



# SEL ICON VSN Interoperability Test Report



## **Schweitzer Engineering Laboratories**

SEL ICON VSN Interoperability Test Report Project No. 98030

> Revision 0 8/28/2017

## SEL ICON VSN Interoperability Test Report

prepared for

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

Project No. 98030

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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 packetbased utility networks and measure their performance over the core networks. The following tests have been conducted:

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- 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.

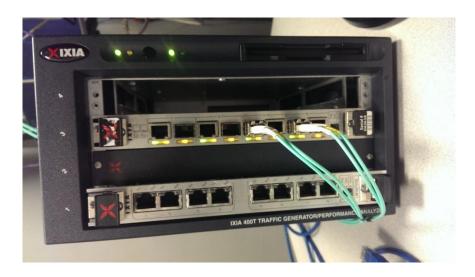
- 1. (2) SEL-411L Relays
- 2. (3) SEL ICON's
- 3. (3) Nokia 7705 SAR-8 MPLS Routers
- 4. (3) Ciena Carrier Ethernet Switches Ciena 3930, Ciena 3932, Ciena 5142
- 5. (2) Cisco ASR-903 Routers
- 6. (1) Cisco Catalyst 6509-E Switch
- 7. (1) IXIA Traffic Generator
- 8. (1) GPS Antenna
- 9. (2) Transition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

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#### 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	
Transmit Delay (ms)	0.0	0.0	87L
Receive Delay (ms)	0.0	0.0	0/L
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	
Transmit Delay (ms)	0.6	0.5	87L
Receive Delay (ms)	0.5	0.6	0/L
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.

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	Nokia		
	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	
Transmit Delay (ms)	0.6	0.5	87L
Receive Delay (ms)	0.5	0.6	071
Asymmetry (ms)	0.18	0.14	
	Ci	ena	
	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	
Transmit Delay (ms)	0.5	0.5	87L
Receive Delay (ms)	0.5	0.5	071
Asymmetry (ms)	0.04	0.02	
	С	isco	
	Relay 1	Relay 2	
Round-Trip Delay (ms)	0.8	0.8	
Transmit Delay (ms)	0.5	0.3	87L
Receive Delay (ms)	0.3	0.5	0/L
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 <i>n</i> OK ( <i>n</i> = 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.
	87CHnLX ( <i>n</i> = 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	
Transmit Delay Avg. (ms)	0.6	0.5	
Receive Delay Avg. (ms)	0.5	0.6	
Asymmetry Avg. (ms)	0.13	0.12	87L
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	
Transmit Delay Avg. (ms)	0.5	0.5	
Receive Delay Avg. (ms)	0.5	0.5	
Asymmetry Avg. (ms)	0.05	0.06	87L
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.

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V	/eighted Random Frame	Size			
	Random Mode				
	Uniform Distribution				
	C Weight Pairs	Min.	70		
	C Predefined Distributions	Max.	1,500		
	🔿 Quad Gaussian				
				ОК	Cancel

#### 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

		Latency	Latency Max	
ICON Software	Missed Packets	Min (µs)	(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

		Latency Min	Latency Max	
ICON Software	Missed Packets	(μs)	(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.

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

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

		Latency Min	Latency Max	
ICON Software	Missed Packets	(μs)	(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				87L APPLICATION STATUS			
		erminals with single	serial channel			erminals with single	serial channel
	DISABLED				DISABLED		
MEDIUM/PROTOCOL	Configurati		Status	MEDIUM/PROTOCOL	Configurati		Status
Serial Channel 2	850nm C37.9		OK	Serial Channel 2 Synchronization	850nm C37.9 External-ti		OK High precision
Synchronization	External-ti	me-pased	High precision	Synchronization Time Fallback	Mode 1	me-based	OK
Time Fallback	Mode 1		OK	TIME Fallback	Houe I		ON
TIME SOURCE	Local Statu	10	Remote Status	TIME SOURCE	Local Statu	g	Remote Status
	Locked		Locked		Locked		Locked
CHANNEL ADDRESSING				CHANNEL ADDRESSING			
Local Address				Local Address			
Remote Address 2				Remote Address 2			
				STATISTICS	Channel 2		
STATISTICS	Channel 2			Channel Status	OK		
Channel Status Channel Role	OK In use			Channel Role	In use		
Receive Status	OK USE			Receive Status	OK		
Synch Config	Ext-time-ba	ised		Synch Config	Ext-time-ba	sed	
Synch Status	Ext-time-ba			Synch Status	Ext-time-ba		
Synch Accuracy	High precis			Synch Accuracy	High precis		
Time Status	Locked			Time Status	Locked		
High Lost Packet Count				High Lost Packet Count			
High Latency				High Latency			
High Asymmetry				High Asymmetry			
Round-Trip Delay (ms)				Round-Trip Delay (ms)			
Transmit Delay (ms)	0.0			Transmit Delay (ms)	0.0		
Receive Delay (ms)	0.0			Receive Delay (ms)	0.0 0.01		
Asymmetry (ms)				Asymmetry (ms) Lost Packet Count 40s			
Lost Packet Count 40s Lost Packet Count 24hr				Lost Packet Count 403			
Host Facket Count 24hr				rabiet count 24m			
MAXIMUM VALUES				MAXIMUM VALUES			
Channel 2		Date and Time (UTC)		Channel 2		Date and Time (UTC)	
Lost Packet Count 24hr		04/10/2017 20:29:45		Lost Packet Count 24hr		04/10/2017 20:30:27	
Round-Trip Delay (ms)		04/10/2017 20:30:18.		Round-Trip Delay (ms)		04/10/2017 20:31:12.	
Transmit Delay (ms)		04/10/2017 20:30:18.		Transmit Delay (ms)		04/10/2017 20:30:42.	
Receive Delay (ms)	0.0	04/10/2017 20:30:08.		Receive Delay (ms)	0.0	04/10/2017 20:30:42. 04/10/2017 20:31:14.	
Asymmetry (ms)		04/10/2017 20:30:08.	821	Asymmetry (ms)	0.02	04/10/201/ 20:31:14.	313
HISTOGRAMS				HISTOGRAMS			
Channel Round-Trip Del				Channel Round-Trip Dela	av (last 24	hours)	
Delay (ms)	Channel 2	(%)		Delay (ms)	Channel 2 (		
0 - 2	100.0			0 - 2	100.0		
2 - 4							
4 - 6 6 - 8	0.0						
6 - 8 8 - 10	0.0						
10 - 12	0.0						
10 - 12 12 - 15	0.0			10 - 12	0.0		
15 - 20	0.0			12 - 15			
20 - 30				15 - 20			
30+				20 - 30 30+	0.0		
				301	0.0		
Channel Asymmetry (las				Channel Asymmetry (last	z 24 hours)		
Asymm (ms)	Channel 2	(%)		Asymm (ms)	Channel 2 (	응)	
0.00 - 0.25	100.00			0.00 - 0.25	100.00		
0.25 - 0.50 0.50 - 0.75	0.00			0.25 - 0.50			
0.50 = 0.75 0.75 = 1.00	0.00						
1.00 - 1.50	0.00						
1.50 - 2.00	0.00			1.00 - 1.50	0.00		
2.00 - 3.00	0.00			1.50 - 2.00	0.00		
3.00 - 4.00	0.00			2.00 - 3.00	0.00		
4.00 - 5.00				3.00 - 4.00 4.00 - 5.00	0.00		
5.00+				4.00 - 5.00 5.00+	0.00		
				3.001	0.00		

#### Figure 6-2 – Direct Fiber Raw Data

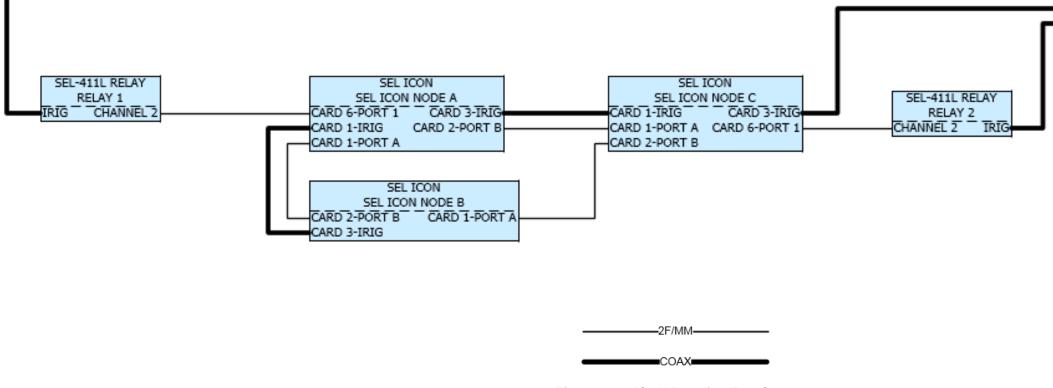
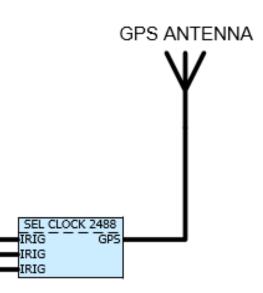


Figure 6-3 – ICON Baseline Test Setup



071 300110-00				87L APPLICATION STATUS			
87L APPLICATION STATUS		erminals with single	serial channel	OTE APPLICATION STATUS		erminals with singl	e serial channel
MEDIUM/PROTOCOL	Configurati	on	Status	MEDIUM/PROTOCOL	Configurati	on	Status
Serial Channel 2	850nm C37.9		OK	Serial Channel 2	850nm C37.9		OK
Synchronization	External-ti	me-based	High precision	Synchronization	External-ti	me-based	High precision
Time Fallback	Mode 1		OK	Time Fallback	Mode 1		OK
TIME SOURCE	Local Statu		Remote Status	TIME SOURCE	Local Statu	q	Remote Status
TIME SOURCE	Locked	15	Locked	THE SOURCE	Locked		Locked
	HOCKCO		HOCKCU				
CHANNEL ADDRESSING				CHANNEL ADDRESSING			
Local Address				Local Address			
Remote Address 2				Remote Address 2			
STATISTICS	Channel 2			STATISTICS	Channel 2		
Channel Status	OK			Channel Status	OK		
Channel Role	In use			Channel Role	In use		
Receive Status	OK			Receive Status	OK		
Synch Config Synch Status	Ext-time-ba Ext-time-ba			Synch Config Synch Status	Ext-time-ba Ext-time-ba		
Synch Status Synch Accuracy	High precis			Synch Accuracy	High precis		
Time Status	Locked			Time Status	Locked		
High Lost Packet Count	: OK			High Lost Packet Count			
High Latency				Round-Trip Delay (ms)			
High Asymmetry				Transmit Delay (ms) Receive Delay (ms)	0.5		
Round-Trip Delay (ms) Transmit Delay (ms)	1.1 0.6			Asymmetry (ms)	0.16		
Receive Delay (ms)	0.5			Lost Packet Count 40s			
Asymmetry (ms)	0.17			Lost Packet Count 24hr			
Lost Packet Count 40s				MAXIMUM VALUES			
Lost Packet Count 24hr	r 0			Channel 2		Date and Time (UTC	)
MAXIMUM VALUES				Lost Packet Count 24hr		04/11/2017 14:05:1	
Channel 2		Date and Time (UTC)		Round-Trip Delay (ms)		04/11/2017 14:05:1	
Lost Packet Count 24hr		04/11/2017 14:03:30		Transmit Delay (ms)		04/11/2017 14:05:1	
Round-Trip Delay (ms)		04/11/2017 14:03:39.		Receive Delay (ms) Asymmetry (ms)	0.6 0.14	04/11/2017 14:05:1 04/11/2017 14:05:2	
Transmit Delay (ms) Receive Delay (ms)	0.6 0.5	04/11/2017 14:03:34 04/11/2017 14:03:30			0.14	04/11/201/ 14.05.2	0.922
Asymmetry (ms)	0.15	04/11/2017 14:03:34		HISTOGRAMS Channel Round-Trip Del	av (last 24	hours)	
HISTOGRAMS				Delay (ms)	Channel 2 (		
Channel Round-Trip Del	lay (last 24	hours)		0 - 2			
Delay (ms)	Channel 2	(%)		2 - 4			
0 - 2 2 - 4	100.0			4 - 6 6 - 8	0.0		
2 - 4 4 - 6	0.0			6 - 8 8 - 10	0.0		
4 - 0 6 - 8	0.0			10 - 12	0.0		
8 - 10				12 - 15			
10 - 12				15 - 20			
12 - 15 15 - 20				20 - 30 30+	0.0		
15 - 20 20 - 30	0.0			301	0.0		
30+				Channel Asymmetry (las	t 24 hours)		
				Asymm (ms)	Channel 2 (	%)	
Channel Asymmetry (las		(8)		0.00 - 0.25	100.00		
Asymm (ms) 0.00 - 0.25	Channel 2 100.00	(*)		0.25 - 0.50 0.50 - 0.75	0.00 0.00		
0.00 = 0.23 0.25 = 0.50	0.00			0.75 - 1.00	0.00		
0.50 - 0.75	0.00			1.00 - 1.50			
0.75 - 1.00				1.50 - 2.00	0.00		
1.00 - 1.50	0.00			2.00 - 3.00	0.00		
1.50 - 2.00 2.00 - 3.00	0.00			3.00 - 4.00 4.00 - 5.00	0.00 0.00		
3.00 - 4.00	0.00			4.00 - 5.00	0.00		
4.00 - 5.00	0.00						
5.00+							

#### Figure 6-4 – ICON Baseline Raw Data

Protected Line Module @ slot 2		
Ethernet DRI Configuration	Port Alias	
Line Ports	Port Enabled Up	
Port B     SFP		۶
□ Packet Transport	Auto Negotiate En	nable 🔽
Tunnel Configuration		
Far-End Information	VSN Bandwidth ST	rs-3 🖌
Path Monitor		
Ingress Filtering	Connected To Ot	ther Network Device
± VSN		
	VSN Status Ru	Will change if directly
Port Group to EPipe Mapping Port D	Ethernet Link Status Up	
Hairpin Settings		"Other Network Device"
Ethernet Settings	Restart VSN Receiver	Reset
<ul> <li>Time Distribution</li> </ul>		
<ul> <li>IRIG-B Output</li> </ul>		
Protected Line Module @ slot 2		
SSM Status		
Ethernet DRI Configuration	Maximum PDV (μs)	= 50 μs
Line Ports		
Port B	PDV Learning Time 1 minut	ite 💌
SFP Packet Transport	Destination MAC Address 00-30-/	A7-F0-01-12
		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Far-End Information	802.1Q Priority (PCP) 7	
Ingress Filtering	802.1Q VLAN-ID 100	
VSN		
<ul> <li>EPipe Statistics</li> <li>Port Group to EPipe Mapping</li> </ul>		
Port D		
Hairpin Settings		
Ethernet Settings		
Time Distribution		
IRIG-B Output		
Protected Line Module @ slot 2		
Protected Line Module @ slot 2     SSM Status		
Ethernet DRI Configuration	Ingress Filtering VLAN	N only 🖌 🖌
Line Ports		
Port B	Expected Destination MAC Address 00-0	00-00-00-00
SFP	Received Destination MAC Address 00-00	0.00.00.00
Packet Transport	Received Destination MAC Address 00-00	0-00-00-00
Tunnel Configuration Far-End Information	Expected Source MAC Address 00-3	30-A7-F0-01-12
Path Monitor		576 TO 01 12
Ingress Filtering	Received Source MAC Address 00-30	0-A7-F0-01-12
VSN		
EPipe Statistics	Expected 802.1Q VLAN-ID 100	
Port Group to EPipe Mapping		
Port D • Hairpin Settings	Received 802.1Q VLAN-ID 100	
Ethernet Settings		
Time Distribution		
IRIG-B Output		

Figure 6-5 – Basic Line Port ICON Settings

6.3 ICON Integrated with Core Network Baseline Test

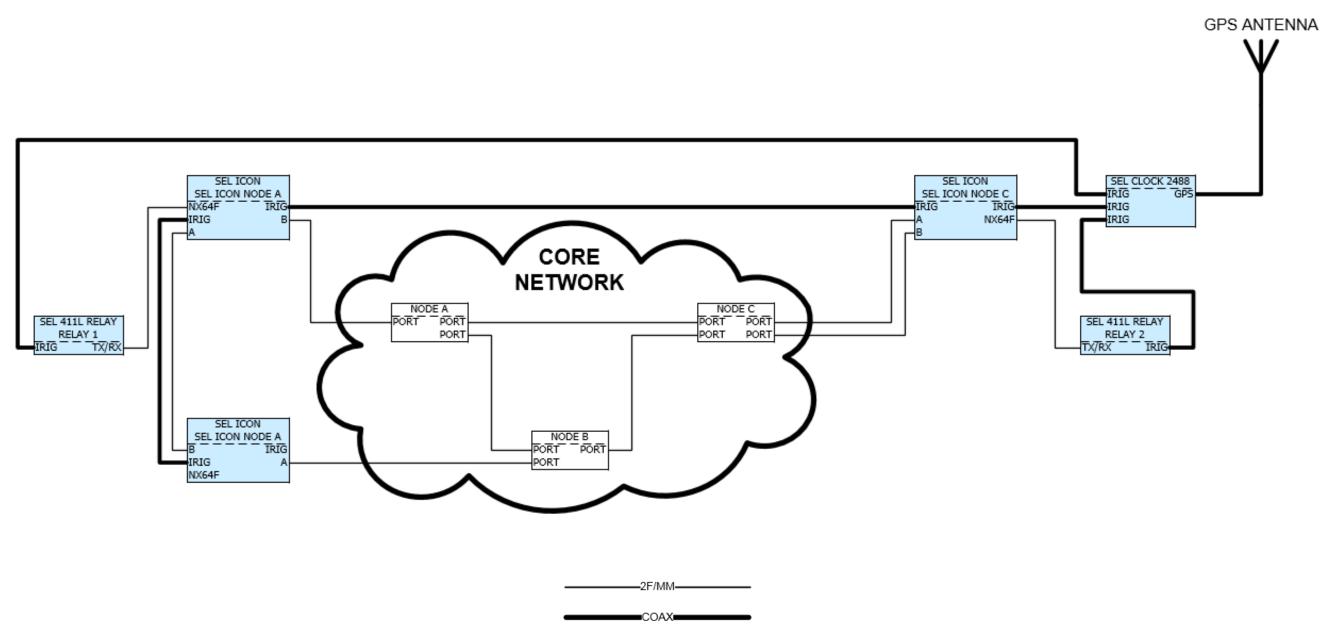


Figure 6-6 – ICON/Nokia & Ciena Network Baseline Test Setup

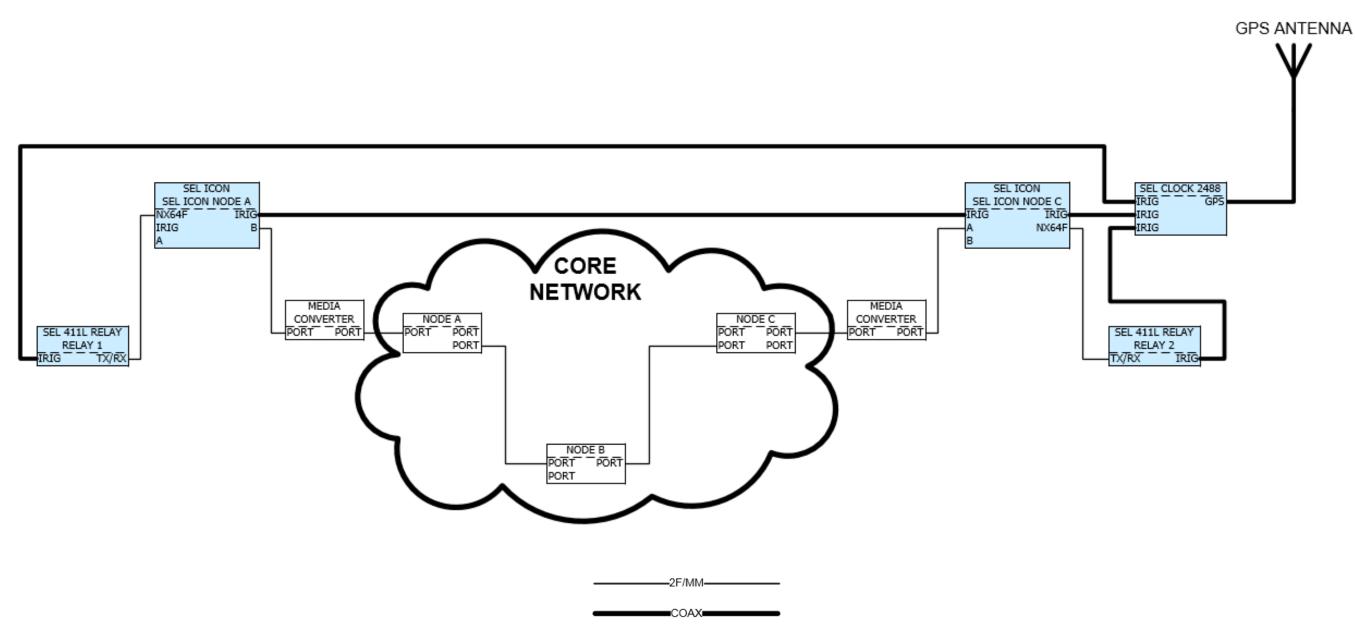


Figure 6-7 – ICON/Cisco Network Baseline Test Setup

Appendix

87L APPLICATION STATUS		erminals with single	serial channel	87L APPLICATION STATUS		erminals with single	e serial channel
MEDIUM/PROTOCOL	Configurati	on	Status	MEDIUM/PROTOCOL	Configurati		Status
Serial Channel 2	850nm C37.9	4 Fiber	OK	Serial Channel 2	850nm C37.9		OK
Synchronization	External-ti	me-based	High precision		External-ti	me-based	High precision
Time Fallback	Mode 1		OK	Time Fallback	Mode 1		OK
TIME SOURCE	Local Statu Locked		Remote Status Locked	TIME SOURCE	Local Statu Locked		Remote Status Locked
CHANNEL ADDRESSING				CHANNEL ADDRESSING			
Local Address				Local Address			
Remote Address 2				Remote Address 2			
STATISTICS	Channel 2			STATISTICS	Channel 2		
Channel Status	OK			Channel Status	OK		
Channel Role	In use			Channel Role	In use		
Receive Status	OK			Receive Status	OK		
Synch Config	Ext-time-ba			Synch Config	Ext-time-ba	sed	
Synch Status	Ext-time-ba			Synch Status	Ext-time-ba	.sed	
Synch Accuracy	High precis			Synch Accuracy	High precis	ion	
Time Status	Locked			Time Status	Locked		
High Lost Packet Count High Latency	: OK			High Lost Packet Count	OK		
High Asymmetry				High Latency High Asymmetry			
Round-Trip Delay (ms)	1.1			Round-Trip Delay (ms)	1.1		
Transmit Delay (ms)	0.6			Transmit Delay (ms)	0.5		
Receive Delay (ms)	0.5			Receive Delay (ms)	0.6		
Asymmetry (ms)	0.18			Asymmetry (ms)	0.14		
Lost Packet Count 40s				Lost Packet Count 40s			
Lost Packet Count 24hr				Lost Packet Count 24hr			
MAXIMUM VALUES				MAXIMUM VALUES			
Channel 2		Date and Time (UTC)		Channel 2		Date and Time (UTC)	
Lost Packet Count 24hr		04/11/2017 19:04:07		Lost Packet Count 24hr		04/11/2017 19:04:02	
Round-Trip Delay (ms)		04/11/2017 19:04:07.		Round-Trip Delay (ms)		04/11/2017 19:04:02	2.798
Transmit Delay (ms)	0.6	04/11/2017 19:04:07.		Transmit Delay (ms)		04/11/2017 19:04:12	
Receive Delay (ms)		04/11/2017 19:04:07.		Receive Delay (ms)	0.6	04/11/2017 19:04:02	
Asymmetry (ms)	0.15	04/11/2017 19:04:07.	530	Asymmetry (ms)	0.14	04/11/2017 19:04:14	.025
HISTOGRAMS Channel Round-Trip Del	law (last 04	hound)		HISTOGRAMS	(2		
Delay (ms)	Channel 2			Channel Round-Trip Del			
0 - 2	100.0	( 6 )		Delay (ms) 0 - 2	Channel 2 ( 100.0	(8)	
2 - 4	0.0			0 - 2 2 - 4	0.0		
4 - 6				4 - 6	0.0		
6 - 8							
8 - 10							
10 - 12				10 - 12			
12 - 15 15 - 20				12 - 15			
15 - 20 20 - 30	0.0			15 - 20	0.0		
20 = 30 30+	0.0			20 - 30 30+	0.0		
				001	0.0		
Channel Asymmetry (las				Channel Asymmetry (las	t 24 hours)		
Asymm (ms)	Channel 2	(*)		Asymm (ms)	Channel 2 (		
0.00 - 0.25 0.25 - 0.50	100.00			0.00 - 0.25	100.00		
0.25 - 0.50 0.50 - 0.75	0.00			0.25 - 0.50	0.00		
0.75 - 1.00	0.00			0.50 - 0.75 0.75 - 1.00	0.00		
1.00 - 1.50	0.00			1.00 - 1.50	0.00		
1.50 - 2.00	0.00			1.50 - 2.00	0.00		
2.00 - 3.00				2.00 - 3.00	0.00		
3.00 - 4.00				3.00 - 4.00	0.00		
4.00 - 5.00	0.00			4.00 - 5.00			
5.00+	0.00						

#### Figure 6-8 – Nokia Network Baseline Raw Data

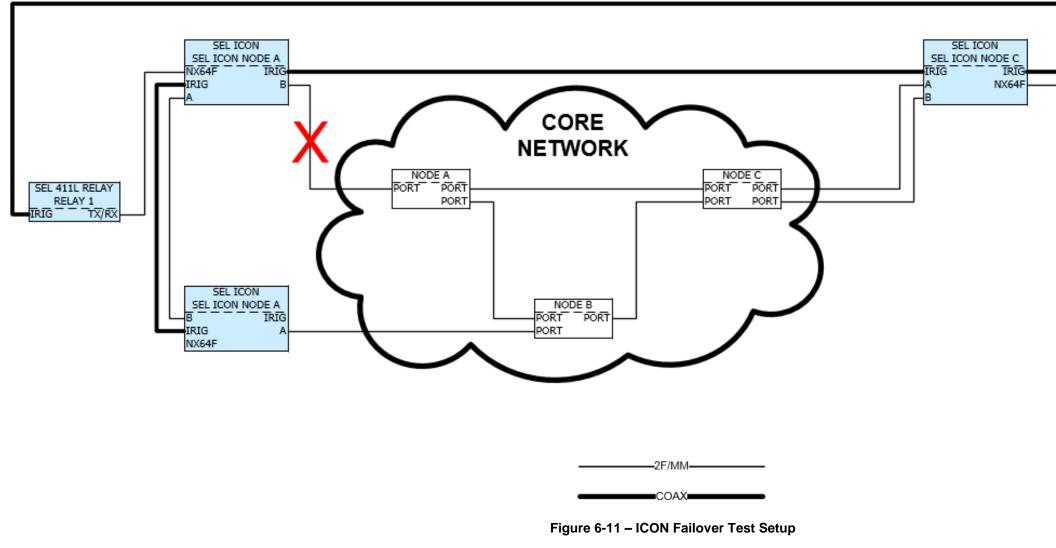
				87L APPLICATION STATUS			
87L APPLICATION STATUS		erminals with single	serial channel	671 AFFLICATION STATUS		erminals with single	serial channel
MEDIUM/PROTOCOL	Configurati	on	Status	MEDIUM/PROTOCOL	Configurati		Status
Serial Channel 2	850nm C37.9		OK	Serial Channel 2	850nm C37.9	4 Fiber	OK
Synchronization	External-ti	me-based	High precision	Synchronization	External-ti	me-based	High precision
Time Fallback	Mode 1		OK	Time Fallback	Mode 1		OK
TIME SOURCE	Local Statu Locked		Remote Status Locked	TIME SOURCE	Local Statu Locked		Remote Status Locked
CHANNEL ADDRESSING				CHANNEL ADDRESSING			
CHANNEL ADDRESSING Local Address				Local Address			
Remote Address 2				Remote Address 2			
Nemote Marcos 2							
STATISTICS	Channel 2			STATISTICS	Channel 2		
Channel Status	OK			Channel Status	OK		
Channel Role	In use			Channel Role Receive Status	In use		
Receive Status Synch Config	OK Ext-time-ba	cod		Synch Config	OK Ext-time-ba	sed	
Synch Config Synch Status	Ext-time-ba			Synch Status	Ext-time-ba		
Synch Accuracy	High precis			Synch Accuracy	High precis		
Time Status	Locked			Time Status	Locked		
High Lost Packet Count	OK			High Lost Packet Count			
High Latency				High Latency			
High Asymmetry				High Asymmetry			
Round-Trip Delay (ms)				Round-Trip Delay (ms)	1.0		
Transmit Delay (ms) Receive Delay (ms)	0.5			Transmit Delay (ms) Receive Delay (ms)	0.5		
Asymmetry (ms)	0.04			Asymmetry (ms)	0.02		
Lost Packet Count 40s				Lost Packet Count 40s			
Lost Packet Count 24hr				Lost Packet Count 24hr			
MAXIMUM VALUES				MAXIMUM VALUES			
Channel 2		Date and Time (UTC)		Channel 2		Date and Time (UTC)	
Lost Packet Count 24hr		04/12/2017 19:02:48		Lost Packet Count 24hr		04/12/2017 19:02:52	
Round-Trip Delay (ms)		04/12/2017 19:02:52.	670	Round-Trip Delay (ms)		04/12/2017 19:02:52.	262
Transmit Delay (ms)		04/12/2017 19:02:51.		Transmit Delay (ms)		04/12/2017 19:02:53.	
Receive Delay (ms)		04/12/2017 19:02:48.		Receive Delay (ms)		04/12/2017 19:02:52.	
Asymmetry (ms)		04/12/2017 19:02:48.	743	Asymmetry (ms)		04/12/2017 19:02:52.	187
HISTOGRAMS Channel Round-Trip Del	av (last 24	hours)		HISTOGRAMS			
Delay (ms)	Channel 2			Channel Round-Trip Dela			
0 - 2	100.0			Delay (ms) 0 - 2	Channel 2 ( 100.0	%)	
2 - 4	0.0			0 = 2 2 = 4	0.0		
4 - 6				2 - 4 4 - 6	0.0		
6 - 8					0.0		
8 - 10							
10 - 12 12 - 15	0.0			10 - 12			
12 - 15 15 - 20	0.0			12 - 15			
20 - 30	0.0			15 - 20 20 - 30	0.0 0.0		
30+				20 - 30 30+	0.0		
Channel Asymmetry (las	+ 24 hours						
Asymm (ms)	Channel 2	(%)		Channel Asymmetry (last Asymm (ms)	t 24 hours) Channel 2 (	\$)	
0.00 - 0.25	100.00			0.00 - 0.25	100.00	01	
0.25 - 0.50				0.25 - 0.50	0.00		
0.50 - 0.75	0.00			0.50 - 0.75	0.00		
0.75 - 1.00	0.00						
1.00 - 1.50 1.50 - 2.00	0.00			1.00 - 1.50	0.00		
2.00 - 3.00	0.00			1.50 - 2.00 2.00 - 3.00	0.00		
3.00 - 4.00	0.00			3.00 - 3.00 3.00 - 4.00	0.00		
4.00 - 5.00				4.00 - 5.00	0.00		
5.00+				5.00+	0.00		

#### Figure 6-9 – Ciena Network Baseline Raw Data

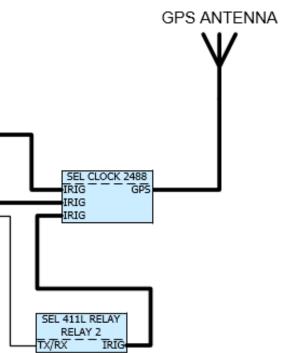
87L APPLICATION STATUS				87L APPLICATION STATUS			
671 APPLICATION STATUS		erminals with single	serial chan			erminals with single	serial chanr
MEDIUM/PROTOCOL	Configurati	on	Status	MEDIUM/PROTOCOL	Configurati	on	Status
Serial Channel 2	850nm C37.9		OK	Serial Channel 2	850nm C37.9	4 Fiber	OK
Synchronization	External-ti	me-based		sSynchronization	External-ti	me-based	High precis
Time Fallback	Mode 1		OK	Time Fallback	Mode 1		OK
TIME SOURCE	Local Statu		Remote Sta	TIME SOURCE	Local Statu	q	Remote Stat
	Locked		Locked		Locked		Locked
CHANNEL ADDRESSING				CHANNEL ADDRESSING			
Local Address Remote Address 2				Local Address Remote Address 2			
Remote Address 2				Remote Address 2			
STATISTICS	Channel 2			STATISTICS	Channel 2		
Channel Status	OK			Channel Status	OK		
Channel Role	In use			Channel Role	In use		
Receive Status	OK			Receive Status	OK		
Synch Config	Ext-time-ba			Synch Config	Ext-time-ba		
Synch Status	Ext-time-ba High precis			Synch Status Synch Accuracy	Ext-time-ba High precis		
Synch Accuracy Time Status	Locked	1011		Synch Accuracy Time Status	Locked	1011	
High Lost Packet Count				High Lost Packet Count			
High Latency				High Latency			
High Asymmetry				High Asymmetry			
Round-Trip Delay (ms)	0.8			Round-Trip Delay (ms)	0.8		
Transmit Delay (ms)				Transmit Delay (ms)			
Receive Delay (ms)				Receive Delay (ms)	0.5		
Asymmetry (ms)	0.19			Asymmetry (ms) Lost Packet Count 40s	0.18		
Lost Packet Count 40s Lost Packet Count 24hr				Lost Packet Count 403 Lost Packet Count 24hr			
1050 Packet Coulit 24III				host racket count 24m			
MAXIMUM VALUES				MAXIMUM VALUES			
Channel 2		Date and Time (UTC)		Channel 2		Date and Time (UTC)	
Lost Packet Count 24hr		05/11/2017 20:21:10	000	Lost Packet Count 24hr Round-Trip Delay (ms)		05/11/2017 20:21:35 05/11/2017 20:21:37	0.60
Round-Trip Delay (ms) Transmit Delay (ms)		05/11/2017 20:21:13. 05/11/2017 20:21:12.		Transmit Delay (ms)	0.3	05/11/2017 20:21:37	
Receive Delay (ms)	0.3	05/11/2017 20:21:12.		Receive Delay (ms)	0.5	05/11/2017 20:21:37	
Asymmetry (ms)	0.18	05/11/2017 20:21:11.		Asymmetry (ms)	0.20	05/11/2017 20:21:37	
				HISTOGRAMS			
HISTOGRAMS				Channel Round-Trip Del			
Channel Round-Trip Del Delay (ms)	ay (last 24 Channel 2 (			Delay (ms)	Channel 2 (	%)	
0 - 2	100.0			$   \begin{array}{r}     0 - 2 \\     2 - 4   \end{array} $	100.0		
2 - 4	0.0			2 - 4 4 - 6	0.0		
4 - 6				4 – 6 6 – 8	0.0		
6 – 8				8 - 10	0.0		
8 - 10				10 - 12			
10 - 12 12 - 15	0.0			12 - 15			
12 - 15 15 - 20	0.0			15 - 20			
20 - 30	0.0			20 - 30 30+			
30+				307	0.0		
				Channel Asymmetry (las	t 24 hours)		
Channel Asymmetry (las				Asymm (ms)	Channel 2 (	%)	
Asymm (ms) 0.00 - 0.25	Channel 2 ( 100.00	(8)		0.00 - 0.25	100.00		
0.00 = 0.25 0.25 = 0.50	0.00			0.25 - 0.50	0.00		
0.50 - 0.75	0.00			0.50 - 0.75 0.75 - 1.00	0.00		
0.75 - 1.00	0.00			1.00 - 1.50	0.00		
1.00 - 1.50	0.00			1.50 - 2.00	0.00		
1.50 - 2.00	0.00			2.00 - 3.00	0.00		
2.00 - 3.00	0.00			3.00 - 4.00			
3.00 - 4.00 4.00 - 5.00	0.00			4.00 - 5.00	0.00		
4.00 - 5.00 5.00+	0.00			5.00+			

#### Figure 6-10 – Cisco Network Baseline Raw Data

#### 6.4 ICON Failover Tests



Burns & McDonnell



	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	87L
Asymmetry (ms)	0.15	0.15	071
Lost Packet Count	0	1	
SER	0	0	

	Relay 1	Relay 2	
Round-Trip Delay (ms)	*	*	
Transmit Delay (ms)	*	*	
Receive Delay (ms)	*	*	87L
Asymmetry (ms)	*	*	071
Lost Packet Count	4	0	
SER	0	0	

\* COM statistics not cleared

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.1	1.1	
Transmit Delay (ms)	0.6	0.5	
Receive Delay (ms)	0.5	0.6	87L
Asymmetry (ms)	0.15	0.15	071
Lost Packet Count	3	0	
SER	0	0	

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

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

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

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

	Relay 1	Relay 2	
Round-Trip Delay (ms)	1.0	1.0	
Transmit Delay (ms)	0.5	0.5	
Receive Delay (ms)	0.5	0.5	87L
Asymmetry (ms)	0.03	0.02	071
Lost Packet Count	5	0	
SER	1*	0	

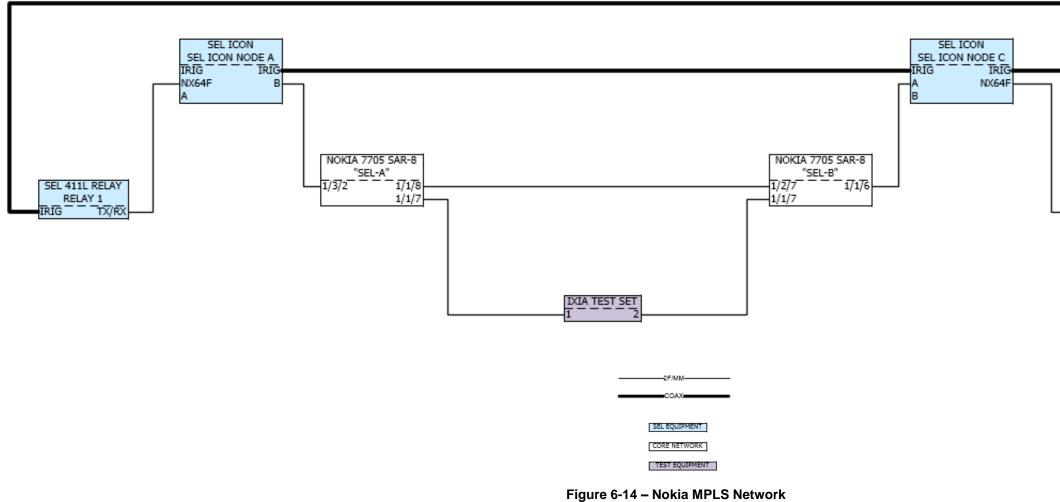
\*\*\* 8.5 millisecond failover time detected

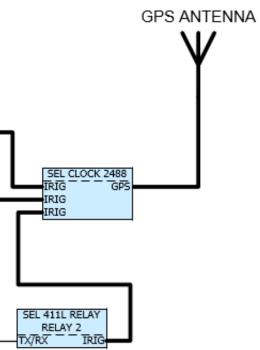
	Relay 1	Relay 2	
Round-Trip Delay (ms)	0.9	0.8	
Transmit Delay (ms)	0.4	0.5	
Receive Delay (ms)	0.5	0.4	87L
Asymmetry (ms)	0.08	0.11	0/L
Lost Packet Count	1	2	
SER	0	0	

		Relay 1	Relay 2		
	Round-Trip Delay (ms)	0.8	0.8		
	Transmit Delay (ms)	0.5	0.5		
	Receive Delay (ms)	0.4	0.4	87L	
	Asymmetry (ms)	0.08	0.12	0/L	
	Lost Packet Count	1	0		
	SER	0	0		
DATE	TTME	ELEMEI	VТ	STA	\TTE
	017 19:29:48.0526	87CH201	K		serted
*** 04/12/2	017 19:29:48.0611	87CH20	X	Asse	erted

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

6.5 Congestion and Priority Tests







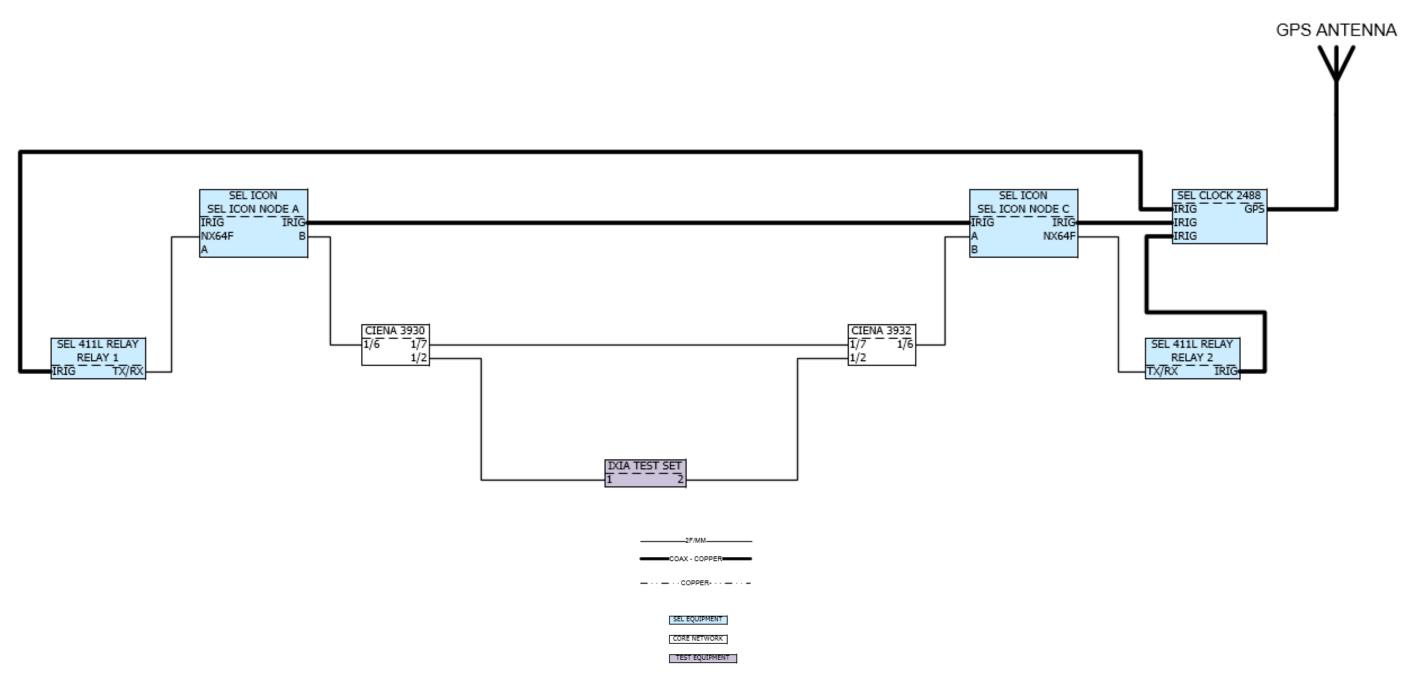


Figure 6-15 – Ciena Carrier Ethernet Network





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