provided RJ45 to DB9 cable, connect the serial port of a PC running terminal emulation software to the CONSOLE port of the Linktropy WAN Emulator. Set the serial port parameters to 9600 baud, 8 bits, no parity, 1 stop bit, and disable flow control. See the *Hardware Guide* for your model for more details on connecting to the serial console.

❷ Press [ENTER] to display a login prompt. At the prompt, log in as "admin". Initially, there is no password.

```
linktropy login: admin
```

❸ Use the following commands to set the IP address, IP netmask, and default gateway of the Linktropy management interface:

```
mgmt set addr <interface-ip-address> netmask <ip-netmask>
mgmt set gw <default-gateway>
```

IP addresses and netmasks are entered in dotted-decimal format. For example:

```
linktropy> mgmt set addr 192.168.1.1 netmask 255.255.255.0
```

❹ After the management interface has been configured, use an Ethernet cable to connect the MGMT port to the management network. Open a browser and enter the IP address of the MGMT interface. Review the End User License Agreement.

❺ Linktropy units are shipped with a temporary license pre-installed for initial operation. Follow the instructions on the screen to download and install a regular license. This step may be skipped and the license installed later.

2.5 Operation

The Linktropy WAN Emulator is installed between two LAN segments (or two individual devices) using the ports labeled LAN A and LAN B. The Linktropy WAN Emulator acts as a bridge or router between those two LAN segments. Frames received on one port are subjected to the emulated WAN conditions before being forwarded to the opposite port.

Emulated WAN conditions are configured in the Linktropy GUI. To set the emulation parameters, use a web browser to connect to the Linktropy GUI at the IP address of the management interface. All emulation parameters are found on the **Link Emulation** tab. Emulation is disabled until the "Emulation On/Off" button at the top of the screen is pressed. See the following chapters for details on Linktropy emulation parameters or click the ⓘ buttons on the GUI for information on specific parameters.

On Linktropy models that emulate multiple links, each link is configured separately and acts as an independent emulator

3 LINKTROPY GUI

3.1 Overview

The browser-based Linktropy GUI is the primary method of configuring the Linktropy WAN Emulator. The GUI is compatible with Internet Explorer, Firefox, Chrome, and Safari. JavaScript must be enabled. The GUI is accessible via HTTP or HTTPS.

The Linktropy GUI consists of a Configuration window and the Linktropy Monitor.

Figure 1: Configuration Window

Figure 2: Linktropy Monitor

The Configuration window contains a set of tabs used to specify the emulation parameters and device settings. Sections 4 through 8 of this *User's Guide* describe each of the individual tabs.

The top portion of the Configuration window also includes the Status Box, Emulation On/Off button, and Message Bar, and a Link Selector on models that support multiple links. These elements remain visible across the various tabs.

Each input field is checked for validity when modified. Valid changes are displayed in bold. Invalid changes are marked with a red box around the field. Additional checks are performed when the *Apply Changes* button is pressed and any errors are marked with a red box at that time.

Clicking any ⓘ info button opens a Help window with documentation for the specific field. This *User's Guide* is also accessible from any Help window.

The Monitor displays real-time statistics and throughput graphs of the traffic traversing the emulated WAN link. The Monitor also includes the Linktropy Player functionality for importing a time-series of delay and loss conditions recorded from a live network, the Linktropy Scheduler to automate a series of emulations, and the ARP table. See Section 9 for an overview of the Monitor and Sections 10 through 12 for details on the Linktropy Monitor, Player, and Scheduler.
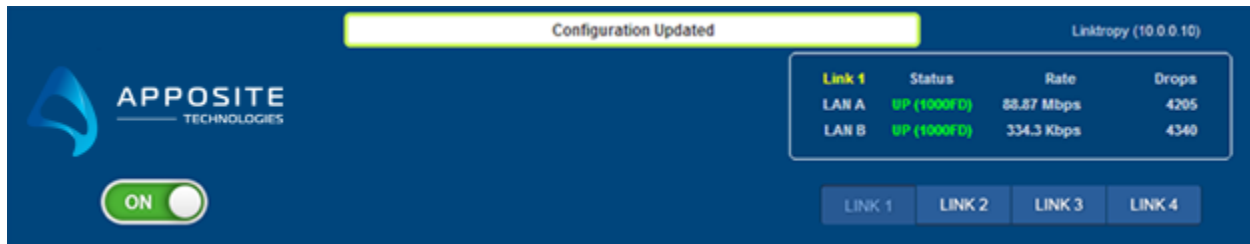

Figure 3: Configuration Window Status Box, Message Bar, and Link Selector

3.2 Status Box

The Status Box, at the top right corner of the Configuration window, displays interface status and basic statistics of the currently selected link.

The Status Box displays the status of the LAN A and LAN B Ethernet interfaces. During normal operation, the speed and duplex state of the interface are displayed in green. If the interface is unplugged or fails to negotiate an Ethernet connection, "DOWN" is displayed in red.

When emulation is turned on, the Status Box displays the current instantaneous throughput in each direction, averaged over 1 second intervals, and the total number of dropped frames. More detailed statistics and throughput graphs are shown in the Linktropy Monitor.

3.3 Emulation On/Off Button

The Emulation On/Off Button displays and controls the state of the currently selected link. The button is gray when emulation is turned off and green when emulation is on. Click the button to toggle between on and off.

Emulation is turned off when the Linktropy WAN Emulator is first installed.

3.4 Message Bar

The Message Bar, located at the top of the screen, is only visible when status messages are displayed. Confirmation messages are displayed on a white background, error messages on a red background, and alerts on a yellow background.

3.5 Link Selector

The Linktropy models that include multiple pairs of Ethernet ports have a Link Selector at the top section of the Configuration and Monitor windows. Use the link buttons to select the link to configure or monitor.

In general, all settings displayed in the GUI are specific to the selected link except for device settings such as the device name and MGMT interface address.

Link Emulation Tab: all settings are specific to the currently selected link

Bridge/Route Tab: all settings are specific to the currently selected link

Device Settings Tab: all settings apply to the device, except the Ethernet Ports row which configures the speed and duplex settings of the ports of the currently selected link.

Save/Load Tab: saving and loading an emulation applies only to the currently selected link. However, all saved emulations are accessible to be loaded from any link.

Upgrade Tab: all settings apply to the device.

Monitor: all settings and statistics are specific to the currently selected link.

☞　　Multiple links can be displayed simultaneously by opening multiple browser windows.

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4 LINK EMULATION TAB:

LINK EMULATION PARAMETER CONFIGURATION

The **Link Emulation** tab contains all of the parameters for configuration of the emulated WAN link. All parameters are configured separately for the LAN A to B and LAN B to A directions.

Basic parameter settings are always visible on the **Link Emulation** tab. Advanced parameters, which generally only need adjustment for specialized conditions, are hidden by default. To display the advanced parameters, click the s*how* link. Click the *hide* link to hide them again if desired.

The active configuration is not modified until the *Apply Changes* button at the bottom of the tab is pressed. The *Apply Changes* button is grayed out when there are no changes to apply. It is also grayed out if there are any invalid entries. To return to the active configuration without applying any changes, press the *Clear Changes* button.

When the *Apply Changes* button is pressed, final validation of the configuration is performed. If there are no errors in the configuration, the new configuration will take effect and the message, "Configuration Updated" will be displayed in the Message Bar. If there are any errors in the configuration, a red box will be displayed around the invalid field or an error message will be displayed.

> ⚠️ Advanced parameter settings are used in the emulation, even if the parameters are hidden.

All settings on the **Link Emulation** tab apply only to the currently selected link.

		LAN A → LAN B	LAN B → LAN A
BANDWIDTH	ⓘ	1000 Mbps ▾	1000 Mbps ▾
DELAY	ⓘ	● Constant ○ Uniform ○ Normal 25 ms	● Constant ○ Uniform ○ Normal 40 ms
LOSS	ⓘ	Packet Loss 0.1000 % BER 0 x 10⁻¹⁴	Packet Loss 0.1000 % BER 0 x 10⁻¹⁴
BACKGROUND TRAFFIC	ⓘ	Link Utilization 15.0 % Burst Size 1500 Bytes	Link Utilization 25.0 % Burst Size 1500 Bytes

ADVANCED PARAMETERS [hide]

		LAN A → LAN B	LAN B → LAN A
REORDERING	ⓘ	Probability 0.0000 % min max Delay 22.0 ms 33.0 ms	Probability 0.0000 % min max Delay 333.0 ms 444.0 ms
DUPLICATION	ⓘ	0.0000 %	0.0000 %
QUEUE DEPTH	ⓘ	250 ● Packets ○ KB ○ ms	250 ○ Packets ○ KB ● ms
FRAMING OVERHEAD	ⓘ	18 -- Ethernet HDR+FCS ▾	18 -- Ethernet HDR+FCS ▾

[Apply] [Clear]

Figure 4: Link Emulation Tab

4.1 Basic Parameters

4.1.1 Bandwidth

The Bandwidth row is used to configure the link rate of the emulated WAN.

The link rate is set independently in each direction in increments of 1 bps, with a minimum rate of 300 bps and a maximum rate of 1 Gbps unless limited to a lower bandwidth by the license key. (See Section 8.2 for details on the license key.)

The link rate is set in units of bps (bits per second), Kbps (kilobits per second), Mbps (megabits per second), or Gbps (gigabits per second) selected from the drop-down menu next to the rate.

If the entered link bandwidth is over 1 Gbps or larger the license key, a red error box will be drawn around the invalid field when the *Apply Changes* button is pressed and the changes will not be applied.

> ☞   1 Kbps is 1,000 bps, not 1,024 bps. Similarly, 1 Mbps is 1,000,000 bps.

4.1.2 Delay

The Delay parameter specifies the link latency in milliseconds, and is set independently for each direction. Delay can be set from 0 milliseconds to 10 seconds. Entered values are rounded to the nearest 0.1 millisecond. The delay parameter will not reorder frames.

Radio buttons are used to specify the delay distribution:

▸ Constant: A single, fixed value for delay.

▸ Uniform: A uniform distribution of delay ranging between the configured minimum and maximum values.

▸ Normal: A truncated normal distribution curve, with a specified minimum, mean and standard deviation.

If the entered minimum delay is greater than the entered maximum (for a uniform distribution) or mean (for a normal distribution), a red error box will be drawn around the invalid fields when the *Apply Changes* button is pressed and the changes will not be applied.

☞   The round trip time (RTT) of the link is the sum of the delay in both directions.

☞   Using the delay parameter, frames are not reordered even if subjected to differing delays. For example, if the delay is specified as a uniform distribution between 10 and 100 ms and the first frame is subjected to a 90 ms delay and the second frame is subjected to a 20 ms delay, the second frame will not be transmitted until after the first frame has been transmitted.

     To emulate delay with frame reordering, use the Reordering parameter in the Advanced Parameters section.

4.1.3 Loss

Data loss rates are configured as packet loss rates, bit error rates, or both. Losses due to packet loss and bit errors are emulated independently and may be combined to emulate links with physical layer corruption as well as congestion-induced packet loss.

For a lossless link, set the packet loss rate and bit error rate to 0. The default setting is for a lossless link.

Packet loss rates can be set from 0 – 100% in increments of 0.0001%.

Bit error rates can take values of $1x10^{-14}$ or greater and are entered in scientific notation. The coefficient of the rate (the field on the left) must be entered as a value greater than or equal to 0 and less than 10. The exponent may be between -1 and -14. The minus sign is supplied and only the digits of the exponent should be entered in the exponent field.

Losses are assumed to occur over the WAN link itself. Discarded packets therefore consume WAN bandwidth. For example, if a 1 Mbps link is specified to have a 10% packet loss rate, the maximum possible average throughput is 900 Kbps.

4.1.4 Background Traffic

The Background Traffic row is used to specify extra traffic that competes for link bandwidth with the frames that arrive on the Ethernet interfaces.

Background traffic is specified as a link utilization rate and a burst size. The link utilization rate controls the average percentage of configured link bandwidth consumed by background traffic. The burst size controls the size of the background traffic frames. Larger bursts will induce greater jitter in competing traffic.

Background traffic is modeled as a Poisson process in which bursts of data of a fixed sized are transmitted at an average rate such that the link will be occupied at the specified link utilization rate. Because it is a random process, over short periods the actual background traffic link utilization rate may vary from the configured value.

Background traffic frame size is not adjusted by the configured framing overhead.

Background traffic can be used to test the performance of applications when link bandwidth is consumed by other traffic. It can also be used to induce jitter for testing real-time applications.

Link utilization rates can be set to 0 – 100% of the link bandwidth in increments of 0.1%. Burst size is specified in bytes from 1 – 1,000,000 bytes. The total burst rate is limited to 250,000 bursts per second except on the Linktropy 10G, which is limited to 1,000,000 bursts per second.

☞   The Linktropy Scheduler can be used to vary the link utilization rate over time.

4.2 Advanced Parameters

To view and configure advanced emulation parameters, click on the *show* link next to the Advanced Parameters label. Note that even when hidden, the advanced parameter settings are used in the emulation. The Advanced Parameters section cannot be hidden while any of the parameters have invalid settings.

4.2.1 Reordering

The Reordering row specifies the probability that each frame is reordered and the amount of time that reordered frames are delayed from their original position. This behavior is controlled by two parameters:

▸ Probability: specifies the likelihood that each individual frame will be held for reordering. Probability can be set from 0 – 100% in increments of 0.0001%.

▸ Delay: specifies how long each reordered frame is held before being reinserted into the data stream. Selected frames are delayed for a random amount of time between the specified minimum and maximum values using a uniform distribution. Minimum and maximum reordering delay can be set from 0 milliseconds to 10 seconds. Entered values are rounded to the nearest 0.1 millisecond.

For a constant reordering delay, set the minimum and maximum reordering delay to the same value.

To disable reordering, set the reordering probability to 0%. Reordering is disabled by default.

If the entered minimum reordering delay is greater than the entered maximum, a red error box will be drawn around the invalid fields when the *Apply Changes* button is pressed and the changes will not be applied.

☞   The delay induced by frame reordering is in addition to any delay configured in the basic (non-reordering) Delay row.

☞   Frames selected for reordering are reinserted into the data stream after being held for the specified reordering delay. However, if no additional frames arrive during that period, the sequence of frames will not change. The configured reordering probability can therefore differ from the percentage of frames that are actually reordered.

4.2.2 Duplication

The Duplication parameter specifies the probability that a frame will be duplicated.

Duplicate frames are inserted into the data stream immediately after the original frame. Duplicate frames are then subjected to rate control, delay, loss, and reordering independently of the original frame.

The duplication probability can be set from 0 – 100% in increments of 0.0001%.

To disable frame duplication, set the duplication probability to 0%. Duplication is disabled by default.

4.2.3 Queue Depth

The Queue Depth row specifies the maximum amount of data that will be buffered when data is received at a rate exceeding the emulated link rate. Any frames that arrive when the queue is full are discarded.

The queue depth can be set as a maximum numbers of packets, maximum amount of data in kilobytes, or a maximum queuing delay in milliseconds. The queue depth is specified separately for each direction. Valid entries are limited to 100,000 packets, KB, or milliseconds.

By default, the queue depth is set to 250 ms. For most networks, this setting will lead to few packet drops, but the queuing delay can reach 250 ms in each direction. A smaller queue depth will lead to a smaller maximum delay, but potentially more dropped packets. If possible, specify the queue depth and units to match the queuing behavior of the WAN transmission equipment on the network being emulated.

4.2.4 Framing Overhead

Framing overhead is the number of additional bytes required by a link-layer technology when transmitting a packet of data. Typically, the framing overhead consists of link-layer addressing and error checking information.

To emulate a link-layer technology with a particular framing overhead, select the value from the drop-down list, if available, or choose C*ustom* and enter the specific value.

To emulate the traversal of a frame over a link, the Linktropy WAN Emulator calculates the effective size of the frame as the data portion of the Ethernet frame (without the Ethernet header or FCS) plus the specified framing overhead.

The Linktropy WAN Emulator includes three choices for framing overhead:

‣   Ethernet (header + FCS)
    This option emulates a WAN link layer with an Ethernet-like frame of 18 bytes of header and frame check sequence (FCS). This is the default option and is a reasonable choice if the properties of the link layer are unknown.

‣   Ethernet (header, FCS, preamble, pad)
    This option emulates an actual Ethernet link, including the preamble and padding between Ethernet frames. Select this option to emulate an Ethernet-based WAN network.

‣   Custom
    This option allows the specification of any link layer framing overhead in bytes per data packet up to a maximum of 300 bytes. Select this option if the link layer framing overhead is known.

5 BRIDGE/ROUTE TAB:

BRIDGE AND ROUTING MODE CONFIGURATION

The Linktropy WAN Emulator can be installed as either a bridge or router to forward frames between the LAN A and LAN B Ethernet interfaces. By default, the Linktropy WAN Emulator is configured as a bridge, and this mode is recommended for simplicity and efficiency unless the LAN A and LAN B interfaces need to be on separate subnets.

To switch to IP Routing Mode from Bridging Mode, click on the link *switch to IP Routing Mode*. To revert to Bridging Mode, click on the link s*witch to Bridging Mode*.

Bridge/Route settings are not stored with emulation parameters and will not change when a stored emulation is loaded.

On Linktropy models that support multiple links, each link can be configured independently in bridging or routing mode. All settings on the Bridge/Route tab apply only to the currently selected link.

5.1 Bridging Mode

In Bridging Mode, the Linktropy device functions as a bridge between the Ethernet segments connected to the LAN A and LAN B ports. In this mode, it can forward any Ethernet-based frame regardless of network layer protocol. VLAN tagged frames (IEEE 802.1Q) are supported, but no special action is taken based on VLAN.

5.1.1 Emulation Bypass

By default, all frames bridged by the Linktropy appliance are assumed to be part of the WAN traffic and are subjected to the configured WAN link conditions. This includes ARP and multicast traffic, which on a production network may be processed or filtered prior to traversal of the WAN link.

The Emulation Bypass row is used to specify whether ARP and multicast frames are to be included as part of the emulated WAN traffic or be passed directly between the LAN A and LAN B interfaces. ARP and multicast frames will bypass the emulated link and be passed directly between the two interfaces when the corresponding boxes are checked. Frames that bypass the WAN emulation are not subjected to loss or delay and do not consume emulated link bandwidth.

Figure 5: Bridging Mode

5.1.2 Learning Bridge

By default, the Learning Bridge feature is disabled and the Linktropy WAN Emulator forwards all frames received on the LAN A and LAN B interfaces to the opposite side. This provides the fastest packet handling rates and highest throughput, and is recommended except when learning bridge functionality is specifically required.

When the box labeled "Enable MAC address learning/filtering" is checked, the Linktropy WAN Emulator acts as a learning bridge and provides MAC address learning and filtering. The device examines the source MAC address of received frames to learn the network segment (LAN A or LAN B) on which each directly connected device is located. Received frames for which the source and destination devices are on the same network segment are discarded.

Learning Bridge functionality is generally only required when connecting multiple devices on a network segment through a repeater/hub. When using a switch, the switch provides the filtering functionality and learning bridge functionality is not needed on the Linktropy WAN Emulator.

5.2 IP Routing Mode

In IP Routing Mode, the Linktropy WAN Emulator functions as a router between the Ethernet segments connected to the LAN A and LAN B ports.

IP Routing Mode provides a default routing mechanism that eliminates the need for multiple static routes. When a gateway address is set for both interfaces, the default next-hop for packets received on one interface is the gateway address of the opposite interface. For example, if a packet is received on the LAN A interface and has a destination address on a subnet that is not directly connected to either the LAN A or LAN B interface, the packet is forwarded across the emulated link to the LAN B gateway router.

Packets that are forwarded out the same interface on which they were received do not traverse the emulated WAN link. Packets are never forwarded between the MGMT and LAN A or LAN B interfaces.

Routing Mode supports only the forwarding of IP frames and does not support multicast forwarding.

Figure 6: Routing Mode

5.2.1 IP Addresses

In IP Routing Mode, an IP address and netmask must be configured for the LAN A and LAN B interfaces. Use of the gateway field is optional. All addresses are entered in dotted-decimal notation.

If a gateway address is set, it must be on the same subnet as the corresponding LAN A or LAN B address. If a gateway address is set for only one interface, then the Linktropy WAN Emulator will use this address as its default next-hop router. When gateway addresses are set for both interfaces, the default next-hop router for packets received on one interface is the gateway of the opposite interface.

The following entries are invalid:

‣ a gateway address not on the same subnet as the interface address

‣ an interface address or gateway address with an all-zeros host component

‣ an interface address or gateway address with an all-ones host component

If there are any invalid entries when the *Apply Changes* button is pressed, a red error box will be drawn around the row or an error message will be displayed. Changes are not applied until the errors are fixed and the *Apply Changes* is button pressed again.

6 DEVICE SETTINGS TAB:

DEVICE AND INTERFACE PARAMETERS

The device name and interface settings are configured on the **Device Settings** tab. Settings are saved by pressing the *Apply Changes* button on the bottom of the tab. Settings remain unchanged through reboots and power cycles. Device settings are not stored with emulation parameters and will not change when a stored emulation is loaded.

On Linktropy models that support multiple links, all settings apply across the device, except for the Ethernet Ports row which displays and configures the speed and duplex settings of the LAN A and LAN B interfaces only for the currently selected link.

Figure 7: Device Settings Tab

6.1 Device Name

The name of the Linktropy unit is displayed and changed here. This name is also shown at the top of the Status Box and on the browser title bar.

6.2 MGMT Interface

The MGMT Interface row is used to set the IP address of the Linktropy management interface, the subnet mask, and the IP address of the default gateway. All values are entered in dotted-decimal notation.

If the entered IP address and default gateway address are not on the same subnet, or if either address is the all-zeros or all-ones subnet address, then a red error box will be drawn around the Network Settings row when the *Apply Changes* button is pressed and the changes will not be applied.

When the IP address of the Linktropy device is changed, connectivity to the Linktropy GUI will be lost and a link to the newly-configured IP address will be displayed in the Message Bar. If the new address is reachable from the browser, click on this link to reconnect to the Linktropy GUI.

⚠️ If you cannot regain connectivity to the Linktropy WAN Emulator after a change to the network settings, use the `CONSOLE` interface to verify or change the network settings.

6.3 Management Access

By default, the Linktropy GUI is accessible only through the MGMT interface. Checking the box labeled "Allow management through LAN A/B" enables management from directly connected devices on the LAN A or LAN B network.

When this feature is enabled in Bridging Mode, the IP address of the MGMT interface can be reached through the LAN A and LAN B interfaces.

When this feature is enabled in IP Routing Mode, the device can be managed using the MGMT, LAN A, or LAN B interface addresses.

For maximum performance, this feature should be disabled if not required.

On Linktropy models that support multiple links, in-band management access is available through one specified link. When in-band management is enabled, a set of radio buttons appears to select the link to use.

6.4 Ethernet Ports

By default, all Ethernet ports are set to auto-negotiate the proper speed and duplex settings. On the 10/100/1000baseT emulation ports, auto-negotiation can be disabled and the ports forced to a particular setting via the drop-down menu. However, it is strongly recommended to keep the interfaces set to auto-negotiate unless auto-negotiation is not working properly. Auto-negotiation cannot be disabled on SFP and 10 Gbps ports.

Jumbo frames of up to 9 KB are supported.

A separate 10/100/1000baseT Ethernet port, labeled MGMT, is used for device management and monitoring. Auto-negotiation cannot be disabled on the management port.

> ⚠️ If full-duplex is selected manually, the device the port is connected to must be forced to the same setting.

7 SAVE / LOAD TAB:

SAVE, LOAD, AND DELETE NAMED EMULATIONS

Use the **Save / Load** tab to store emulation parameters to a named configuration or to reload a previously stored emulation. The **Save / Load** tab also provides the ability to rename and delete stored emulations.

Radio buttons on the left side of the tab are used to select between Save, Load, and Delete operations.

On Linktropy models that support multiple links, saving and loading an emulation applies only to the currently selected link. However, all saved emulations are accessible to be loaded from any link.

Figure 8: Save / Load Tab

> Save and load operations only save or load the emulation parameters from the **Link Emulation** tab. Other device configuration parameters, including the settings from the **Bridge/Route** tab and the **Device Settings** tab are not affected by saving or loading an emulation.

7.1 Save Emulation

The Save screen is used to store the current emulation parameters as a named emulation. Emulations are stored on the Linktropy device. There are ten separate groups with twenty slots each, for a total of 200 separate emulations. Groups can be used to separate emulations by project, date, network, user, or any other criteria.

If the Save screen is not displayed, click on the *Save* radio button.

To save an emulation, first select a Group from the drop-down menu next to *Group*. Then pick a slot number from the drop-down menu next to *Slot*. Until a slot is selected, the name and description fields and the *Save* button remain grayed out. Select an empty slot or write over an existing configuration.

Once the slot is selected, the Name and Description fields become active. If an existing emulation is selected, the Name and Description of the emulation are shown and may be edited. If an empty slot is selected, the Name and Description fields are blank. The Name field must be filled in. The Description field is only for reference to record identifying details of the emulation and may be left blank.

Once the Group and Slot are selected and a Name assigned, the *Save* button becomes active. Press *Save* to store the emulation.

The preset group names of "Group 1" through "Group 10" can be changed by clicking the *Rename* link adjacent to the Group drop-down list. Changing the name of a Group does not affect the emulations stored in that Group.

7.2 Load Emulation

Previously stored emulations can be reloaded from the Load screen. Click the *Load* radio button to display the Load screen.

To load an emulation, first select the *Group* from the drop-down list. Only Groups that contain stored emulations are shown. Next, select a stored emulation from the *Name* drop-down list. The emulation description will be displayed. Clicking the *display configuration* link will show a description of the configuration in a pop-up window. If this is the correct emulation, click the *Load* button to restore the emulation.

Once the emulation has been loaded, the emulation parameters can be viewed and changed on the **Link Emulation** tab.

> ⚠ Loading a saved emulation overwrites the current emulation parameters. To preserve the current emulation, save the emulation before loading a new emulation.

7.3 Delete Emulation

Stored emulations can be deleted from the Delete screen. Click the *Delete* radio button to display the Delete screen.

To delete an emulation, first select the *Group* from the drop-down list. Only Groups that contain stored emulations are shown. Next, select a stored emulation from the *Name* drop-down list. The emulation description will be displayed. Click the *Delete* button to delete the selected emulation.

⚠️ Once deleted, emulations cannot be recovered.

8 UPGRADE TAB:

FIRMWARE UPGRADES AND LICENSE KEYS

Use the **Upgrade** tab to upgrade the Linktropy firmware and install new license keys.
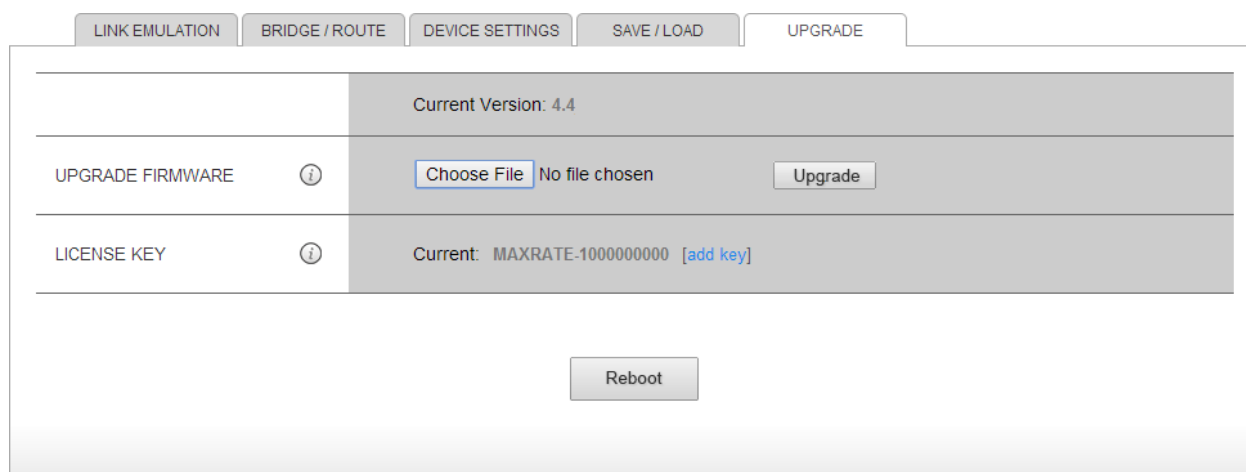
Figure 9: Upgrade Tab

8.1 Upgrade Firmware

The firmware version currently installed on the device is displayed in the Upgrade Firmware row.

To upgrade the firmware, download the new firmware image from the Linktropy support site. Save the firmware image on a device accessible from the browser.

In the *Upgrade Firmware* row, click the *Browse* button to select the image, then click the *Upgrade* button to install the new firmware.

A popup window displays the status of the upgrade operation. The new firmware will not run until the unit is rebooted.

| ☞ | The same procedure can be used to restore an older firmware version if necessary. However, when downgrading to an older version, some settings may not be preserved. |

| ☞ | Firmware updates are available on the Linktropy support section of the Apposite website. To obtain access the support site, register your unit at apposite-tech.com/register.html. An active product license or maintenance contract is required. Registered users will also receive email notices of firmware updates. |

8.2 License Key

The license expiration date and bandwidth limit are displayed on the License Key row. If an expiration date is not shown, the license does not expire. For information on renewing a license, see apposite-tech.com/renewals.html.

The license key controls the maximum emulated link bandwidth that can be configured in each direction.

To add a new license key, click the *add key* link, then cut and paste the new license key into the space below "Enter New Key." Click the *Apply* button to install the new key.

9 LINKTROPY MONITOR

The Linktropy Monitor contains four separate pages to display the Link Monitor, Linktropy Player, Linktropy Scheduler, and ARP table. To access the window, click on the *Monitor/Schedule* link in the Configuration window. The Monitor opens in a separate browser window.

> The Link Monitor displays real-time statistics and throughput graphs of the traffic traversing the emulated WAN link. The Link Monitor is described in Section 10.
>
> The Linktropy Player emulates a time series of delay and loss conditions captured from a live link using the Linktropy Recorder for Windows and Linux or the Apposite Recorder for Android™ or any arbitrary series of delay and loss values specified in a recording file. The Linktropy Player is described in Section 11.
>
> The Linktropy Scheduler provides a convenient way within the GUI to automate changes to any emulation parameters over time. The Linktropy Scheduler is described in Section 12.
>
> For troubleshooting purposes, the ARP table is shown in a separate page of the Monitor. The ARP table is described below.

To switch between these four pages, click the links in the top bar of the Monitor.

On Linktropy models that support multiple links, use the Link Selector at the top to choose the specific link.

9.1 ARP Table

The ARP table page displays the current ARP table. In Bridging Mode, the ARP table only contains entries used for device management. In IP Routing Mode, the ARP table includes entries for the MGMT, LAN A, and LAN B interfaces. On Linktropy models that support multiple links, the LAN A and LAN B ARP entries are for the currently selected link only.

To update the display with the current ARP table, click the *Refresh* button at the top of the page.

10 LINK MONITOR:

LINK STATISTICS AND TRANSMISSION RATE GRAPHS

The statistics page of the Monitor displays real-time statistics and throughput graphs of the traffic over the emulated link. Traffic from LAN A to LAN B is shown on the top half of the page and traffic from LAN B to LAN A is shown below. For each direction, there is a summary of the current emulation settings, a table of statistics, a graph of the transmission rate, and a table of average transmission rates over various time periods.

All statistics are based on values since the last reset and are independent of whether the Monitor has been open or not. Rebooting or power cycling the device resets all values. The *reset* button at the top of the page resets values for the window. After reset, average transmission rates are displayed in the table only after sufficient data is available for each respective interval.

The page is refreshed at the rate set in the drop-down menu in the upper right corner. If the Scheduler is running, the display is also refreshed whenever the configuration changes.

☞	The *reset* button resets statistics for its browser window only. Opening a new Monitor will restore statistics from the last reboot or power cycle. Reloading the current window also restores all statistics.

⚠️	Statistics cannot be recovered after a reboot or power cycle of the device.

A graph of throughput of external traffic traversing the emulated link in each direction is shown for the previous 10 minutes in 1 second intervals. Extra traffic generated by the Background Traffic emulation feature is not shown on the graphs. The y-axis automatically adjusts to the maximum transmission rate over the period. The average transmission rates for the previous 1 second, 10 seconds, 1 minute, and 10 minute intervals are displayed in tabular form next to the graph.
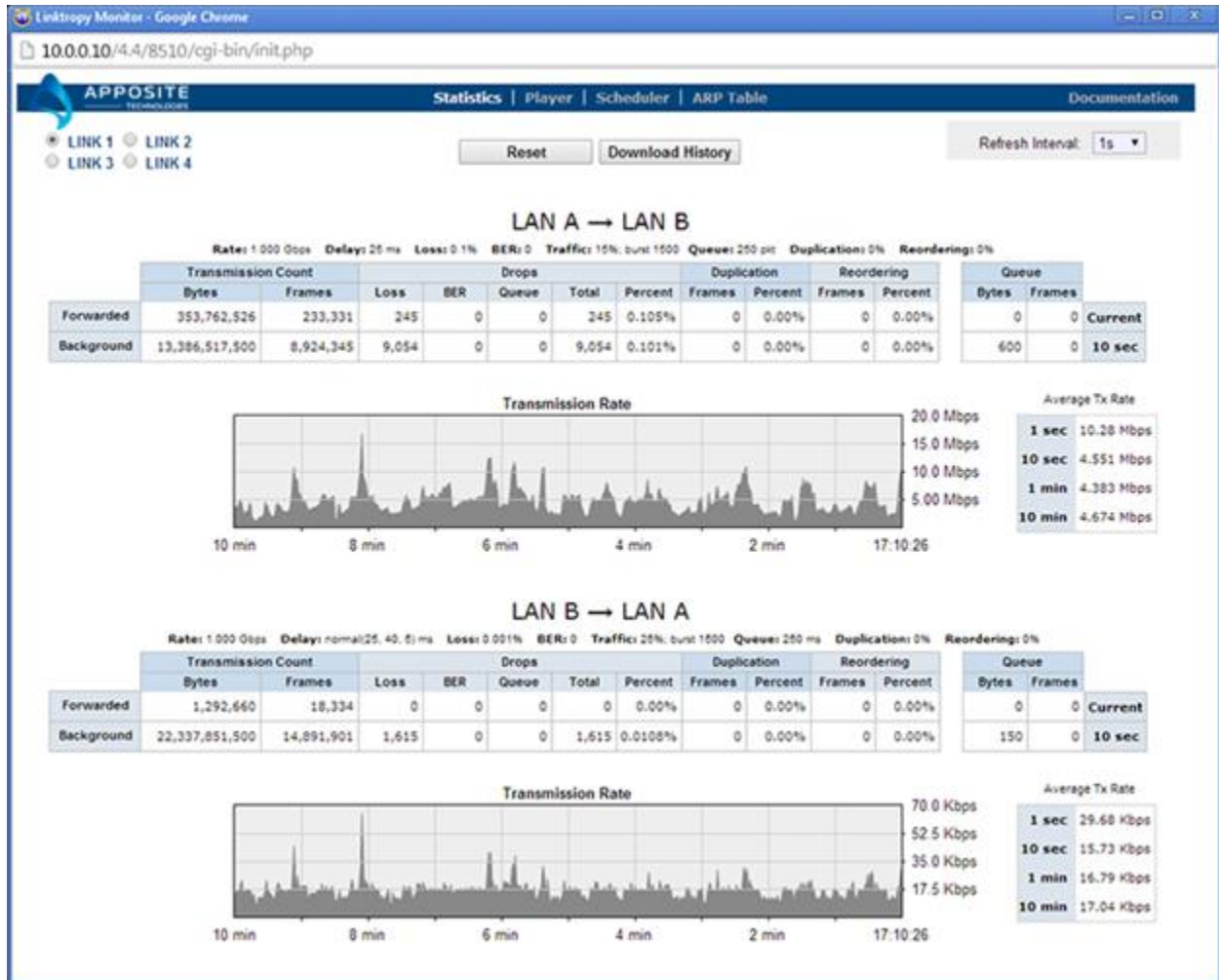
Figure 10: Link Monitor

Statistics are displayed in real-time in a table for each direction. One row displays statistics for external traffic forwarded between LAN A and LAN B. The second row displays statistics for the frames generated internally by the Background Traffic emulation feature. The data displayed are:

- Transmission Count

  Bytes: number of bytes transferred over the emulated link.

  Frames: number of Ethernet frames transferred over the emulated link.

- Drops

  Loss: number of frames dropped due to packet loss.

  BER: number of frames dropped due to bit errors.

  Queue: number of frames dropped due to configured queuing limits.

  Total: total number of frames dropped due to loss, BER and queuing limits.

  Percent: total number of dropped frames as a percentage of the total number of frames received.

- Duplication

  Frames: number of frames duplicated.

  Percent: percent of frames duplicated.

- Reordering

  Frames: number of frames subjected to reordering.

  Percent: percent of frames subjected to reordering.

A second table shows the amount of data on the emulated link's transmit queue in bytes and frames. The table shows both the current value and an average of the instantaneous values taken once per second over the past ten seconds. The data on the queue includes both forwarded and background traffic. The data displayed are:

- Queue

  Bytes: number of bytes in the emulated link's transmit queue.

  Frames: number of frames in the emulated link's transmit queue.

10.1 Data Download

Up to 24 hours of statistics and transmission rate data, in 1 second intervals, can be downloaded to a file by clicking the *Download History* button. Select the number of hours of data and the link direction to download from the pop-up window, then click the *Download* button. The file is in a comma separated value (CSV) format that can be imported into Microsoft Excel or other data visualization or manipulation application.

By default, the downloaded file is named `linktropy_<direction>_<date>_<time>.log`. The direction and date and time of download are also listed in first line of the file.

The individual data fields in the file are described in the following table:

Field	Description
TimeIdx	Time Index – the number of seconds since the last reboot
Frames	Number of frames transmitted
Bytes	Number of bytes transmitted
Rate1s	Average transmission rate in bps over the current 1 second interval
Rate10s	Average transmission rate in bps over the current 10 second interval
Rate1m	Average transmission rate in bps over the current 1 minute interval
Rate10m	Average transmission rate in bps over the current 10 minute interval
DropsQueue	Number of frames dropped due to queuing limits
DropsPLR	Number of frames dropped due to packet loss
DropsBER	Number of frames dropped due to bit errors
DropsTotal	Total number of frames dropped
Dups	Number of frames duplicated
Reorders	Number of frames subjected to reordering
Qlen	Number of frames currently in the emulated link's transmit queue.

Qbytes	Number of bytes currently in the emulated link's transmit queue.
BGFrames – BGReorders	A set of all of the above statistics for the internally generated background traffic.
CfgIdx	Configuration Index – an index incremented each time the emulation parameters are changed, whether via the main Configuration window or as a stage in the Scheduler. The Configuration Index is reset by a reboot or power cycle.
CfgStep	Configuration Step – the currently running intermediate step between stages in the Scheduler. (A value other than 0 is only displayed when the Scheduler is running and is transitioning between stages.)
CfgDesc	Configuration Description – a description of the currently running emulation parameters. (Only displayed at the time when the parameters change.)

Except where indicated, all fields are relative to the last reset of the statistics page. When insufficient data is available to calculate an average over the indicated time span, the field is marked as "-1."

In addition to a separate line for each second of data, a separate line is recorded in the file each time the emulation parameters are changed, up to a maximum of ten times per second. These separate lines for each change can reduce the total length of time for which data can be downloaded to less than 24 hours.

11 LINKTROPY PLAYER

11.1 Overview

The Linktropy Player replays a time series of delay and loss conditions contained in a user-supplied file. The Linktropy Player is usually combined with the Linktropy Recorder for Windows and Linux or the Apposite Recorder for Android to capture the conditions from a live network and reproduce them in the emulator. However, the Linktropy Player offers the flexibility to utilize any properly formatted file to generate any desired time sequence of emulated delay and loss conditions.

The Linktropy Recorder is an application for Windows and Linux available for free download from the Apposite website. The Apposite Recorder for Android provides similar functionality on Android-based phones and tablets and is available for free download on Google Play™. The Linktropy or Apposite Recorder sends ICMP Echo Requests from the device on which it is running to a specified destination on the other side of the network, then records the reported delay and loss values to a file. For more information on the Recorder software, please consult the *Linktropy Recorder User's Guide* or the Help text within the Apposite Recorder for Android.

To create a file of delay and loss conditions without using the Recorder software, or to edit a file created by the Recorder, refer to the Recording File Format at the end of this section.

11.2 Operation

To use the Linktropy Player, click on the *Player* link on the top bar of the Monitor.

Use the *Load Recording* button to browse to the desired recording file stored on or accessible from the computer running the GUI. The recording is uploaded and stored locally on the Linktropy WAN emulator, and is available for use by the Player even after reboot or power cycle.

Set the link rate and any other emulation parameters in the Additional Emulation Parameters box. Only parameters set on this page are used in the emulation. Parameters set on the **Link Emulation** tab of the Configuration window are ignored.

Press the *Play* button to start operation of the Linktropy Player. Press the button again to pause the Player or the *Stop* button to stop the Player.
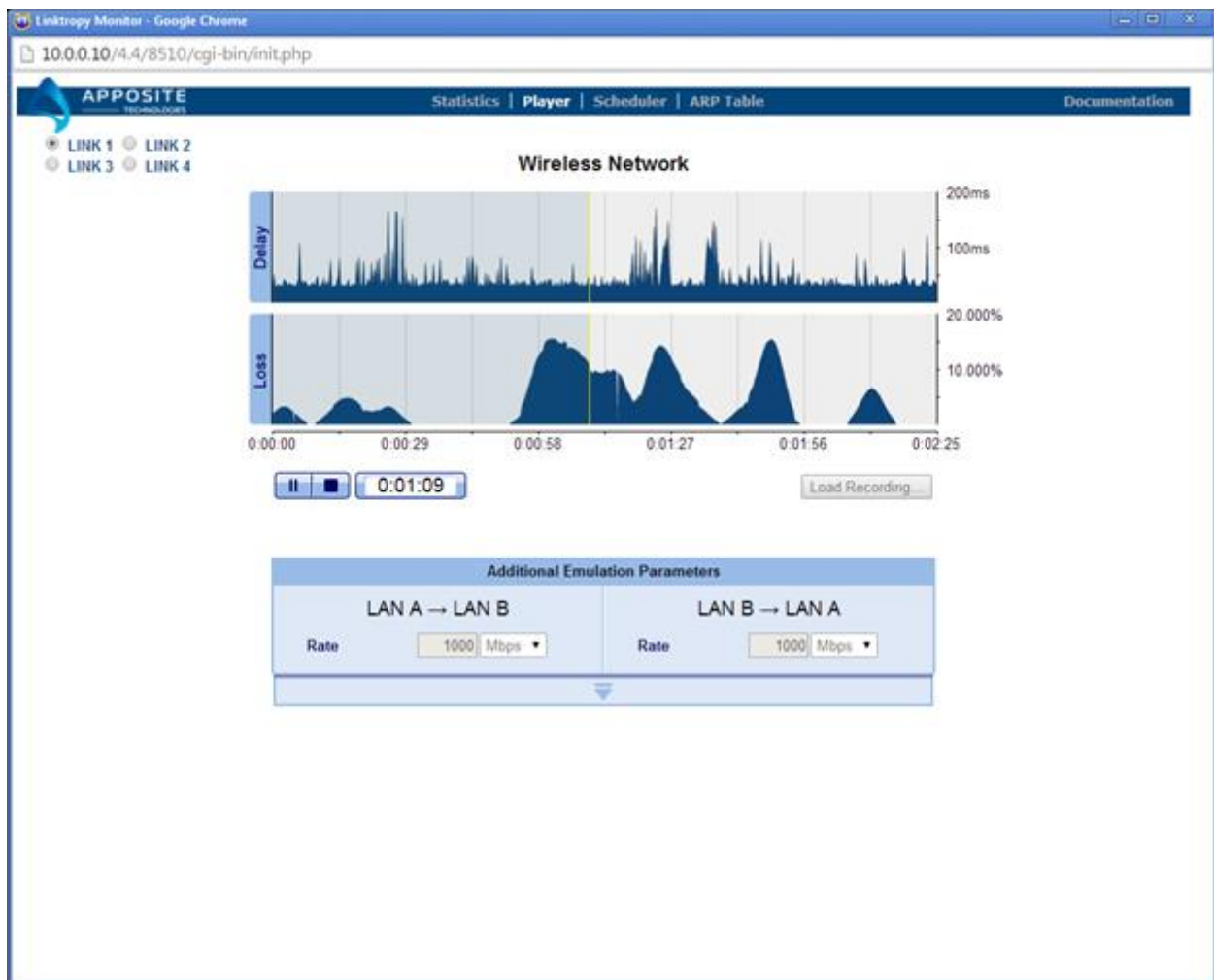
Figure 11: Linktropy Player

While the Player is running, the yellow position needle on the graph indicates the currently playing conditions, and the shaded section of the graph shows the portion of the recording that has already been replayed. When the Linktropy Player reaches the end of the recording, it continues from the beginning. The recording runs until the Player is paused or stopped.

When the Player is paused, emulation remains enabled using the conditions in effect at the time the Player is paused. The *Stop* button disables emulation and resets the position needle to the beginning of the graph.

On Linktropy models that support multiple links, configuration of the Linktropy Player applies only to the selected link. The Linktropy Player may be enabled on one or more links while regular emulation parameters run on the other links. If the Linktropy Player is used on multiple links, each link is configured independently with a separate recording file and emulation parameters.

☞ Recordings can only be loaded while the Player is stopped. The *Load Recording* button is grayed out while the Player is running or paused.

☞ After running the Linktropy Player, regular emulation from the **Link Emulation** tab of the Configuration window remains disabled until explicitly re-enabled by clicking the On/Off button. Clicking the Emulation On/Off button while the Player is running automatically turns off the Player and enables regular emulation.

11.3 Delay and Loss Parameters

Once a recording is loaded, graphs of the round-trip delay and loss are displayed as a function of time. The time axis applies to both the delay and loss graphs above it. Delay is shown in milliseconds and loss in percent.

The actual emulation uses separate one-way delay and loss values taken from the recording file for the LAN A to LAN B and the LAN B to LAN A directions. For simplicity, the delay and loss graphs show a single, composite, round-trip value with the following meanings:

▸ Delay: Round-trip time (RTT), calculated as the sum of the latency in each direction

▸ Loss: Round-trip packet loss rate, calculated as the probability of packet loss over the round trip based on the separate probabilities of packet loss in each of the two directions.

The actual one-way delay and loss values in use at any time during the emulation can be seen on the Statistics page.

11.4 Additional Emulation Parameters

Link conditions other than delay and loss are configured in the Additional Emulation Parameters box. By default, only the Rate is displayed, but the box can be expanded to configure background traffic, packet duplication and reordering, maximum queue depth, and framing overhead parameters. See Section 4 for details on the configuration of any of these emulation parameters.

11.5 Recording File Format

The recording file imported into the Linktropy Player is a text file with the format described in the table below. The recording file may contain up to 100,000 lines of data.

Line Type	Syntax and Description

metadata	`# <attribute> : <value>`
	
	A list of attributes of the recording and their values. Must be at the beginning of the file, prior to any recording data, and preceded by a "#" symbol. Defined attributes are:
	
	`# Title : <recording title>`
	
	The title of the recording displayed above the recording graphs.

data	`<start time> <delay> <loss> [<delay> <loss>]` Start time is the time in seconds, relative to the beginning of the recording, when the delay and loss values of the line take effect. Start time is a floating point number and must be at least 0.01 seconds greater than the start time of the previous line. Delay is the one-way latency, specified in milliseconds with a resolution of 0.1 ms. Loss is the packet loss rate in each direction, specified as a percentage (without the percent sign) between 0.0000 and 100.0000. The second pair of delay and loss values are optional. If two pairs of values are supplied, the first pair is the LAN A to LAN B direction and the second pair is the LAN B to LAN A direction. If only one pair of values is supplied, the same values are used in both directions. Note that a single pair of values are used as two identical one-way values and not a single round-trip value. On the final line in the file, the start time is used to determine the duration of the previous line. Delay and loss values are ignored.

12 Linktropy Scheduler:

Emulating Dynamic Conditions in the GUI

12.1 Scheduler Usage

The Linktropy Scheduler provides a mechanism to automate running a sequence of different emulation parameters. This can be useful both for emulating dynamically changing link conditions, and for automating a series of independent tests. To access the Scheduler, click on the Scheduler link in the bar at the top of the Monitor.

The basic operation of the Scheduler consists of configuring one or more sets of emulation parameters, called "stages," setting the length of time for each stage to run, and specifying the transition between the stages.

When the Scheduler page is opened, it is initialized to the currently running or last run schedule. Any Scheduler parameters entered but not run are lost when the Monitor is closed or switched to a different link.

12.1.1 Constant Emulation Parameters

Certain emulation parameters cannot vary between stages. These parameters are located in the Constants row of the Scheduler. To configure these parameters, click on the *edit* link in the constants box and set the desired values. In the current version of the firmware, Framing Overhead is the only constant emulation parameter.

12.1.2 Emulation Stages

The Scheduler allows configuration in a compact form of nearly all of the emulation parameters found in the **Link Emulation** tab of the Configuration window. Parameters are configured independently in the LAN A to LAN B and LAN B to LAN A directions.

Stages can be in either edit mode, where values for the emulation parameters can be entered or modified, or in a compact view-only mode. To toggle between editing and viewing modes, click the *edit* or *view-only* link for the stage.

To configure the emulation parameters for a stage, enter the desired values for the various emulation parameters. (See Section 4 for details on any of the emulation parameters.) Then specify the duration for the stage to run in milliseconds, seconds, minutes, or hours.

Once the configuration of a stage is complete, if there are additional stages to configure, click the *Add Another Stage* button. For convenience, the new stage will have the conditions of the previous stage pre-filled in, and can be modified as needed. To remove the final stage, click on the *delete* link in the final stage box. Only the final stage can be deleted.
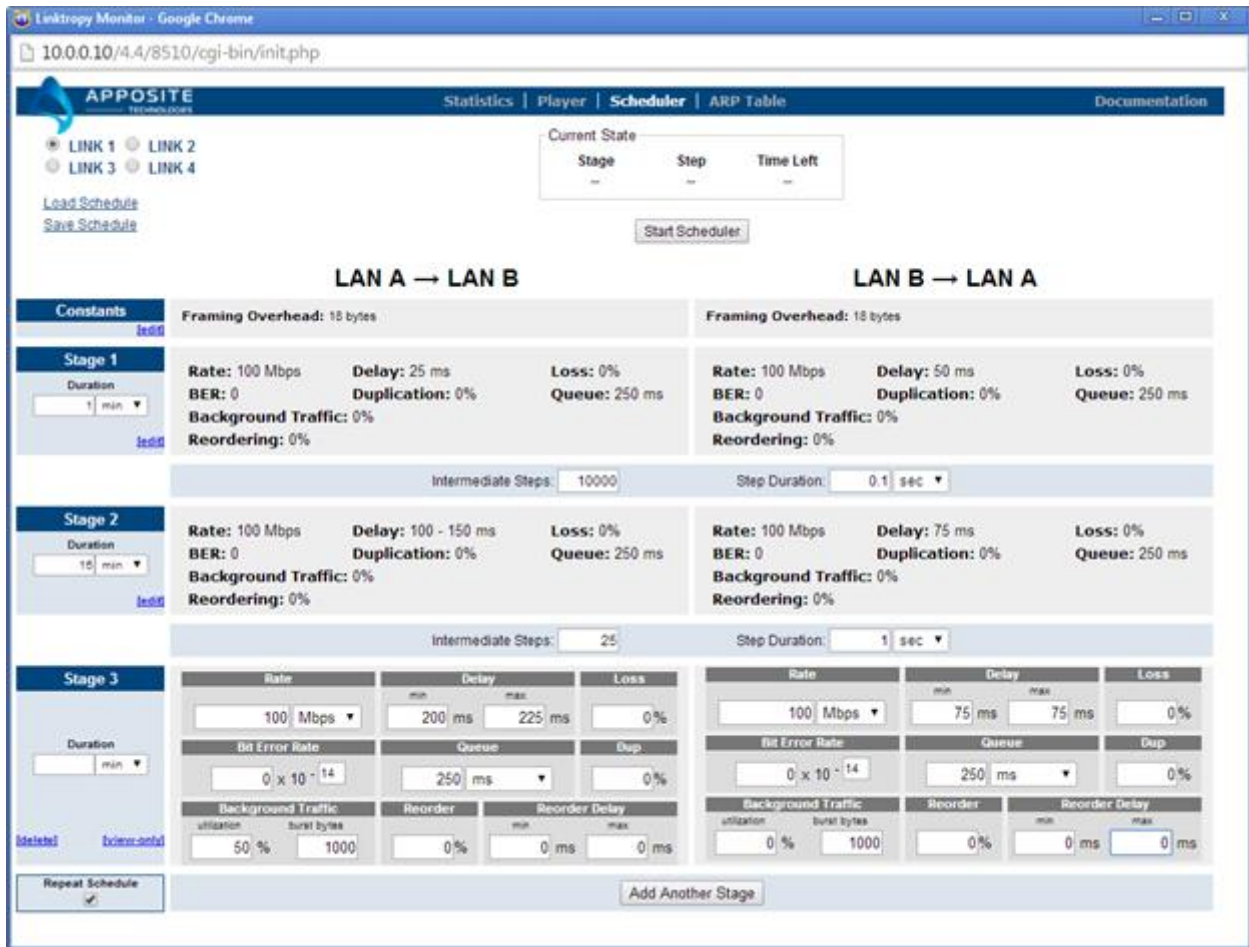
Figure 12: Linktropy Scheduler

By default, after the final stage is run, the test is complete and emulation is disabled. To have the Scheduler loop back to Stage 1 instead, check the *Repeat Schedule* box.

The Scheduler can be configured with up to 10 stages. Each stage can have a duration of between 0.1 ms and 1000 hours.

⚠️	In the Scheduler, the delay can be only a constant or uniform distribution. A normal distribution for the delay cannot be configured. For a constant value for delay, set the minimum and maximum delay to the same value.

12.1.3 Intermediate Steps

At the conclusion of a stage, the Scheduler can either immediately switch to the next stage, or can transition between the stages in a series of intermediate "steps."

To control the transition between stages, in the row between the two stages specify the number of intermediate steps to use, and set the duration for each step to run. The Scheduler uses linear interpolation to determine the values of the emulation parameters at each step. For example, if the bandwidth varies from 1.0 Mbps in stage 1 to 2.0 Mbps in stage 2 with one intermediate step, the bandwidth at that step will be 1.5 Mbps. If three intermediate steps are specified instead, the bandwidth at those steps will be 1.25 Mbps, 1.5 Mbps, and 1.75 Mbps.

To switch directly between any two stages, set the number of intermediate steps to 0. The step duration will be ignored.

Each transition can have up to 100,000 steps with a duration of between 0.1 ms and 1000 hours for each step. However, if the bit error rate changes between stages, the transition is limited to a maximum of 10 steps.

☞	There are no intermediate steps for the transition from the final stage back to the first stage when looping is enabled. If intermediate steps are needed for this transition, add another stage after the final stage with the same emulation conditions as the first stage.

12.1.4 Start/Stop Scheduler

Once configuration of the Scheduler is complete, press the *Start Scheduler* button to begin running the scheduled emulations. While the Scheduler is operating, the Current State status bar displays the stage that is currently running, the current step (during transition periods), and the time remaining in the current stage or step.

To turn off the scheduled emulation, click the *Stop Scheduler* button.

⚠️ The Linktropy configuration cannot be changed while the Scheduler is running. Attempting to apply a change will generate an error message.

The Status Bar in the Configuration window remains active even when the Scheduler is running. The Emulation On/Off button overrides operation of the Scheduler. Clicking the Emulation On button turns on emulation of the parameters configured in the **Link Emulation** tab and turns off the Scheduler. Similarly, clicking the Emulation Off button turns off all emulation even if the Scheduler is running.

12.1.5 Data Validation

Parameters for each stage are validated when the stage is switched from edit mode to view-only mode and when the *Add Another Stage* button is pressed. Stage durations and transition fields are validated when the *Start Scheduler* button is clicked. In addition, any stages in edit mode when the *Start Scheduler* button is clicked are switched to view-only mode and validated.

Invalid data entries are reported in a pop-up message box.

12.1.6 Save/Load Schedules

To save the Scheduler configuration, click the *Save Schedule* link in the upper left corner of the window. A separate pop-up window will appear. Select one of the ten spaces to save the configuration, optionally add a name, and click the *save* button.

To load a previously saved Scheduler configuration, click the *Load Schedule* link. Select the desired configuration in the pop-up window, and click the *load* button.

On Linktropy models that support multiple links, saving and loading a schedule applies only to the selected link.

12.2 Scheduler Examples

The Linktropy Scheduler is a flexible tool for emulating a wide variety of dynamic WAN conditions. The following are examples of a few common situations that can be emulated using the Linktropy Scheduler.

12.2.1 Link Outage / Burst Loss

To emulate a link outage or burst loss, first create a schedule with the normal transmission conditions, then add a stage configured with a packet loss rate of 100%. Set the loss rate to 100% in both directions for a bidirectional link outage, or in only one direction for a unidirectional outage.

Set the length of the outage by configuring the duration of the loss stage. For a burst loss, the duration can be as short as 0.1 ms.

For a periodic outage, set the schedule to repeat. For a single outage and recovery, add a final stage with normal transmission conditions.

12.2.2 Routing Changes / Route Flapping

Changes to the network route between two endpoints causes a change in the transit time between those endpoints. If the new transit time is shorter, the first packets transmitted after the routing change may arrive at the destination before the last packets transmitted before the routing change. If the new transit time is longer, there will be an interval during which no packets arrive at the destination.

In a 'route flapping' condition, routing alternates between the two paths. This causes packet traversal times to fluctuate between the two states.

To emulate routing changes, configure a Scheduler stage for each route. The change in delay between the stages corresponds to a routing change. For simple routing change situations, configure the delay of each route using a constant reordering delay with 100% reordering probability. Set the number of intermediate steps to 0 to represent the abrupt change of the route.

For example, if the link delay increases from 50 ms to 75 ms when the route changes, configure one stage with a reordering probability of 100% and a constant 50 ms reordering delay. Configure the next stage with the same values except with a constant reordering delay of 75 ms.

More complex situations can be emulated by combining the basic delay with the reordering delay. For example, if the second stage in the above example had a variable delay of 75 ms to 100 ms, set the basic delay to a variable 0 to 25 ms, and set the reordering delay to a constant 75 ms, thereby creating the desired total delay of 75 ms to 100 ms. Configuring the variable component of the total delay using the non-reordering basic delay parameter ensures that packet reordering occurs only during the transition and not within the stage itself.

12.2.3 Wireless Interference / Satellite Rain Fade

The effects of interference and weather can cause wireless and satellite links to deteriorate from a normal state to a degraded state and eventually recover. To emulate this situation, model the normal and degraded states as two stages in the Scheduler and specify the transition between them.

For a single degradation event and recovery, add a third stage with the same conditions as the first stage.

For periodic degradation with an abrupt recovery, set the schedule to repeat after the degraded stage. For periodic degradation with a gradual recovery, add a third stage with the same conditions as the first stage and specify the recovery period, then set the schedule to repeat after the third stage.

13 SECURITY

13.1 Passwords

13.1.1 Setting the Password

By default, a password is not required to access the Linktropy GUI and CLI. However, a single password that applies to both the CLI and GUI may optionally be set from the CLI.

To set the password, connect to the Linktropy command line interface. The username is "admin".

Use the following command from the CLI to set the password:

```
password set <password>
```

Use the following command to clear the password:

```
password clear
```

13.1.2 Recovering from a Lost Password

If the password has been lost, boot to the recovery firmware to gain access to the device and reinitialize the configuration to factory defaults.

1. Connect to the serial console port.

2. Power cycle the unit. Type "recovery" at the boot prompt to boot to the recovery image.

    ```
    boot: recovery
    ```

3. At the prompt, log in as "admin".

    ```
    linktropy login: admin
    ```

4. Check the firmware version for the recovery image which will differ from the operational image if the firmware has ever been upgraded:

```
linktropy> version
```

5. If the recovery firmware is v4.3.1 or later, the configuration can be reset to factory defaults with no password using the following command:

```
linktropy> init config
```

For recovery firmware version v4.3 or earlier, please contact Apposite support for assistance.

6. Reboot or power cycle the unit and return to the regular operating firmware. The management interface will also be reset to the default of 10.0.0.10.

13.2 SSL

The Linktropy GUI is accessible via HTTP or HTTPS. HTTPS allows administration of the GUI using SSL security. Linktropy includes a non-unique, self-signed certificate. Use of this self-signed certificate may generate an error in the browser that the signing certificate authority is unknown and not trusted. Either ignore this error or install your own certificate.

To install a new certificate, use the "http" command from the CLI:

```
http load <certificate file name> <server address> ["tftp"]
```

For example:

```
linktropy> http load /certs/certificate.crt 192.168.0.100
```

By default, HTTP is used to download the firmware image. Specify "tftp" to use TFTP instead.

13.3 SSH

The Linktropy CLI is accessible over the network via SSH. To verify the identity of the Linktropy SSH server, use the "ssh fingerprint" command to display the fingerprints of the SSH server's public keys.

14 COMMAND LINE INTERFACE

The Linktropy WAN Emulator includes a command line interface (CLI) that can be accessed via the CONSOLE interface or over the network through a Telnet or SSH connection. The CLI provides the following subset of the functionality available in the Linktropy GUI:

▸ Configure the management IP address, subnet mask, and default gateway

▸ Configure link emulation parameters

▸ Turn emulation on or off

▸ Load previously stored emulations

To access the CLI, log into the device at the prompt as "admin".

SSH can be used to either log into the Linktropy CLI, similar to Telnet, or to execute a single command.

The SSH and Telnet services can be enabled or disabled through the CLI using the telnet and ssh commands. By default, both are enabled. Multiple simultaneous sessions are allowed.

14.1 CLI Command Syntax

Command	Syntax and Description
help	`help or ?` Displays a list of commands available through the CLI. A question mark after any command displays the command syntax.
http	`http load <certificate file name> <server address> ["tftp"]` Installs an SSL certificate. Uploaded certificate replaces the self-signed certificate supplied in the firmware. If the certificate is not located in the root directory of the HTTP server or TFTP server, the file name must include the full path name. Specify the IP address of the HTTP or TFTP server. By default, HTTP is used to download the firmware image. Specify "`tftp`" to use TFTP instead.
init	`init config ["nolicense"]` Returns the configuration to factory default settings. Include "`nolicense`" to also reset the license acceptance. Takes effect upon reboot unless there is a subsequent save of the configuration.
link	`link <link-number> {enable	disable}` Enable or disable emulation for the link. `link {<link-number>|<link-id>} show` Displays the current emulation state and emulation properties of the link number or link id. `link {<link-number>|<link-id>} stats [reset|show [since-reboot]]` Displays the cumulative statistics for the link number or link id since last reset or reboot, or resets all counters. Reset only affects the statistics displayed by the CLI and not the GUI. `link {<link-number>|<link-id>} set`   `bandwidth <bps>`   `delay {constant <value>	uniform <min> <max>	normal <min> <mean> <stddev>}`   `loss <percent>`   `ber {0	[1.000 - 9.9999]e[-14 -- -1]}`   `background-traffic <percent> burst <bytes>`   `duplication <percent>`   `reordering <percent> [min-delay <value> max-delay <value>]`   `queue <value> {ms	KB	pkt}`   `overhead <bytes>`

link (cont')	Sets the emulation properties for the link. Using the link id set the emulation properties in the specified direction. Multiple parameters of a link can be set with a single command, i.e.: `link 1AB set bandwidth 100000 delay constant 10 loss 5%` Notes: On Linktropy models with a single link, the link number is always 1. On the models that support multiple links, the link number match the labels on the device and in the GUI. The link id is the combination of link number and direction. Direction is specified as "AB" or "BA". For example, link id 1AB is link 1 in the direction from LAN A to LAN B. All delay values are entered in milliseconds. Values specified as a percent can be entered using either percentage notation or as a decimal (i.e. "10.1%" or "0.101").
list	`list saved` Displays a list of saved configurations, ordered by Group index and Slot index
load	`load {<group-idx>	<group-name>} {<slot-idx>	<config-name>} [link <link-number>]` Loads a saved configuration specified by Group and Slot to the specified link number. The Group and Slot may be specified by name or index. Any spaces in the name must be surrounded by double quotes. Link 1 is assumed if no link number is specified.
logout	`logout` Logout from the command line interface. Returns user to the login prompt.

mgmt	`mgmt set addr <addr> netmask <mask>`
	
	    Sets the IP address and netmask of the MGMT interface
	
	`mgmt set gw <addr>`
	
	    Sets the default gateway of the device
	
	`mgmt show`
	
	    Displays the IP address and netmask of the MGMT interface and default gateway of the device.

password	`password clear`
	
	    Clears the password.
	
	`password set <password>`
	
	    Sets administration password used to login to the GUI and CLI.
	
	Unless the password has been set using this command, no password is needed to access the GUI and CLI.

ping	`ping <address> [<size>]`
	
	    Pings from the device to `address` with the specified sized packets.
	
	    Use CTRL-C to stop.

reboot	`reboot` Reboots the device. Returns user to the login prompt after reboot.
ssh	`ssh [enable	disable	fingerprint]`      Enables or disables SSH service, or displays the fingerprint of the SSH server's public keys. If service is disabled, any sessions in progress are terminated. With no argument, '`ssh`' reports current status of the service.
telnet	`telnet [enable	disable]`      Enables or disables telnet service. If service is disabled, any sessions in progress are terminated. With no argument, '`telnet`' reports current status of the service.

upgrade	`upgrade <image name> <server address> ["tftp"]`
	
	    Upgrades the Linktropy firmware. If the image is not located in the root directory of the HTTP server or TFTP server, the image name must include the full path name.
	
	    Specify the IP address of the HTTP or TFTP server.
	
	    By default, the Linktropy WAN Emulator will use HTTP to download the firmware image. Specify "`tftp`" to use TFTP instead.

version	`version` Displays the operating firmware version.

15 APPOSITE SUPPORT

15.1 Registration

For access to the Linktropy support site with firmware upgrades, documentation, and other support materials, register your unit at: http://www.apposite-tech.com/register.html. License key download will automatically register you.

Registered users will receive email notification whenever new firmware versions are released.

15.2 Customer Support

If you experience any problem with the Linktropy hardware, consult the *Hardware Guide* for your model. If you have any questions about the firmware not answered in this *User's Guide*, please check the Linktropy support site for updated firmware and documentation. If your question is not answered, please contact Apposite Support.

Linktropy units with a product license receive support and maintenance for the term of the license, including hardware warranty, firmware updates, and customer support. The license expiration date is shown on the Upgrade Tab of the Linktropy GUI for limited term licenses.

For units with an unlimited term license (purchased prior to August 2017), one year of maintenance is included with purchase, after which a yearly maintenance renewal is required for ongoing support. License and maintenance renewals are available from Apposite or your Linktropy reseller.

If you believe the firmware is not functioning properly, please upgrade to the latest firmware release. If the problem persists, please contact Apposite Support at:

> support@apposite-tech.com
> 1.310.477.9955 ext. 2

When contacting Apposite Support, please include the following information:

- ▸ Linktropy model
- ▸ Serial number
- ▸ Your e-mail address and phone number
- ▸ Installed firmware version
- ▸ A detailed description of the problem

> ⚠️ Do not attempt to fix any hardware problem yourself. The Linktropy WAN Emulator contains no user serviceable parts. Opening the chassis voids the warranty.

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