SEL ICON VSN Interoperability Test Report

Schweitzer Engineering Laboratories

SEL ICON VSN Interoperability Test Report
Project No. 98030

Revision 0
8/28/2017

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prepared for

Schweitzer Engineering Laboratories
SEL ICON VSN Interoperability Test Report
Pullman, WA

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prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, MO

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
ICON	Integrated Communications Optical Network
IMIX	Internet Mix
MPLS	Multiprotocol Label Switching
QoS	Quality of Service
SEL	Schweitzer Engineering Laboratories
SER	Sequential Events Recorder
SONET	Synchronous Optical Network
TDM	Time-Division Multiplexing
VSN	Virtual SONET Network
WAN	Wide Area Network

1.0 EXECUTIVE SUMMARY

The Schweitzer Engineering Laboratories (SEL) ICON currently supports time-division multiplexing (TDM) over a synchronous optical network (SONET) to transport teleprotection data for power system operations. SEL has introduced new Virtual SONET Network (VSN) firmware, which enables the SEL ICONs to interface with common packet based core utility networks. The purpose of this testing was to validate the interoperability of the new SEL ICON firmware over a variety of common packet based utility networks. The interoperability of the SEL ICONs VSN has been tested over a Nokia MPLS network, a Ciena Carrier Ethernet network, and a Cisco network. Additional edge failover tests and congestion tests have been conducted on the Nokia and Ciena networks to measure the performance and interoperability of the new SEL ICON VSN firmware. The tests that were completed have validated that the new SEL ICON VSN firmware operates with packet based networks and effectively fails over in the event of a network link failure.

2.0 TESTING OBJECTIVES

The objectives of the tests were to validate the interoperability of the SEL ICON devices with packet-based utility networks and measure their performance over the core networks. The following tests have been conducted:

- Baseline Tests: Measured the latency and asymmetry of SEL 411L's over direct fiber, over the SEL ICON devices, and over the ICONs integrated with the core networks (Nokia, Ciena, and Cisco).

- Failover Tests: Measured the minimum, maximum, and average healing times of break tests at the edge ICON network. The number of packets lost during failover was tabulated.

- Congestion and Priority Tests: Measured the latency, asymmetry and packet delay variation of the ICONs integrated with the core network when stressing the core network with an IXIA traffic generator. This included assigning different priority values to the IXIA and ICON traffic respectively to ensure that the core network respected the QoS settings of the ICON traffic.

NOTE: Failover tests and Congestion and Priority tests do not include Cisco MPLS network

Additional details on each of these tests will be provided in subsequent sections of this test report.

3.0 TEST EQUIPMENT

The following equipment was used during testing in the Burns & McDonnell Interoperability and Automation lab.

1. (2) SEL-411L Relays
2. (3) SEL ICON's
3. (3) Nokia 7705 SAR-8 MPLS Routers
4. (3) Ciena Carrier Ethernet Switches – Ciena 3930, Ciena 3932, Ciena 5142
5. (2) Cisco ASR-903 Routers
6. (1) Cisco Catalyst 6509-E Switch
7. (1) IXIA Traffic Generator
8. (1) GPS Antenna
9. (2) Transition Networks Media Converters

4.0 NETWORK TEST EQUIPMENT

4.1 IXIA

The IXIA network traffic generator pictured in Figure 4-1 was used to inject Ethernet traffic streams into each core network.

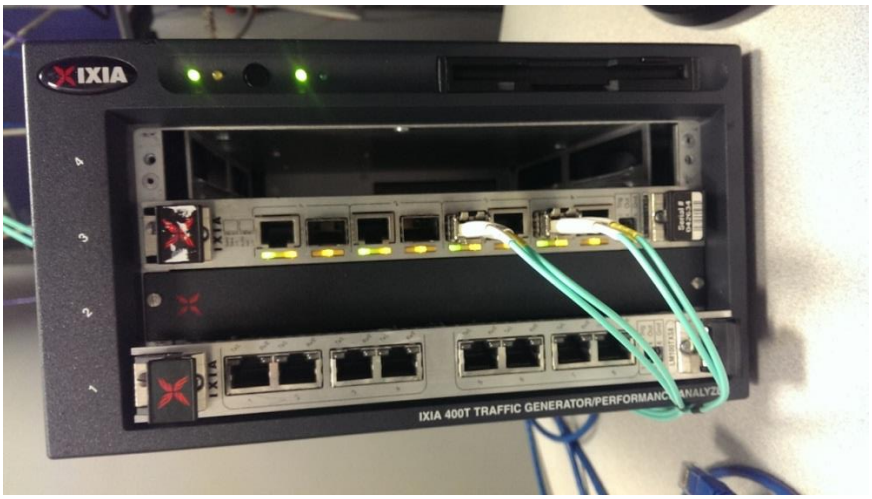


Figure 4-1 – IXIA Network Traffic Generator

The IXIA was configured to send one traffic stream using a VLAN-tagged gigabit Ethernet interface at varying Priority Bits depending on the test. The IXIA over-subscribed the maximum throughput available on the core networks by transmitting up to 1 Gbps of data. Based on the QoS policies configured, the core network dropped traffic starting with the lowest priority frames during network congestion.

The IXIA was used to capture the following measurements for each data stream:

- System data throughput (bits/sec)
- Latency (µsec)
- Sequence gaps (dropped packets)
- Maximum packet inter-arrival time (µsec)

5.0 APPLICATION TEST RESULTS

5.1 Baseline Device Tests

These test cases have captured the baseline performance for the SEL-411L relay-to-relay communication under three different scenarios: through a direct fiber connection, through an SEL ICON network, and through an SEL ICON network that has been packetized to run through the three different core networks.

5.1.1 Direct Fiber Baseline Test

This test measured the latency of an 87L communications channel used by the SEL-411Ls connected via multimode fiber to establish baseline performance metrics. This test was run for a total of five minutes. The COM report from the SEL-411Ls provided the results tabulated below. See Appendix 6.1 for a schematic of the test topology and more detailed results.

	Relay 1	Relay 2	
Round-Trip Delay (ms)	0.0	0.0	87L
Transmit Delay (ms)	0.0	0.0	
Receive Delay (ms)	0.0	0.0	
Asymmetry (ms)	0.02	0.01	

Figure 5-1 – Direct Fiber Baseline Test Results

5.1.2 ICON Baseline Test

The ICON Baseline test measured the latency and asymmetry present in a pure ICON network. For ICON settings, test topology, and more detailed results, see Appendix 6.2. This test was run for a total of five minutes. The COM report from the SEL-411Ls provided the results tabulated below:

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	87L
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	
Asymmetry (ms)	0.17	0.16	

Figure 5-2 – ICON Baseline Test Results

5.1.3 ICON Integrated with Core Network Baseline Test

This test measured the latency and asymmetry of an 87L channel through an SEL ICON network, which was then packetized and transported via a Nokia, Ciena, and Cisco core network. The test was run for five minutes, and the data was collected via the SEL-411Ls COM report. For more detailed information on the results and test topology see Appendix 6.3.

	Nokia		
	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	87L
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	
Asymmetry (ms)	0.18	0.14	
	Ciena		
	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	87L
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.5	0.5	
Asymmetry (ms)	0.04	0.02	
	Cisco		
	Relay 1	Relay 2	
Round-Trip Delay (ms)	0.8	0.8	87L
Transmit Delay (ms)	0.5	0.3	
Receive Delay (ms)	0.3	0.5	
Asymmetry (ms)	0.19	0.18	

Figure 5-3 – ICON Integrated with Core Network Baseline Test Results

5.2 Failover Tests

Failover tests were conducted to measure the healing time and functionality of the failover mechanisms provisioned in the ICONs. The SEL relay event logs were intended to be utilized to determine the duration of outages as perceived by the relay during network failure testing. The following relay word bits were added to the event logs of the SEL-411Ls to determine when outages were recorded to have started and recovered inside the relay. Table 5-1 below outlines the relay word bits utilized to determine outages.

Device	Relay Word Bit	Description
SEL-411L	87CH*n*OK (*n* = 1-3)	The relay declares a given active channel as OK (87CHpOK Relay Word bit) if this channel receives more than one valid packet in a row. The 87CHpOK Relay Word bit deasserts if five consecutive packets fail to meet the validity criteria.
	87CH*n*LX (*n* = 1-3)	Lost packet count among the scheduled 10,000 packets for the 87L Channel 2

Table 5-1 – SEL Relay Word Bit

5.2.1 ICON Failover Tests

To determine the duration required for the ICON network to fail over, the physical cable from ICON Node A to Router/Switch A in the Nokia/Ciena networks was removed to create an outage. In this test, the Nokia/Ciena networks were configured with a static route so that the SEL ICON network would be responsible for healing the network. See Appendix 6.4 for a schematic of the test setup and more detailed information on the test results. Using the SEL Relay Word Bit settings identified in Table 5-1, the minimum/maximum number of lost packets was tabulated below when tested with the Nokia and Ciena networks. The intent of the SEL Word Bits was to also to find the average duration of the outages via the SEL events log. Notably, in only one instance from all ten tests was more than five packets dropped during the failover period – the threshold for the triggering the 87CHnOK word bit in the events recorder of the SEL-411L. Accurate failover durations cannot be deduced because of this, but it can be stated that in the ten tests conducted, on nine occasions there were fewer than five packets dropped when the SEL ICONs failed over due to a physical removal of the fiber optic cable.

	Relay 1	Relay 2	
Round-Trip Delay Avg. (ms)	1.1	1.1	87L
Transmit Delay Avg. (ms)	0.6	0.5	
Receive Delay Avg. (ms)	0.5	0.6	
Asymmetry Avg. (ms)	0.13	0.12	
Min. Lost Packet Count	0	0	
Max. Lost Packet Count	4	1	
SER (Sum)	0	0	

Table 5-2 – ICON Failover Test (Nokia)

	Relay 1	Relay 2	
Round-Trip Delay Avg. (ms)	0.9	0.9	87L
Transmit Delay Avg. (ms)	0.5	0.5	
Receive Delay Avg. (ms)	0.5	0.5	
Asymmetry Avg. (ms)	0.05	0.06	
Min. Lost Packet Count	1	0	
Max. Lost Packet Count	5	2	
SER (Sum)	1	0	

Table 5-3 – ICON Failover Test (Ciena)

5.3 Congestion and Priority Tests

To measure the performance of the SEL ICON network over the Nokia and Ciena core networks, an IXIA traffic generator was configured to produce a single VLAN-tagged uniform distribution of a weighted random frame size Ethernet traffic stream over the course of a 10-minute test. Figure 5-4 illustrates the normal distribution settings on the IXIA.

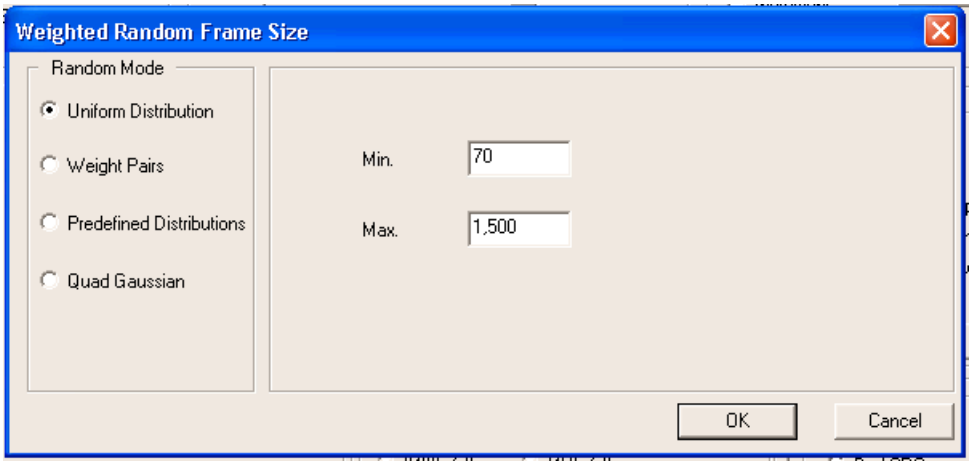


Figure 5-4 – Weighted Random Frame Size Uniform Distribution Settings

While the ICON VSN was generating approximately 155 Mbps of traffic, the Ethernet traffic stream from the IXIA was injected at full access interface speed (approximately 975 Mbps) over the Nokia and Ciena core networks to simulate congestion. Each core network was provisioned with 1 Gb access interfaces and 1 Gb transport interfaces. Over the course of the test, the IXIA packet group statistic view was used to capture latency values, maximum packet delay variation, and total dropped packet counts for the IXIA traffic. The ICON NetCat software was used to capture maximum packet delay variation and dropped packet data for the ICON VSN traffic. To ensure that each core network sufficiently passed the higher priority ICON traffic, the IXIA traffic was assigned a VLAN tag 200 with a lower 802.1p Priority than the ICON traffic (VLAN tag 100). To view the lab setups for the congestion and priority tests, see Appendix 6.5. Tabulated in Figure 5-5 and Figure 5-6 are the results of the congestion and priority tests. As shown in the below figures, no ICON packets were dropped for either test. As expected, the IXIA traffic experienced congestions as shown by the large variances in latency and numerous dropped packets (see Big Error) while the network was oversubscribed.

Ixia	Latency Min (µs)	Latency Max (µs)	Latency Max-Min (µs)	Big Error*
Ixia Port 1	44.76	96923.48	96878.72	19283889
Ixia Port 2	56.72	100271.22	100214.5	21838856

* Big Error is registered when more than one frame is dropped

ICON Software	Missed Packets	Latency Min (µs)	Latency Max (µs)	Latency Max-Min (µs)
ICON Node A	0	191	310	119

Figure 5-5 – Nokia Congestion and Priority Test Results (1GB)

Ixia	Latency Min (µs)	Latency Max (µs)	Latency Max-Min (µs)	Big Error*
Ixia Port 1	22.42	3808.32	3785.9	289040
Ixia Port 2	8.98	3809.62	3800.64	289006

* Big Error is registered when more than one frame is dropped

ICON Software	Missed Packets	Latency Min (µs)	Latency Max (µs)	Latency Max-Min (µs)
ICON Node A	0	36	49	13

Figure 5-6 – Ciena Congestion and Priority Test Results (1GB)

The variance in latency between Nokia and Ciena networks is due to the added latency of adding and removing labels to the flow. This adds about 80 microseconds on ingress or egress to the MPLS network but does not add any delay at intermediate nodes.

This test was also conducted with 10GB transport links between the nodes. These results show that when a gigabit of congestion traffic and 155Mbps of ICON traffic, both networks were able to process all frames without loss and with no variation on jitter but a MPLS network still has a delay to add and remove labels to each frame.

ICON Software	Missed Packets	Latency Min (µs)	Latency Max (µs)	Latency Max-Min (µs)
ICON Node A	0	204	204	0

Figure 5-7 – Nokia Congestion and Priority Test Results (10GB)

ICON Software	Missed Packets	Latency Min (µs)	Latency Max (µs)	Latency Max-Min (µs)
ICON Node A	0	52	52	0

Figure 5-8 – Ciena Congestion and Priority Test Results (10GB)

6.0 APPENDIX

6.1 Direct Fiber Baseline Test

* 2F/MM = 2 Strand Multimode Fiber

Figure 6-1 – Direct Fiber Baseline Test Setup

```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial channel
                    DISABLED

MEDIUM/PROTOCOL     Configuration                 Status
Serial Channel 2    850nm C37.94 Fiber            OK
Synchronization     External-time-based           High precision
Time Fallback       Mode 1                        OK

TIME SOURCE         Local Status                  Remote Status
                    Locked                        Locked

CHANNEL ADDRESSING
Local Address       1
Remote Address 2    2

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)   0.0
Transmit Delay (ms)     0.0
Receive Delay (ms)      0.0
Asymmetry (ms)          0.02
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                          Date and Time (UTC)
Lost Packet Count 24hr 0           04/10/2017 20:29:45
Round-Trip Delay (ms)    0.0       04/10/2017 20:30:18.426
Transmit Delay (ms)      0.0       04/10/2017 20:30:18.426
Receive Delay (ms)       0.0       04/10/2017 20:30:08.821
Asymmetry (ms)           0.02      04/10/2017 20:30:08.821

HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial channel
                    DISABLED

MEDIUM/PROTOCOL     Configuration                 Status
Serial Channel 2    850nm C37.94 Fiber            OK
Synchronization     External-time-based           High precision
Time Fallback       Mode 1                        OK

TIME SOURCE         Local Status                  Remote Status
                    Locked                        Locked

CHANNEL ADDRESSING
Local Address       2
Remote Address 2    1

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)   0.0
Transmit Delay (ms)     0.0
Receive Delay (ms)      0.0
Asymmetry (ms)          0.01
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                          Date and Time (UTC)
Lost Packet Count 24hr 0           04/10/2017 20:30:27
Round-Trip Delay (ms)    0.1       04/10/2017 20:31:12.453
Transmit Delay (ms)      0.0       04/10/2017 20:30:42.555
Receive Delay (ms)       0.0       04/10/2017 20:30:42.613
Asymmetry (ms)           0.02      04/10/2017 20:31:14.313

HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

Figure 6-2 – Direct Fiber Raw Data

6.2 ICON Baseline Test

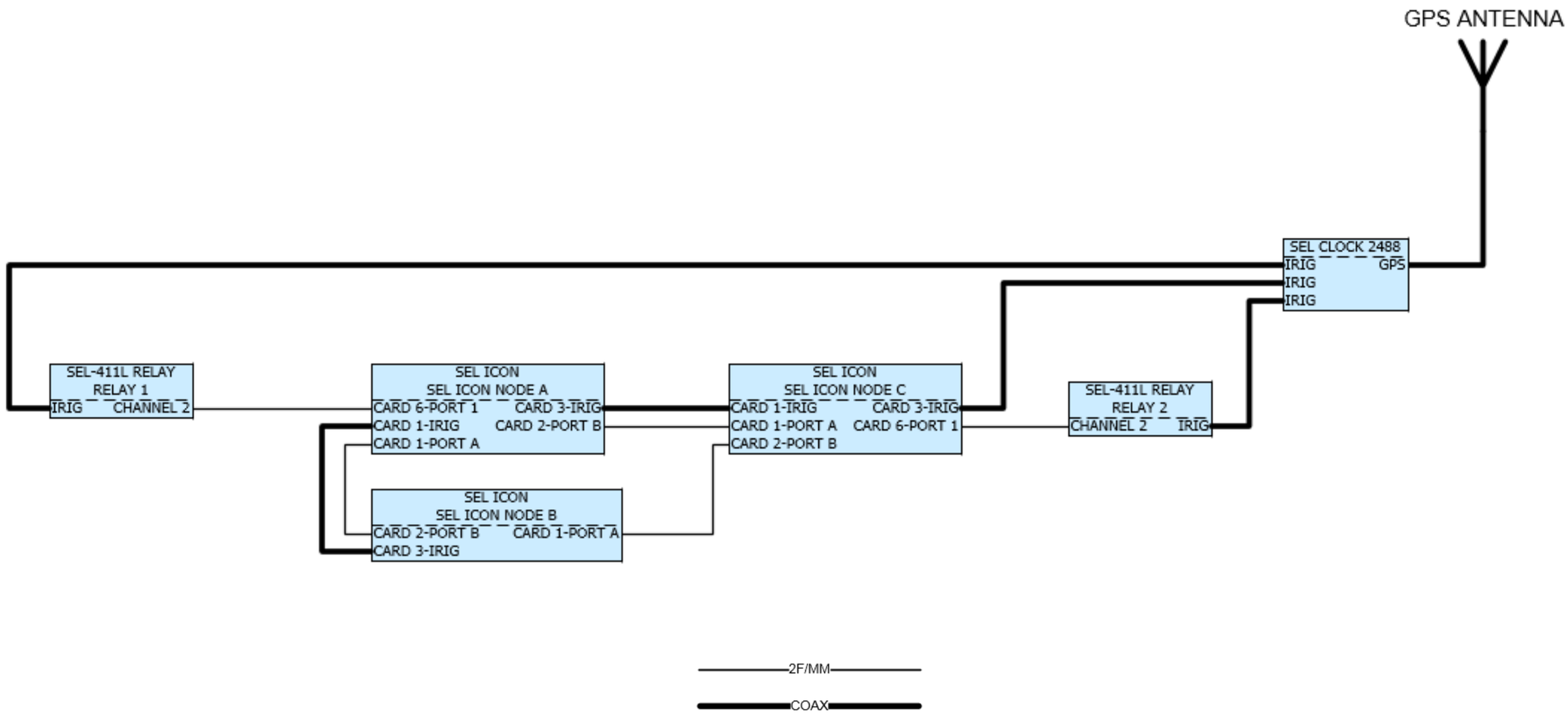
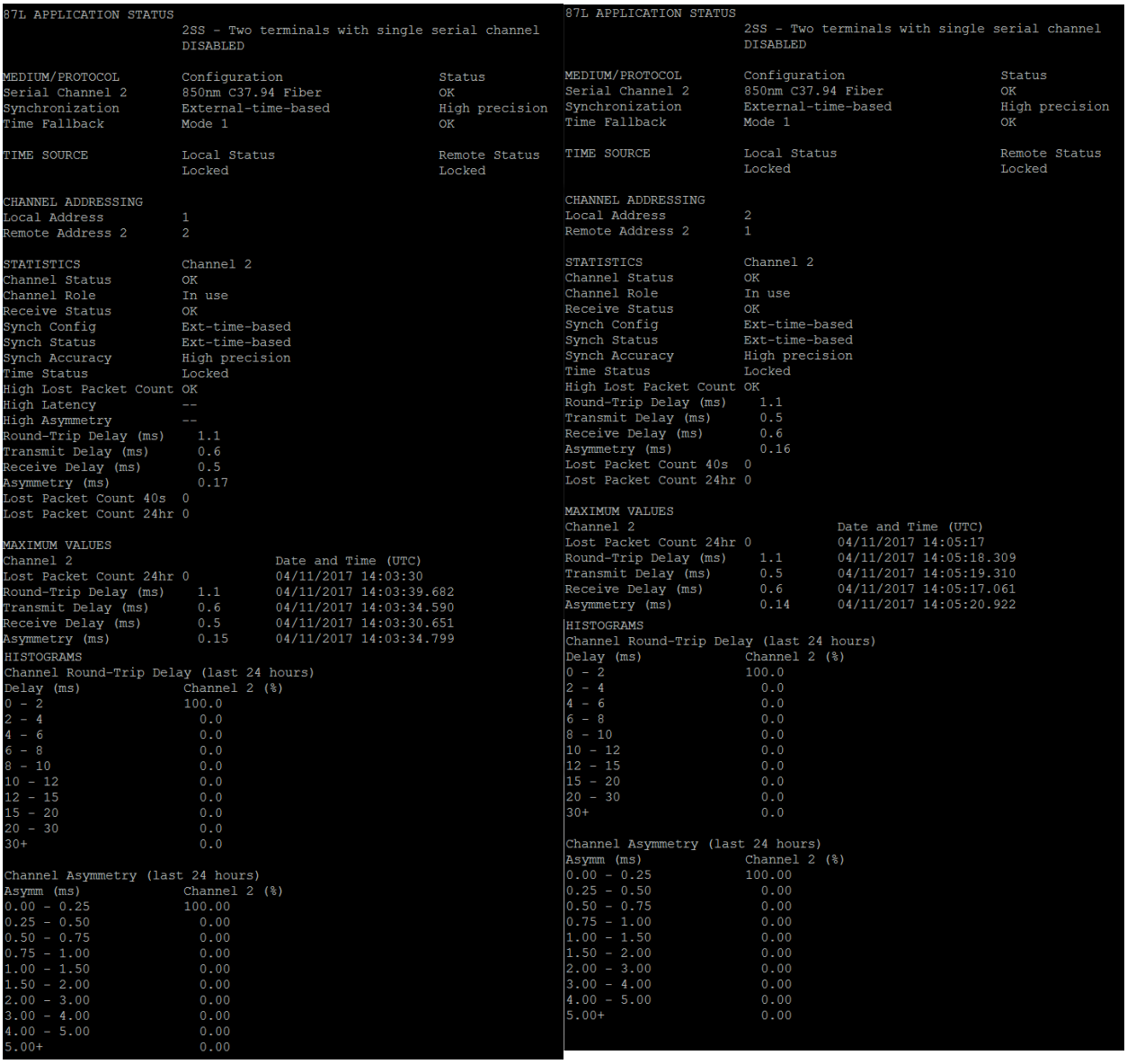


Figure 6-3 – ICON Baseline Test Setup



```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial channel
                    DISABLED

MEDIUM/PROTOCOL     Configuration                 Status
Serial Channel 2    850nm C37.94 Fiber            OK
Synchronization     External-time-based           High precision
Time Fallback       Mode 1                        OK

TIME SOURCE         Local Status                  Remote Status
                    Locked                        Locked

CHANNEL ADDRESSING
Local Address       1
Remote Address 2    2

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)    1.1
Transmit Delay (ms)      0.6
Receive Delay (ms)       0.5
Asymmetry (ms)           0.17
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                       Date and Time (UTC)
Lost Packet Count 24hr 0        04/11/2017 14:03:30
Round-Trip Delay (ms)    1.1    04/11/2017 14:03:39.682
Transmit Delay (ms)      0.6    04/11/2017 14:03:34.590
Receive Delay (ms)       0.5    04/11/2017 14:03:30.651
Asymmetry (ms)           0.15   04/11/2017 14:03:34.799
HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial channel
                    DISABLED

MEDIUM/PROTOCOL     Configuration                 Status
Serial Channel 2    850nm C37.94 Fiber            OK
Synchronization     External-time-based           High precision
Time Fallback       Mode 1                        OK

TIME SOURCE         Local Status                  Remote Status
                    Locked                        Locked

CHANNEL ADDRESSING
Local Address       2
Remote Address 2    1

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
Round-Trip Delay (ms)    1.1
Transmit Delay (ms)      0.5
Receive Delay (ms)       0.6
Asymmetry (ms)           0.16
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                       Date and Time (UTC)
Lost Packet Count 24hr 0        04/11/2017 14:05:17
Round-Trip Delay (ms)    1.1    04/11/2017 14:05:18.309
Transmit Delay (ms)      0.5    04/11/2017 14:05:19.310
Receive Delay (ms)       0.6    04/11/2017 14:05:17.061
Asymmetry (ms)           0.14   04/11/2017 14:05:20.922
HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

Figure 6-4 – ICON Baseline Raw Data

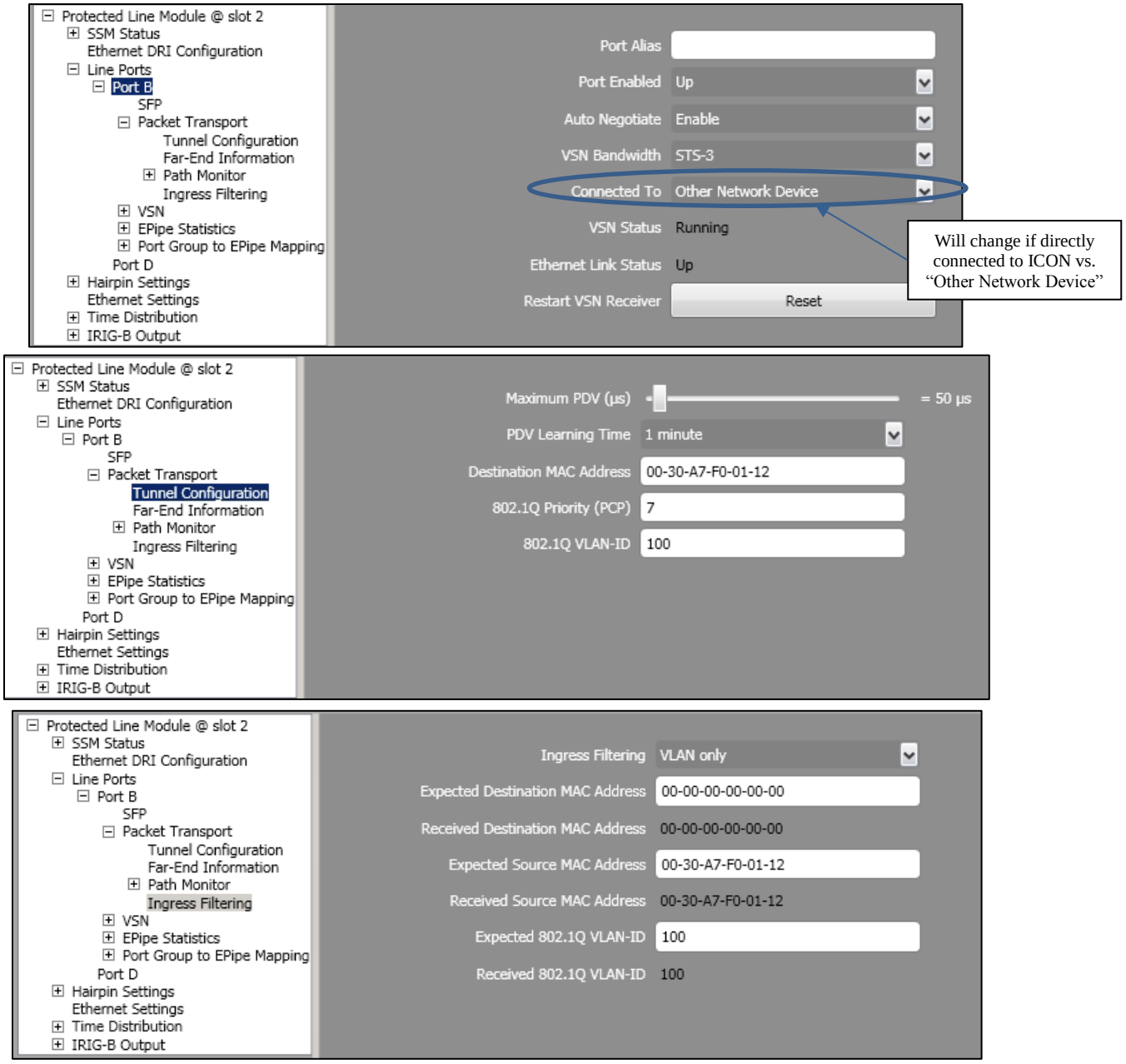


Figure 6-5 – Basic Line Port ICON Settings

6.3 ICON Integrated with Core Network Baseline Test

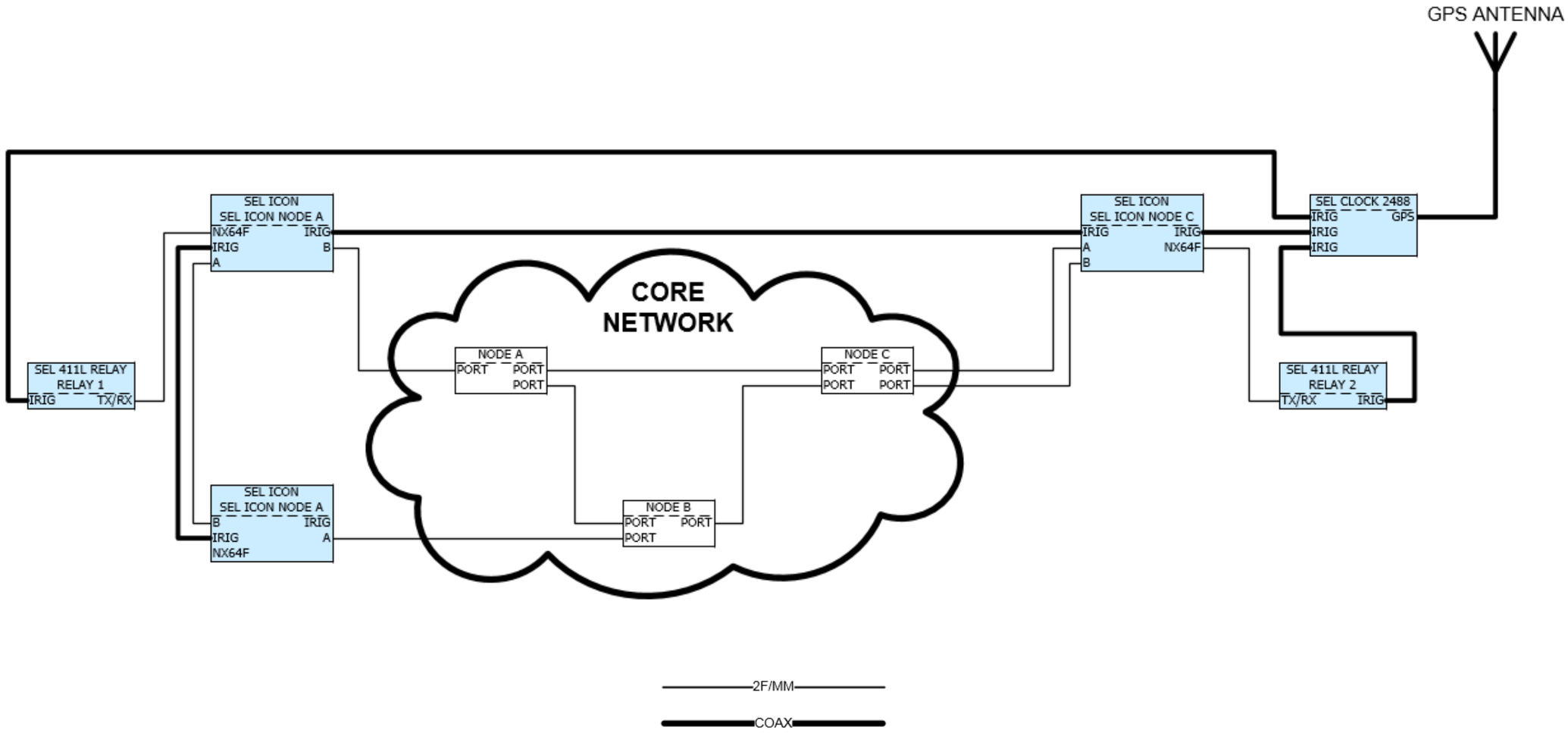


Figure 6-6 – ICON/Nokia & Ciena Network Baseline Test Setup

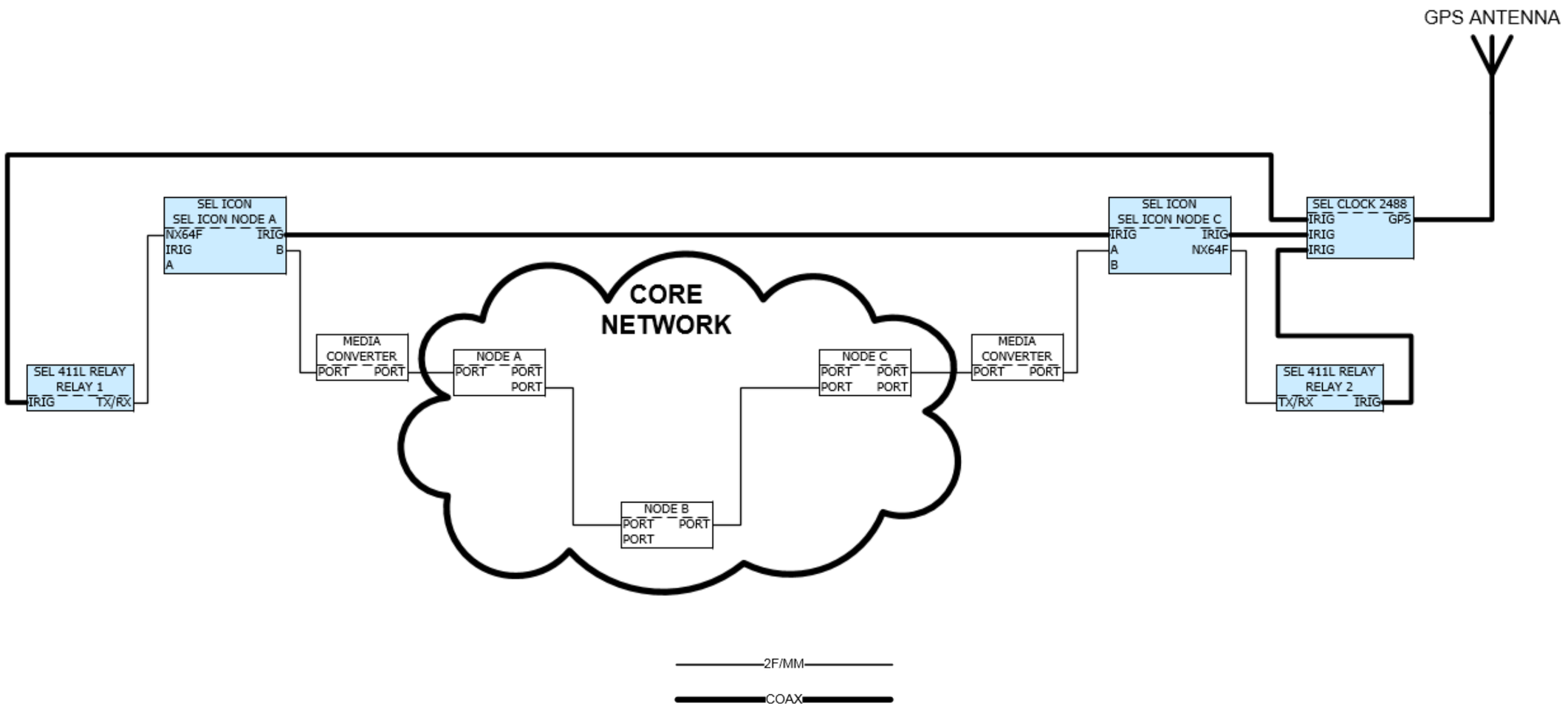
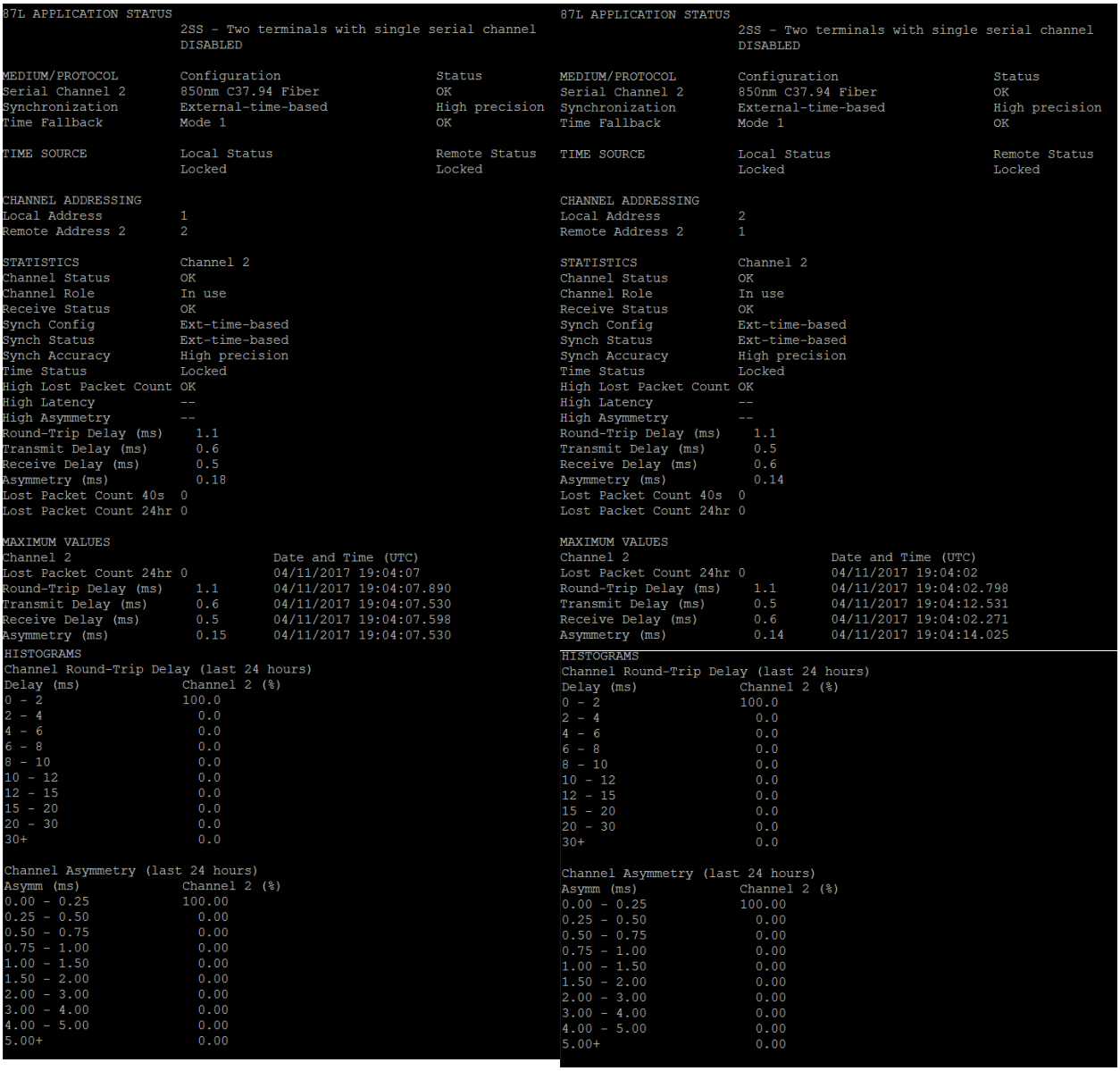


Figure 6-7 – ICON/Cisco Network Baseline Test Setup



87L APPLICATION STATUS

	2SS - Two terminals with single serial channel	
	DISABLED	
MEDIUM/PROTOCOL	Configuration	Status
Serial Channel 2	850nm C37.94 Fiber	OK
Synchronization	External-time-based	High precision
Time Fallback	Mode 1	OK
TIME SOURCE	Local Status	Remote Status
	Locked	Locked

CHANNEL ADDRESSING	
Local Address	1
Remote Address 2	2
STATISTICS	Channel 2
Channel Status	OK
Channel Role	In use
Receive Status	OK
Synch Config	Ext-time-based
Synch Status	Ext-time-based
Synch Accuracy	High precision
Time Status	Locked
High Lost Packet Count	OK
High Latency	--
High Asymmetry	--
Round-Trip Delay (ms)	1.1
Transmit Delay (ms)	0.6
Receive Delay (ms)	0.5
Asymmetry (ms)	0.18
Lost Packet Count 40s	0
Lost Packet Count 24hr	0

MAXIMUM VALUES

Channel 2		Date and Time (UTC)
Lost Packet Count 24hr	0	04/11/2017 19:04:07
Round-Trip Delay (ms)	1.1	04/11/2017 19:04:07.890
Transmit Delay (ms)	0.6	04/11/2017 19:04:07.530
Receive Delay (ms)	0.5	04/11/2017 19:04:07.598
Asymmetry (ms)	0.15	04/11/2017 19:04:07.530

HISTOGRAMS

Channel Round-Trip Delay (last 24 hours)

Delay (ms)	Channel 2 (%)
0 - 2	100.0
2 - 4	0.0
4 - 6	0.0
6 - 8	0.0
8 - 10	0.0
10 - 12	0.0
12 - 15	0.0
15 - 20	0.0
20 - 30	0.0
30+	0.0

Channel Asymmetry (last 24 hours)

Asymm (ms)	Channel 2 (%)
0.00 - 0.25	100.00
0.25 - 0.50	0.00
0.50 - 0.75	0.00
0.75 - 1.00	0.00
1.00 - 1.50	0.00
1.50 - 2.00	0.00
2.00 - 3.00	0.00
3.00 - 4.00	0.00
4.00 - 5.00	0.00
5.00+	0.00

87L APPLICATION STATUS

	2SS - Two terminals with single serial channel	
	DISABLED	
MEDIUM/PROTOCOL	Configuration	Status
Serial Channel 2	850nm C37.94 Fiber	OK
Synchronization	External-time-based	High precision
Time Fallback	Mode 1	OK
TIME SOURCE	Local Status	Remote Status
	Locked	Locked

CHANNEL ADDRESSING	
Local Address	2
Remote Address 2	1
STATISTICS	Channel 2
Channel Status	OK
Channel Role	In use
Receive Status	OK
Synch Config	Ext-time-based
Synch Status	Ext-time-based
Synch Accuracy	High precision
Time Status	Locked
High Lost Packet Count	OK
High Latency	--
High Asymmetry	--
Round-Trip Delay (ms)	1.1
Transmit Delay (ms)	0.5
Receive Delay (ms)	0.6
Asymmetry (ms)	0.14
Lost Packet Count 40s	0
Lost Packet Count 24hr	0

MAXIMUM VALUES

Channel 2		Date and Time (UTC)
Lost Packet Count 24hr	0	04/11/2017 19:04:02
Round-Trip Delay (ms)	1.1	04/11/2017 19:04:02.798
Transmit Delay (ms)	0.5	04/11/2017 19:04:12.531
Receive Delay (ms)	0.6	04/11/2017 19:04:02.271
Asymmetry (ms)	0.14	04/11/2017 19:04:14.025

HISTOGRAMS

Channel Round-Trip Delay (last 24 hours)

Delay (ms)	Channel 2 (%)
0 - 2	100.0
2 - 4	0.0
4 - 6	0.0
6 - 8	0.0
8 - 10	0.0
10 - 12	0.0
12 - 15	0.0
15 - 20	0.0
20 - 30	0.0
30+	0.0

Channel Asymmetry (last 24 hours)

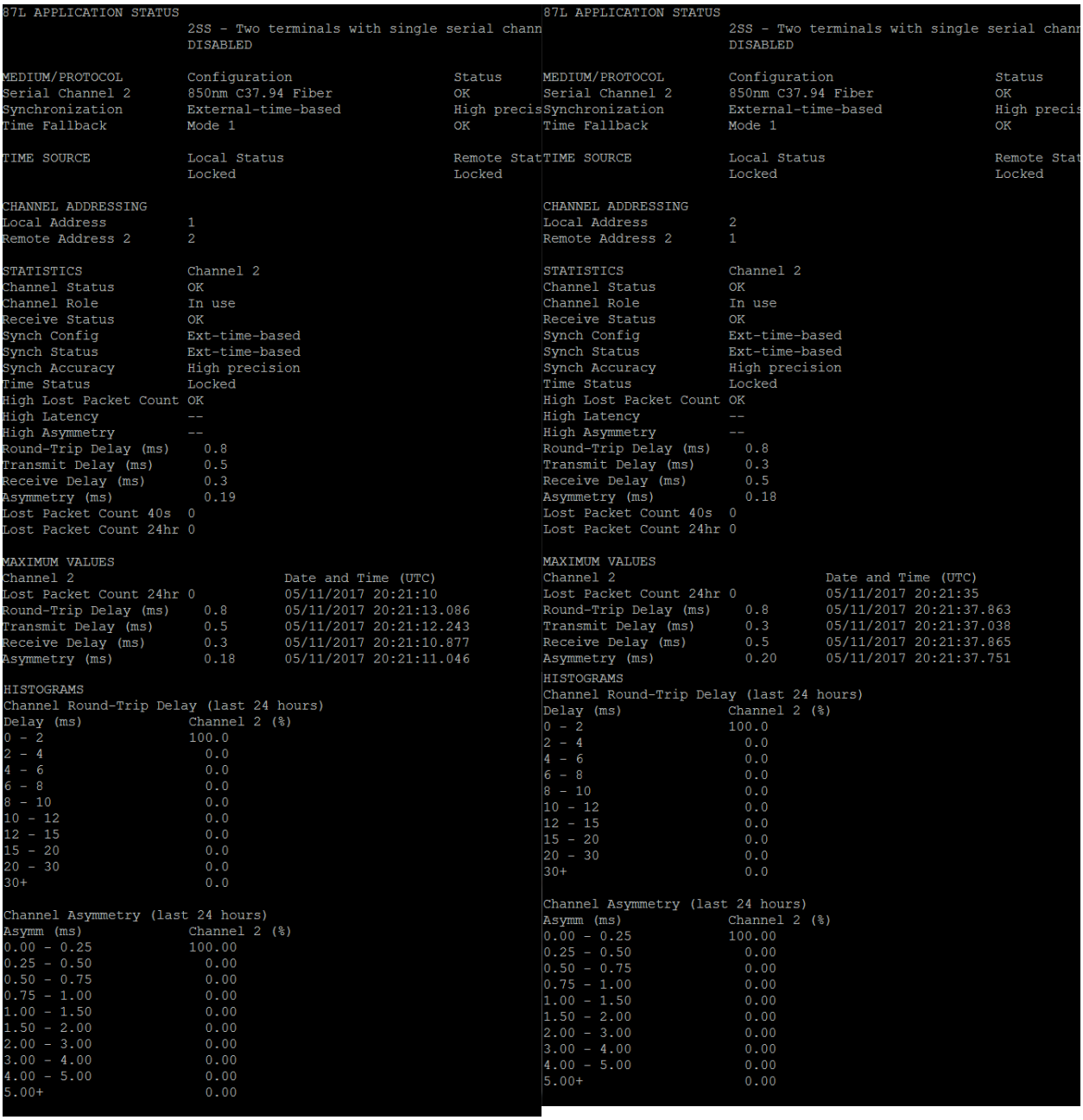
Asymm (ms)	Channel 2 (%)
0.00 - 0.25	100.00
0.25 - 0.50	0.00
0.50 - 0.75	0.00
0.75 - 1.00	0.00
1.00 - 1.50	0.00
1.50 - 2.00	0.00
2.00 - 3.00	0.00
3.00 - 4.00	0.00
4.00 - 5.00	0.00
5.00+	0.00

Figure 6-8 – Nokia Network Baseline Raw Data

```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial channel
                    DISABLED

MEDIUM/PROTOCOL     Configuration                Status
Serial Channel 2    850nm C37.94 Fiber           OK
Synchronization     External-time-based          High precision
Time Fallback       Mode 1                       OK

TIME SOURCE         Local Status                 Remote Status
                    Locked                       Locked

CHANNEL ADDRESSING
Local Address       1
Remote Address 2    2

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)   1.0
Transmit Delay (ms)     0.5
Receive Delay (ms)      0.5
Asymmetry (ms)          0.04
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                       Date and Time (UTC)
Lost Packet Count 24hr 0        04/12/2017 19:02:48
Round-Trip Delay (ms)    1.0    04/12/2017 19:02:52.670
Transmit Delay (ms)      0.5    04/12/2017 19:02:51.513
Receive Delay (ms)       0.5    04/12/2017 19:02:48.826
Asymmetry (ms)           0.03   04/12/2017 19:02:48.743
HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial channel
                    DISABLED

MEDIUM/PROTOCOL     Configuration                Status
Serial Channel 2    850nm C37.94 Fiber           OK
Synchronization     External-time-based          High precision
Time Fallback       Mode 1                       OK

TIME SOURCE         Local Status                 Remote Status
                    Locked                       Locked

CHANNEL ADDRESSING
Local Address       2
Remote Address 2    1

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)   1.0
Transmit Delay (ms)     0.5
Receive Delay (ms)      0.5
Asymmetry (ms)          0.02
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                       Date and Time (UTC)
Lost Packet Count 24hr 0        04/12/2017 19:02:52
Round-Trip Delay (ms)    1.0    04/12/2017 19:02:52.262
Transmit Delay (ms)      0.5    04/12/2017 19:02:53.254
Receive Delay (ms)       0.5    04/12/2017 19:02:52.187
Asymmetry (ms)           0.00   04/12/2017 19:02:52.187

HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

Figure 6-9 – Ciena Network Baseline Raw Data



```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial chann
                    DISABLED

MEDIUM/PROTOCOL     Configuration                 Status
Serial Channel 2    850nm C37.94 Fiber            OK
Synchronization     External-time-based           High precis
Time Fallback       Mode 1                        OK

TIME SOURCE         Local Status                  Remote Stat
                    Locked                        Locked

CHANNEL ADDRESSING
Local Address       1
Remote Address 2    2

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)   0.8
Transmit Delay (ms)     0.5
Receive Delay (ms)      0.3
Asymmetry (ms)          0.19
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                       Date and Time (UTC)
Lost Packet Count 24hr 0        05/11/2017 20:21:10
Round-Trip Delay (ms)    0.8    05/11/2017 20:21:13.086
Transmit Delay (ms)      0.5    05/11/2017 20:21:12.243
Receive Delay (ms)       0.3    05/11/2017 20:21:10.877
Asymmetry (ms)           0.18   05/11/2017 20:21:11.046

HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

```
87L APPLICATION STATUS
                    2SS - Two terminals with single serial chann
                    DISABLED

MEDIUM/PROTOCOL     Configuration                 Status
Serial Channel 2    850nm C37.94 Fiber            OK
Synchronization     External-time-based           High precis
Time Fallback       Mode 1                        OK

TIME SOURCE         Local Status                  Remote Stat
                    Locked                        Locked

CHANNEL ADDRESSING
Local Address       2
Remote Address 2    1

STATISTICS          Channel 2
Channel Status      OK
Channel Role        In use
Receive Status      OK
Synch Config        Ext-time-based
Synch Status        Ext-time-based
Synch Accuracy      High precision
Time Status         Locked
High Lost Packet Count OK
High Latency        --
High Asymmetry      --
Round-Trip Delay (ms)   0.8
Transmit Delay (ms)     0.3
Receive Delay (ms)      0.5
Asymmetry (ms)          0.18
Lost Packet Count 40s  0
Lost Packet Count 24hr 0

MAXIMUM VALUES
Channel 2                       Date and Time (UTC)
Lost Packet Count 24hr 0        05/11/2017 20:21:35
Round-Trip Delay (ms)    0.8    05/11/2017 20:21:37.863
Transmit Delay (ms)      0.3    05/11/2017 20:21:37.038
Receive Delay (ms)       0.5    05/11/2017 20:21:37.865
Asymmetry (ms)           0.20   05/11/2017 20:21:37.751

HISTOGRAMS
Channel Round-Trip Delay (last 24 hours)
Delay (ms)          Channel 2 (%)
0 - 2               100.0
2 - 4                 0.0
4 - 6                 0.0
6 - 8                 0.0
8 - 10                0.0
10 - 12               0.0
12 - 15               0.0
15 - 20               0.0
20 - 30               0.0
30+                   0.0

Channel Asymmetry (last 24 hours)
Asymm (ms)          Channel 2 (%)
0.00 - 0.25         100.00
0.25 - 0.50           0.00
0.50 - 0.75           0.00
0.75 - 1.00           0.00
1.00 - 1.50           0.00
1.50 - 2.00           0.00
2.00 - 3.00           0.00
3.00 - 4.00           0.00
4.00 - 5.00           0.00
5.00+                 0.00
```

Figure 6-10 – Cisco Network Baseline Raw Data

6.4 ICON Failover Tests

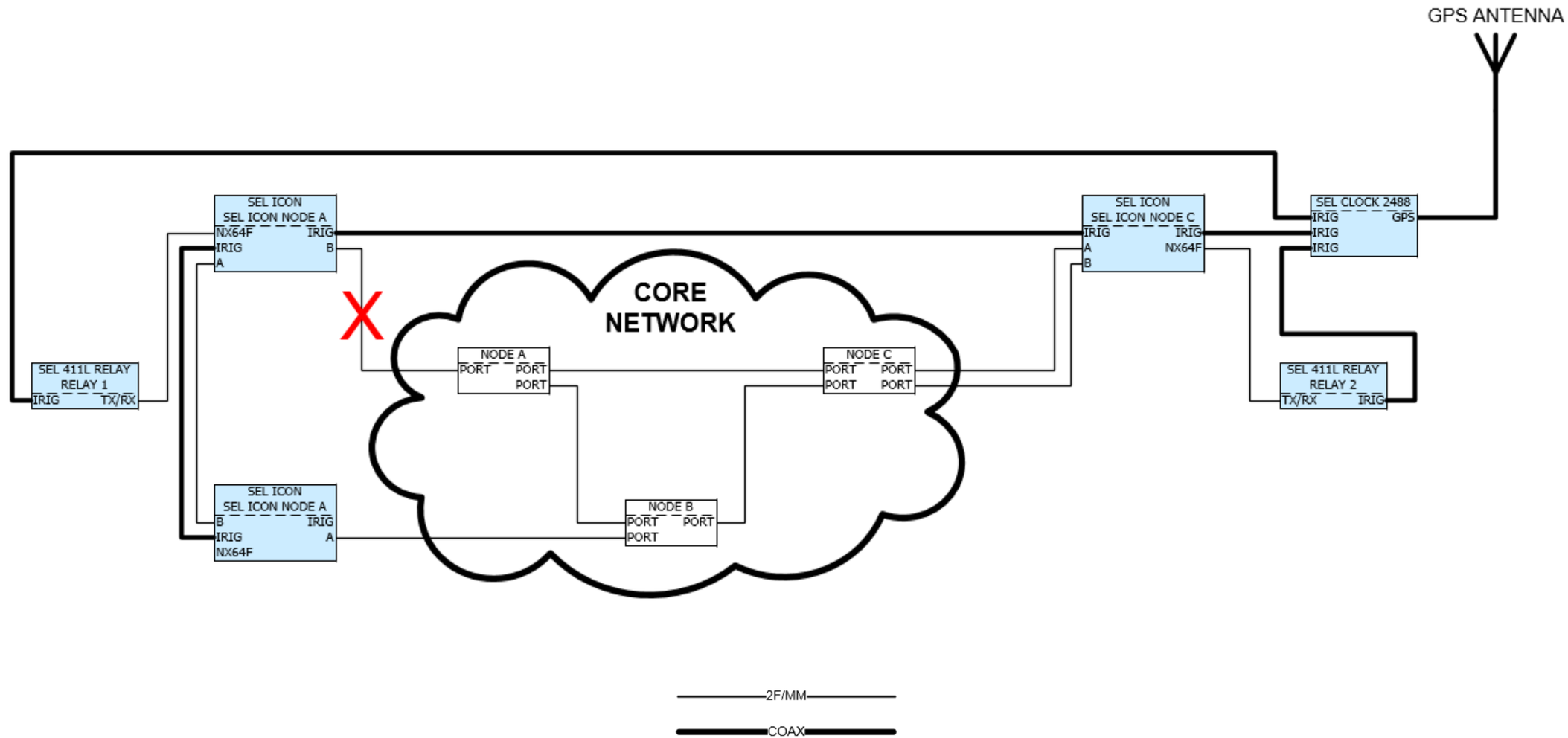


Figure 6-11 – ICON Failover Test Setup

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	87L
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	
Asymmetry (ms)	0.15	0.15	
Lost Packet Count	0	1	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	*	*	87L
Transmit Delay (ms)	*	*	
Receive Delay (ms)	*	*	
Asymmetry (ms)	*	*	
Lost Packet Count	4	0	
SER	0	0	

* COM statistics not cleared

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	87L
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	
Asymmetry (ms)	0.15	0.15	
Lost Packet Count	3	0	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	87L
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	
Asymmetry (ms)	0.17	0.15	
Lost Packet Count	3	1	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	87L
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.5	0.5	
Asymmetry (ms)	0.05	0.02	
Lost Packet Count	3	0	
SER	0	0	

Figure 6-12 – ICON Failover Test Results (Nokia)

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	87L
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.5	0.5	
Asymmetry (ms)	0.03	0.02	
Lost Packet Count	4	0	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	87L
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.5	0.5	
Asymmetry (ms)	0.05	0.02	
Lost Packet Count	1	0	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	87L
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.5	0.5	
Asymmetry (ms)	0.03	0.02	
Lost Packet Count	5	0	
SER	1*	0	

*** 8.5 millisecond failover time detected

	Relay 1	Relay 2	
Round-Trip Delay (ms)	0.9	0.8	87L
Transmit Delay (ms)	0.4	0.5	
Receive Delay (ms)	0.5	0.4	
Asymmetry (ms)	0.08	0.11	
Lost Packet Count	1	2	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	0.8	0.8	87L
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.4	0.4	
Asymmetry (ms)	0.08	0.12	
Lost Packet Count	1	0	
SER	0	0	

```
  DATE         TIME             ELEMENT              STATE
04/12/2017   19:29:48.0526   87CH2OK              Deasserted
04/12/2017   19:29:48.0611   87CH2OK              Asserted
```

***

Figure 6-13 – ICON Failover Test Results (Ciena)

6.5 Congestion and Priority Tests

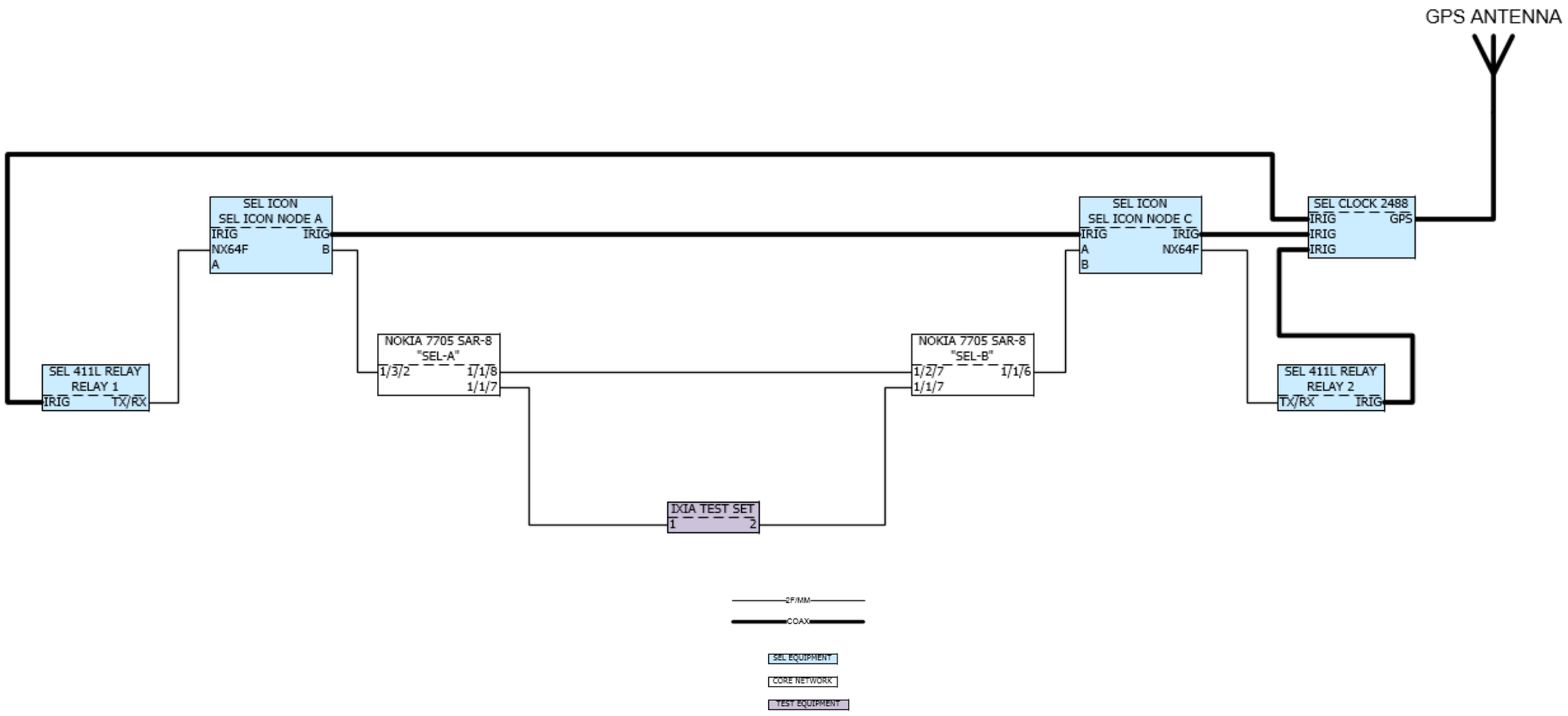


Figure 6-14 – Nokia MPLS Network

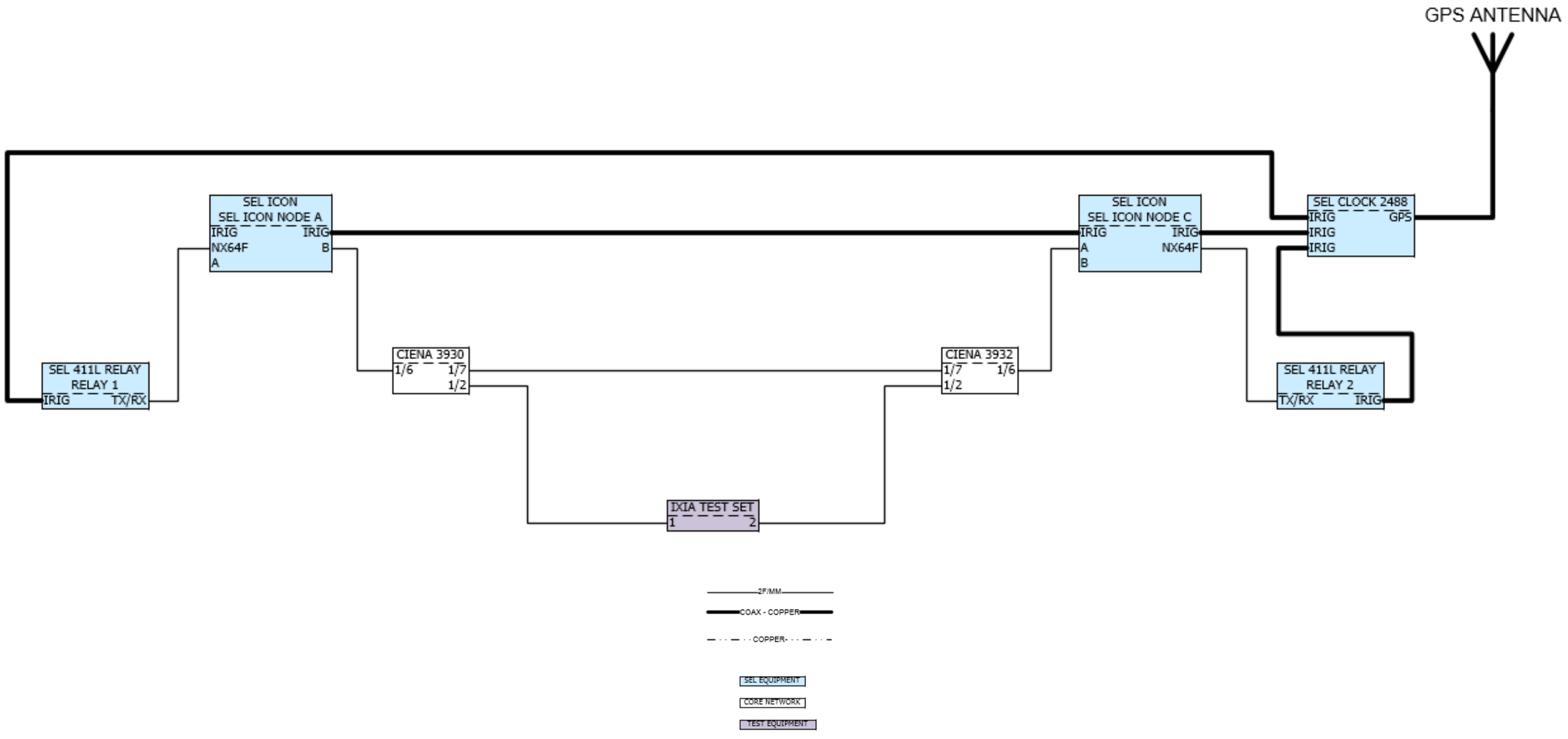


Figure 6-15 – Ciena Carrier Ethernet Network

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