PNE
Network Emulation and Impairment Testing

User Guide

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Certifications

FCC Statement

This device complies with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules.

This equipment has been tested and found to comply with the limits for a Class A digital device pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual may cause harmful interference to radio communications.

Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at the user's own expense.

All trademarks and trade names are the properties of their respective owners.

ROHS

Some models of this product are available in RoHS versions.
Introduction

PNE is a network timing and error emulation device. Its purpose is to allow emulation of real-world network conditions in a bench-top test environment. PNE is simply inserted in the data path between devices under test. PNE may then be configured to emulate the expected operating environment. This includes placing rate limits on the link, adding latency and inducing jitter. Network packets can be dropped, duplicated, or sent out-of-order. These are all conditions that happen in a real environment but are difficult to emulate on the bench.

Hardware

The PNE is a small desk-top device containing a touch-sensitive LCD display/input screen, two 100baseT connections, and a 6 VDC power input. It is normally supplied with a 120VAC wall mount power supply. There is also an unused DB15 port on the left side of the device. Please do not connect anything to this interface. PNE is capable of dealing with 802.1q tagged packets, but does not support jumbo-frame packets.

Connections

To power-up PNE, connect the supplied power supply to the DIN connector located on the back right corner of the device. PNE requires 6 VDC at a minimum of 1.5A.

PNE has two Ethernet ports located on the left side of the device. These ports are labeled P1 and P2. From an emulation standpoint, these two ports behave like a dumb Ethernet hub. Packets received on P1 are transmitted out P2. Likewise whatever is received on P2 is transmitted out P1. PNE must be installed in the path between the devices under test. Usually it is installed as a bump-in-the-wire
between the devices under test. However, it could also be installed between a pair of routers, switches, or a combination of the two. PNE is capable of dealing with 802.1q tagged packets, but does not support jumbo-frame packets.

There is an unused DB15 port on the left side of the device. Please do not connect anything to this interface.

**Specifications**

- Simulates IP networks between 250Kbps and 100Mbps
- Two 10/100 MDI/MDIX Ethernet interface
- 6-16 VDC, External AC adapter supplied with unit
- Power On/Off switch
- Firmware update menu option auto connects to DCB web site for updates
- Power requirements: 6-16 VDC, AC adapter supplied with unit
- Size: 7” W 2.5” H x 5” D

**Test Configuration per Port**

- Simulated network with rate limits from 250K to 100 Mbps
- Packet latency of 0.1ms to 10 seconds
- Packet jitter of 0.1ms to 10 seconds
- All settings may be applied asymmetrically
- Induced packet loss, packet duplication
- Induced out-of-order packet delivery
- Generate errors automatically or on-demand
- Target errors at a specific device and protocol.
- Measuring work traffic rates in real-time.
- Measuring targeted network traffic in real-time.

**Capabilities:**

- Maximum bridging of 60,000 packet-per-second, bi-directional.
- Added packet latency from 0.1ms to 10 seconds Added packet jitter from 0.1ms to 10 seconds
- All settings may be applied asymmetrically. Induced packet loss, duplication, out-of-order delivery
- Errors generated automatically or on-demand
- Errors may be targeted at a specific device and protocol.
- Measures network traffic rates and targeted network traffic in real-time.

**Performance**

- Limits: Minimum packet jitter of 0.1ms
- Internal time resolution of 0.1ms
- Internal buffering for latency and jitter limited to 8000 packets
- Rate limited buffering limited to 104 packets.
Configuration

Navigation

All configuration and control of PNE is performed through the LCD touch screen. To navigate the menu tree, simply press the desired menu button area. Sub-menus display a <back button that will return you to the previous menu.

Configuration screens contain settings that can be modified. To modify a setting, press on the item button. Doing so will bring up an edit box or a pick list. All configuration items have context sensitive help. To access the help information, press on the configuration item's label.

Configuration and Status screens may have more information than can be displayed on a single screen. If a >> button is displayed on the bottom right corner of the display, pressing it will cycle through the pages.
Some help and message screens may have more information than can be displayed on a single page. This is indicated by a scroll-bar on the right side of the display. To scroll the display, touch and drag your finger in the direction you want the page to move. Then lift your finger. The page won't move until you remove your finger from the display.

PNE maintains two types of configuration. First, the PNE Profile which contains configuration items related to PNE's timing and error emulation. These are the items that are commonly modified during the course of performing an emulation. The System Configuration, contain the configuration items related to the PNE device itself. These include items such as the screen-saver time, the optional IP configuration, and the Ethernet Port link and duplex. These items are rarely modified once preferences are configured.

Profile Configuration

These are configuration items related to PNE's timing and error emulation that are commonly modified during the course of performing an emulation. Profile modification doesn't immediately take
effect. For emulation purposes, it may be desirable to make a number of modification and then apply them all at the same time. An *apply* button will appear anytime there are profile modifications that have not been applied.

The Profile is not automatically saved to non-volatile memory. To save the profile, you must navigate to the “Save/Load” profile menu and explicitly save the profile. A saved profile will automatically load on power-up. The Profile may be cleared without effecting the System Settings.

### System Configuration

The System Configuration, contain the configuration items related to the PNE device itself. These includes items such as the screen-saver time, the optional IP configuration, and the Ethernet Port link speed and duplex. These items are rarely modified once preferences are configured. The System Configuration is automatically applied when you exit a system-related configuration screen. It is also automatically stored to non-volatile memory and will become the power-up default.
**System Settings**

Navigate to the *System Settings* screen from the *main menu* screen *System Settings* button. From this screen there are options for network settings, updating the device software, screen saver, and resetting to factory default.

**Network Settings**

From this navigation screen, select the ethernet port to configure, IPv4 parameters, and check network status.

**Ethernet Configuration**

Configure each ethernet port for allowable modes to allow or disable Auto Negotiate, 100Mbps or 10 Mbps, and Full or Half duplex.
IPv4 Settings Screen

It may be useful to assign an IP address to the PNE. Having an IP address allows the PNE to automatically download updated firmware, and respond to typical IP tests such as PING. However, if those features aren’t needed, PNE works without an IP address assignment.

From this screen, select an IPv4 mode by clicking on the Mode value field. Options are DHCP, static IP, or Disable IPv4. If Static is selected, enter the IP configuration values. If disabled or DHCP, the IPv4 Settings are blanked.

Network and Device Status

This screen displays the status of all Network and IPv4 configuration values.
Device Software

From the Device Software screen, the Software Info display can be selected, an automatic software update initiated, or the system rebooted.
Network Emulation and Impairment Tests

Timing Emulation

A core feature of PNE is its ability to manipulate packet timing as packets flow through the device. At the lowest level, PNE is simply moving packets from P1 to P2 and likewise from P2 to P1. In this regard, it functions very similar to a store-and-forward switch. However, while it is storing a packet, PNE can be configured to delay the forwarding action. By delaying the forwarding action, it is possible to emulate the timing characteristics of a real-world link. These characteristics are transmission rate, latency, and jitter.

Transmission Rate-Limit

A network connection has a maximum speed in which it can operate. For example, 100M Ethernet has a maximum speed of 100M bps (bits-per-second). A DSL link may run at a much lower rate, for example, it may only run at 1M bps. In addition, the speed of the link may not be symmetrical. Again, as an example, a DSL link may have a download rate of 1M bps and an upload rate of only 500K bps.

To configure the transmission rate limit, navigate to the Timing Profile submenu. From this menu, the timing for packets flowing in P1 and out P2 and the packets flowing in P2 and out P1 may be independently configured.

Rate limiting is off by default. To set a rate, press on the current setting and enter a new value. Transmission rate limiting can be set in the range from 0.001M to 100M. The value 0 disables rate limiting.
Latency and Jitter

Latency is the time it takes a network packet to travel from the sender to the receiver. In a bench-test environment, this is often very fast, usually a fraction of a millisecond. However, in a real-world environment, the network packet may be traveling a long distance, traversing multiple routers or bridges. Latency may range from 10s of milliseconds to 100s of milliseconds.

Actual latency is rarely a fixed amount of time. There is a fixed component since it will take a fixed amount of time for a packet to physically traverse the network. However there is also a variance to the latency. This variance is called jitter. It is a result of varying network congestion and processing limitations as a packet makes it way from sender to receiver.

PNE allows a fixed latency plus a variable amount jitter to be configured. As packets flow through the device, each packet will be delayed by the latency time. In addition, some jitter time will be added to the base latency. There are three different algorithms used for applying jitter. They are alternate, random, and sweep.
Latency and Jitter Configuration

Alternate mode: The full amount of jitter is applied to every other packet, basically going from min (0) to max with each alternating packet.

Random mode: A pseudo-random time between 0 and the selected jitter time is applied to each packet. The resulting jitter should average approximately half of the selected jitter time.

Sweep mode: The delay added to each packet sweeps back and from no delay to the selected time. For example, if jitter was set to 100ms, the delay would start at 0 and progressively grow to 100ms. Once it reaches 100ms, it would start to decay back to 0. When it reaches 0, the process repeats. The time it takes to sweep is not related to clock time but instead is based on packet flow. Each packet steps the delay by 0.1ms.

Which one to use? Consider the real-world network you are emulating and try to match it. Using DCB’s companion product, the ETTA, to characterize the real network is the best way to understand it. Other methods are simply observing the delay and jitter by running ping tests over time. For new equipment analysis, it may help you understand the equipment responses by running tests using all three modes.

Timing Bypass

PNE operates at layer-2. Doing so greatly simplifies the test environment. However, it also means that PNE will apply rate limiting and packet delay to protocols that are not designed or intended to be delayed. One such example is the ARP protocol. ARP does not cross router boundaries. When emulating the timing of a routed network, it may be unreasonable to apply the same timing to ARP packets. Some devices have fixed ARP time-outs that are quite short and will fail when transiting an emulated high latency link.

PNE can be configured to bypass all non-IP traffic, immediately moving the packet from the receiving port to the transmit port. The packet is not subject to any additional delay, except for the minor store-and-forward delay imposed by PNE. Also, these packets will be excluded from error emulation. Non-
IP traffic includes any packet that does not carry an IPv4 or IPv6 protocol ID in the Ethernet header.

Timing Profile Bypass Configuration

Please keep in mind that when emulating a bridged environment, non-IP traffic should be subjected to timing delays and error induction. This is often overlooked when bench-testing and a cause of field failures when ARP, STP, and other layer-2 protocols behave unexpectedly in bridged environment with high latency. Examples of this type of network are WiFi or other wireless bridges.

**Error Emulation**

Transmission errors are a fact-of-life in a real-world environment. Packets may be dropped, due to network congestion or interference on a wireless link. Wireless links are prone to packet duplication, and multipath routing may cause packets to be delivered out-of-order.

Similar to timing, errors are configured asymmetrically. The specific rates are independently set for each direction of packet flow.

PNE has a very simple but flexible mechanism for automatically generating various errors. For each of the error types an error ratio is configured.
Drop Errors

For example, P1 to P2 drop may be configured to drop 1 packet per every 100 total packets, yielding a 1% drop rate. Likewise, drop rate may be configured to drop 10 packets every 1000 total packets. This is still a 1% drop rate, but with very different implications. Instead of a single packet lost, a block of 10 packets are lost.

To generate a drop error, a packet is simply dropped instead of being transferred from the input port to output port. The drop value configures the number of packets to drop in a block. It must be smaller than the per total value. The per total value may be set anywhere from 1 to 100,000,000.

Duplicate Packets

A duplication error is generated by sending the same packet twice. The dup value configures the number of packets, within a block, to duplicate. It is not the number of times that a packet is duplicated. For example, if the dup value is set to 10, a block of 10 packets is duplicated one time. The per total value controls how frequently to generate the duplicate packets. So a dup of 10 per 100 means a block of 10 packets will be duplicated once every 100 total packets. The amount of time between sending the first instance of a packet and sending the second instance of a packet is specified as the latency.

Out-of-Order Packets

The behavior of out-of-order packets is a little more complex than the other error types. The concept is simple, hold on to a packet, wait until another packet comes along, then deliver the two packets in reverse order. A block of packets can also be reordered. Along the same idea, two or more packets can
be placed in the reorder buffer. Then as additional packets come along, the packets in the reorder buffer are merged back into the packet stream. To really mix this up, the packets are merged back in reverse order from their original receipt.

To explain this a little better, let's take the packet sequence of p1, p2, p3, ... p9. If reorder is set to 3, packets p1, p2, and p3 are placed in the reorder buffer. As the remaining packets arrive, the transmit order will be as follows: p4, p3, p5, p2, p6, p1, p8, p9.

To complicate things, we have to deal with the possibility that “another” packet may not come along in a reasonable amount of time. With streaming type protocols this is an unlikely event. However, lock-step type protocols are prone to this behavior. It's not that another packet will never come along, but that it may take a long period of time before this occurs. The system under test will be handling this as a dropped packet condition instead of an out-of-order condition. The MaxWait configuration item addresses this problem. It specifies how long a packet should sit in the reorder queue before being kicked out based on time.

**Targeting Errors At A Specific Device**

Errors may be directed at a specific device and/or protocol instead of being applied to all packets that traverse the ports. This allows testing to be focused on a particular application and insure that errors are generated against packets related to that specific application. Targeting can be based on Ethernet MAC addresses or by IPv4 addresses. When using IPv4 addresses, it's possible to drill down on a specific TCP or UDP protocol.

Like all other settings, targeting is configured independently for each packet direction, P1 to P2 and P2 to P1. By default all packets are targeted. The options are to target *all* packets, *no* packets, target by Ethernet *MAC address*, or to target by *IPv4* addresses.

**Target Selection**
- Target Selection

**Target Type Selection**
- Target Type Selection

*MAC Addr*: Packets are targeted by source and destination Ethernet MAC address.
IPv4 Address: Packets are targeted by source and destination IPv4 address. When this mode is selected, it is also possible narrow the scope by also targeting protocol and port number.

If the Protocol field is set to TCP or UDP, a specific application can be targeted by setting the port or a range of ports used by the protocol. For example, let's say we want to target a web server attached to P2. HTTP uses TCP port 80. The P1->P2 target would be set to TCP, and the Dst Low and High would be set to port 80. We would leave the Src Low and High set for the full range of 0–65535 since the web browser will be using an ephemeral port as its source. This example target will match any packet moving from P1 to P2 with a destination of TCP port 80.
**Errors On-Demand**

PNE can also be used to generate errors on-demand. Each button press will generate the requested number of errors in either the P1 to P2 direction or the P2 to P1 direction. The same targeting rules, described above, apply to errors on-demand. The title above the buttons will highlight in red while waiting for enough target packets to satisfy the demand request. Keep in mind, if no packets meet the target requirements, the errors won't be generated.
Monitoring

When emulating a network, it is helpful to get some feedback. PNE gathers statistics on traffic flow. This include separate statistics on total traffic flow and targeted traffic flow. Both current and long-term average rates are gathered. In addition, a count of induced errors are kept.

Packet Rates

Packet Rates show the traffic flow over the last 1 second sampling interval. The max fields keep track of the highest level since start-up or the last time the zero button was pressed. This is useful in capturing the short-term bursts.

Pressing the >> button will toggle between all traffic and targeted traffic. This information can be used to verify the effects of rate limiting and latency. It can also be used to measure the load a device or application generates under various condition.
Average Packet Rates

Average Packet Rates show the flow of traffic since start-up or the last time the zero button was pressed. Please note that pressing the zero button will reset all statistics.

Interpreting these displays
All values are for packets transversing a single direction (Port 1 to Port 2, or Port 2 to Port 1).

Drop: Dropped packets
Dup: Duplicate packets
Order: Out of order packets
Pps: Packets dropped due to ingress rate exceeding the configured pps limit.
Rate: Packets dropped due to ingress queue overflow. This error will be a result of the ingress rate
exceeding the configured rate limit. For example, the rate limit is set to 10Mbps and the network is trying to push 20 Mbps.

Tx_q: Packets dropped due to egress queue overflow. This may be caused by hardware rate limiting (rate limit > 40 Mbps) or by a speed/duplex mismatch between ethernet ports. For example, one port is running 100Mbps and the other 10Mbps.
Firmware Updates

PNE has a built-in easy-to-use update feature. Whenever new firmware is released, it’s made available for download via the Internet from a DCB server. Update requires an Internet connection and an appropriate static or DHCP IPv4 address assigned to the PNE.

You can also display the current software version on the “Device Info” screen, accessible from the “System Settings” screen.

From the main screen, press “Settings”.
From the Settings screen, press “System”.
On the System Settings screen, press “Update Software”.

On the Software Update screen, press “OK” and the “Check for Software Update” screen is displayed.
To obtain the latest firmware, there is no need to change any values in this screen. Press “start”.
If you wish to use any other version of software, enter the version number. The HTTP Port should remain configured to port 80. Press “Start”.

The unit will display the “Checking..” screen and connect to the firmware server to download the firmware image. This screen may only display for a second or two.
Firmware Download Complete

After downloading the image, the unit will check that an update is needed. If so, it will load the new firmware and restart.

During the download process if you decide not to complete the update, press the “abort” key.

Once the image is downloaded, you can cancel the operation or install the software. If you accept the install, PNE will update itself and restart.

Previous versions of PNE firmware download files are also available from the update site. If you want to downgrade to a prior version or obtain a custom version, enter the requested version number prior to pressing “start”.

If the requested firmware version isn’t available or the update server can’t be reached, an error screen is displayed, along with a return path to the System Settings screen.
Many of our customers are faced with the “disappearing E&M line blues” as telephone companies withdraw their leased E&M line offerings from the marketplace. They are replacing those with digital lines, typically T1 or packet switched networks (basically ethernet). In some cases TDM networks are being replaced with packet switched networks.

We used PNE to analyze a few TDM and E&M replacement products to help those customers, and in some cases the equipment manufacturers, better characterize the performance of new circuit transport via real world ethernet connections.

The test setup is simple. Two CPE end products are connected via the PNE ethernet ports. Traffic is passed through those CPE products and the ethernet network between them. The tests are straightforward. TDM traffic was generated using a T-Berd, E&M traffic was generated using modems. The results are sometimes surprising, sometimes as expected.

**TDM (T1) Product Tests.**

Test 1: Dropped packets for T1 transport emulation: With jitter buffers and jitter tolerance set at manufacturer’s recommended values, we configured the PNE to drop one packet per each thousand packets. MFRA’s product always generated an error.

Test 2: Duplicate packets for T1 transport emulation: Same equipment as above, and we duplicated one packet per hundred. It always generated an error. We then lowered the error rate to one packet duplication per thousand. Same thing… the hit always generated an error.

Test 3: Out of order packets for T1 transport emulation: One packet out of order per thousand packets. No error was generated, but when we raised it to any number greater than one out of order packet per thousand, there was an error generated.

Test 4: Packet jitter: Jitter didn’t cause a problem up to 20 msec. But, since the jitter buffer setting was 24, we know there will be problems with jitter values near 24 msec or greater.

**E&M Product Tests**

We used a 202T FSK modem over an emulated E&M channel. RFC 5087 – Time Division Multiplexing over IP (TDMoIP) provides various ways for a manufacturer to handle packet switched
network real-world problems. It allows for either configurable or dynamically adjusted jitter buffers, and requires a lost packet processing method.

Test 1: Out of Order Packets: We discovered that the CPE E&M tunnel device does not tolerate any out of order packets.

Test 2: Duplicate Packets: It was more tolerant of duplicate packets. The link worked with ten packets duplicated per hundred packets transmitted.

Test 3: Packet Jitter: The unit under test automatically adjusts its jitter buffer to compensate for network jitter. When the jitter value is changed very quickly, a single error was generated, and then error free operation resumed. When we bumped the jitter from 30 msec up to 600 msec, then back down to 30 msec, again there was a single error with each jump, but it’s obvious that the jitter buffer is elastic and grows and shrinks as necessary.

And a Product Verification

While this one is a bit self-serving, we’ll mention one more test suite we recently performed. We tested two of our AVA-E low bit-rate VOIP boxes. The AVA-E configuration was typical.

Interfaces configured to FXS to FXS–PLAR the P25 3600 bps voice CODEC. Jitter buffer is 40 msec.

For the test, timing was set for 3 msec latency, 100 msec jitter, and random jitter. We tested for typical Internet problems such as drop one packet per thousand, duplicate one packet per thousand, and move three packets per second out of order.

We found no perceptible impact on the voice traffic. Of course, we attribute this to good design work. But, buffering in the network interface engine and CODEC choice are the primary reasons that network imperfections didn’t affect the end to end traffic in this robust product.

Conclusions

PNE enables you to learn things about your ethernet products that aren’t readily apparent. With a low entry cost, it’s convenient to characterize how YOUR installation will operate on a less than perfect real
world network. This appliance provides a solid methodology for comparing alternate products as well as learning how your installation will work in the real world. By measuring the actual network path characteristics using the companion product, the ETTA ethernet transport analyzer, and configuring the PNE appropriately, you can test your proposed equipment installation on the bench using the PNE with repeatable measurements.

**About the PNE**

The PNE (Packet Ethernet Network Emulator) is available from Data Comm for Business, Inc (DCB) either directly or through resellers such as Graybar or Anixter. At only $995, and with a small desktop footprint, there should be one on each technician’s test bench.

Read the PNE data sheet at [https://www.dcbnet.com/datasheet/pneds.html](https://www.dcbnet.com/datasheet/pneds.html)

More information about testing is in the PNE manual at [https://www.dcbnet.com/manuals/pne.pdf](https://www.dcbnet.com/manuals/pne.pdf)

A companion product ETTA, the ethernet performance test set, is used to characterize an existing network. Read the ETTA data sheet at [https://www.dcbnet.com/datasheet/ettads.html](https://www.dcbnet.com/datasheet/ettads.html)