Cisco Connected Utilities

Substation Automation Utility WAN
Teleprotection Implementation Guide Series

Utility WAN 2.3 Release

Teleprotection with 2 Box Solution G.703 Co-directional to E1 Interface

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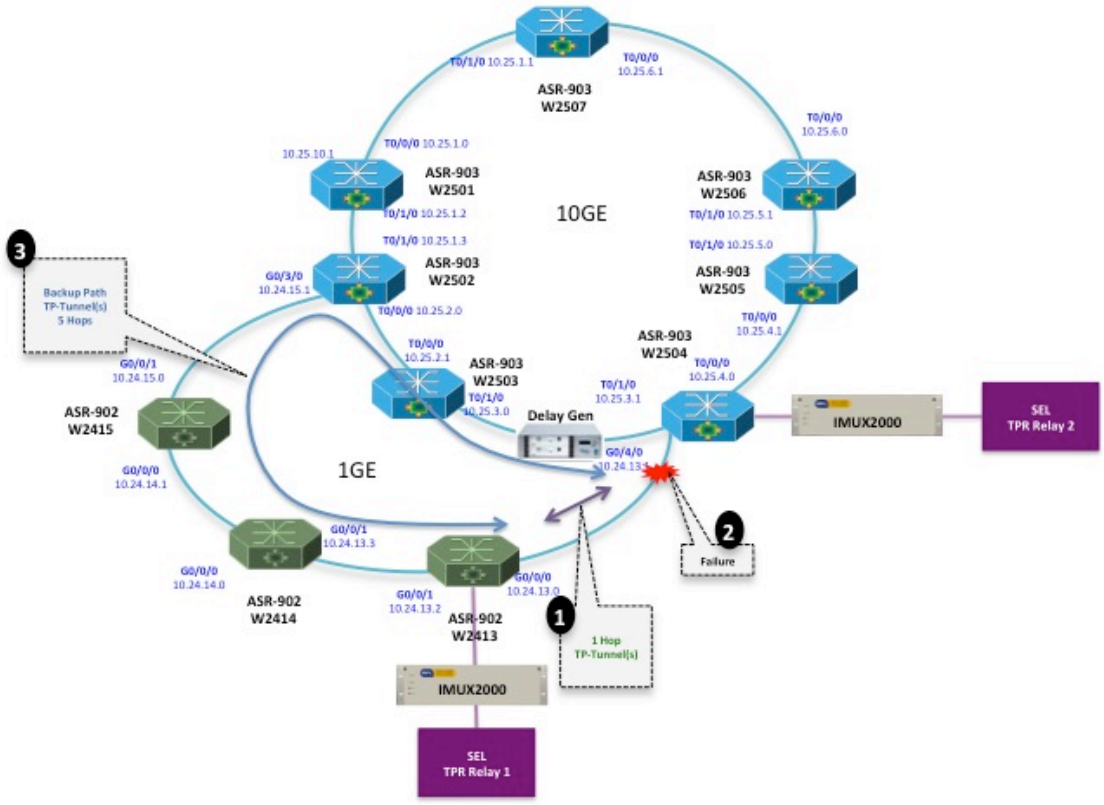
1 Overview

1.1 Teleprotection with 2 Box Solution G.703 Co-Directional to E1 Interface

This document provides information on the validated design to provide Cisco support for teleprotection use cases for line protection relays with G.703 co-directional interfaces. The proposed solution is a 2-box architecture in which the G.703 co-directional interface (64kbps) on a relay is combined into a E1 circuit, using time division multiplexing (TDM). The E1 interface on a multiplexor is connected to the Cisco ASR900 router leveraging the design validated in the previous solution release at the following link: https://docs.cisco.com/share/proxy/alfresco/url?docnum=EDCS-10804593&ver=latest.

The multiplexing is done by a third-party product.

1.2 Topology



1.3 Validated Software

The Cisco IOS 15.6(1)S IOS-XE image was validated as part of this solution on the ASR900 w/ RSP2-64. The image filename is **asr900rsp2-universalk9_npe.03.17.00.S.156-1.S-std.bin** and is available for download from the following link: http://www.cisco.com.

1.4 Third-Party Tools

The third-party devices shown in Table 1 are referenced in this implementation guide. Some tools are necessary for the network to function properly. Others are referenced for validation purposes.

Table 1 Third-Party Tools Reference

Third-Party Tool Hardware	Third-Party Tool Software	Purpose
Schweitzer Engineering Laboratories 411L Relay	SEL-411L-R118-V0-Z010002-D20151228	Line Current Differential Relay to validate teleprotection over TDM-based pseudowires (PWs)
Schweitzer Engineering Laboratories - Communication card 9109XL1BXLXX	NA	G.703 co-directional interface card for the SEL-411L relay
Schweitzer Engineering Laboratories C452 Cable	NA	G.703 co-directional cables
acSELerator QUICKSET SEL-5030 SOFTWARE	6.2.0.0	Configuration software for relay
RFL IMUX2000	MCD2000-05	Multiplexor E1/G.703 co-directional
RFL CM4 Module	MCD2000-05	E1 module in the multiplexor
RFL DS562NC-MA408IA	MCD2000-05	G703 co-directional module in the multiplexor
RFL NMS	3.2.18	Network Management Software for Multiplexor
Omicron CMC356 Test Set	Test Universe V2.41 SR1	Supply current to relays for line differential tests

Ixia Impairment card	NA	Create additional latency and jitter
Ixia Traffic Generator w/ 10/100/1000 Ethernet Line Card	IxOS v6.60, Protocol v7.21.439.20	Create background traffic congestion

2 Service Deployment for CESoPSN with SEL-411L Relays

2.1 SEL-411L

2.1.1 SEL-411L Overview

For information about Schweitzer Engineering Laboratories 411L relay, refer to the following link: https://cdn.selinc.com//assets/Literature/Product%20Literature/Data%20Sheets/411L_DS_20160217.pdf?v=20160408-151350

2.1.2 SEL 411L Relay Settings

Only relay 1 configuration is shown. Relay 2 configuration is very similar in all settings except for a different name and address.

2.1.2.1 Global Settings

```
SID     := "Test Settings"
RID     := "Relay 1 (Top)"
NUMBK   := 1
BID1    := "Breaker 1"
NFREQ   := 60       PHROT   := ABC
FAULT   := 50P1 OR 51S01 OR Z2P OR Z2G OR Z3P OR Z3G OR 87LP OR \
            87LQ OR 87LG OR 87CH2OK OR 87CH2AL


Global Enables

EDCMON  := N        EICIS   := N        EDRSTC  := Y        EGADVS  := Y
EPMU    := N

Control Inputs

IN2XXD  := 0.1250

Settings Group Selection

SS1     := 1
SS2     := 0
SS3     := 0
```

```
SS4     := 0
SS5     := 0
SS6     := 0
TGR     := 180

Frequency Estimation

EAFSRC  := NA
VF01    := VAY      VF02    := VBY      VF03    := VCY

Time-Error Calculation

STALLTE := NA
LOADTE  := NA


Current and Voltage Source Selection

ESS     := N

Time and Date Management

DATE_F  := MDY      IRIGC   := NONE     UTCOFF  := -5.0
BEG_DST := "2,2,1,3"
END_DST := "2,1,1,11"


Data Reset Control

RST_DEM := NA
RST_PDM := NA
RST_ENE := NA
RSTMML  := NA
RSTMMB1 := NA
RSTMMB2 := NA
RST_BK1 := NA
RST_BK2 := NA
RST_BAT := NA
RST_79C := NA
RSTTRGT := PCT01Q
RSTFLOC := NA
```

```
RSTDNPE := TRGTR
RST_HAL := NA



DNP


EVELOCK := 0        DNPSRC  := UTC
```

2.1.2.2 Active Group Settings

The following figure illustrates the configurations of the SEL Line Differential Relay solution:

```
Line Configuration

CTRW    := 120      CTRX    := 120      PTRY    := 2000.0   VNOMY   := 115
PTRZ    := 2000.0   VNOMZ   := 115      Z1MAG   := 39.00    Z1ANG   := 84.00
Z0MAG   := 124.00   Z0ANG   := 81.50    EFLOC   := Y

Relay Configuration

E87L    := Y        E87LCC  := N        E87XFMR := N        E87OCTL := N
EMBA    := N        EMBB    := N        E21MP   := N        E21XP   := N
E21MG   := N        E21XG   := N        ECVT    := N        ESOTF   := N
EOOS    := N        ELOAD   := N        E50P    := 1        E50G    := N
E50Q    := N        E51     := N        E81     := N        E27     := N
E59     := N        E32     := AUTO     ECOMM   := N        EBFL1   := N
E25BK1  := N        E79     := N        EMANCL  := Y        ELOP    := N
EDEM    := N        EADVS   := N

87 Current Differential Element

87CTWL  := 1
87CTPWL := P
87CTXL  := 0
87CTP1R := 120      87LTAPW := 1.00     87LINEV := OFF      87LPP   := 0.95
87LPR   := 2.00     87LPA   := 195      87LQP   := OFF      87LGP   := OFF
ESTUB   := 0
87BLOCK := NOT PLT01
87TMSUP := PLT04
EWDSEC  := 1


87L Channel Configuration

87TADR  := 1        87R1ADR := 2        87R2ADR := 3
87T1P1  := NA
87T2P1  := NA
87T3P1  := NA
87T4P1  := NA
87T1P2  := NA
87T2P2  := NA
87T3P2  := NA
87T4P2  := NA
```

```
Phase Instantaneous Overcurrent Pickup

50P1P   := 3.00

Phase Def.-Time Overcurrent Time Delay

67P1D   := 0.000

Phase Inst./Def.-Time Overcurrent Torque Control

67P1TC  := 1


Directional Control Element

ORDER   := "QV"
50FP    := 0.12     50RP    := 0.08     Z2F     := 19.50    Z2R     := 20.00
a2      := 0.10     k2      := 0.20     Z0F     := 62.00    Z0R     := 62.50
a0      := 0.10
E32IV   := 1


Pole Open Detection

EPO     := 52       SPOD    := 0.500    3POD    := 0.500

Recloser and Manual Closing

BKCFD   := 300
ULCL1   := 52AA1 AND 52AB1 AND 52AC1
BK1MCL  := (CC1 OR PB11PUL) AND PLT06


Voltage Elements

EVCK    := N

Fault Locator

LLR     := 100.00

Mirrored Bits Communications Settings

TMB1A   := NA
TMB2A   := NA
TMB3A   := NA
TMB4A   := NA
TMB5A   := NA
TMB6A   := NA
TMB7A   := NA
TMB8A   := NA
TMB1B   := NA
TMB2B   := NA
TMB3B   := NA
TMB4B   := NA
TMB5B   := NA
```

```
TMB6B   := NA
TMB7B   := NA
TMB8B   := NA


Trip Logic

TR      := 87OP OR 87R01P1
DTA     := NA
DTB     := NA
DTC     := NA
E87DTT  := 1
BK1MTR  := OC1 OR PB12PUL
ULTR    := TRGTR OR PLT10
ULMTR1  := NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD    := 2.000    TULO    := 3        Z2GTSP  := N        67QGSP  := N
TDUR1D  := 6.000    TDUR3D  := 12.000
E3PT    := 1
E3PT1   := 1
ER      := 87LSP OR 87OP OR 87R01P1
```

2.1.2.3 Active Protection Settings

```
1: PLT01S := PB1_PUL AND NOT PLT01 # 87L ENABLED
2: PLT01R := PB1_PUL AND PLT01
3: PLT02S := PB2_PUL AND NOT PLT02 # COMM SCHEME ENABLED
4: PLT02R := PB2_PUL AND PLT02
5: PLT04S := PB4_PUL AND NOT PLT04 # RELAY TEST MODE
6: PLT04R := PB4_PUL AND PLT04
7: PLT06S := PB6_PUL AND NOT PLT06 # MANUAL CLOSE ENABLED
8: PLT06R := PB6_PUL AND PLT06
9: PLT07S := PB7_PUL AND NOT PLT07 # RECLOSE ENABLED
10: PLT07R := PB7_PUL AND PLT07
11: PLT08S := PB8_PUL AND NOT PLT08 # TEST MIRRORED BITS
12: PLT08R := PB8_PUL AND PLT08
13: PLT09S := PB9_PUL AND NOT PLT09 # TRANSFER TRIP
14: PLT09R := PB9_PUL AND PLT09
15: PCT01IN := TRIP
16: PCT01PU := 600.000000
17: PCT01DO := RSTTRGT
```

2.1.2.4 Port 87 Settings

```
87 Channel Enable

E87CH   := 2SS      E87PG   := P

87 Channel Configuration

87PCH   := 2        87TADR  := 1        87R2ADR := 2        87TIMC2 := I
E87VT   := N

87 Channel Monitoring

87CH2SN := C        87CH2MT := 25.0     87CH2MD := OFF
87CHTRG := 87LSP
87CHWP  := N        87CH2PC := OFF
```

```
87 Communications Bits De-bounce Time Delay

87R12PU := 0        87R12DO := 0        87R22PU := 0        87R22DO := 0
87R32PU := 0        87R32DO := 0        87R42PU := 0        87R42DO := 0
```

2.2 IMUX 2000

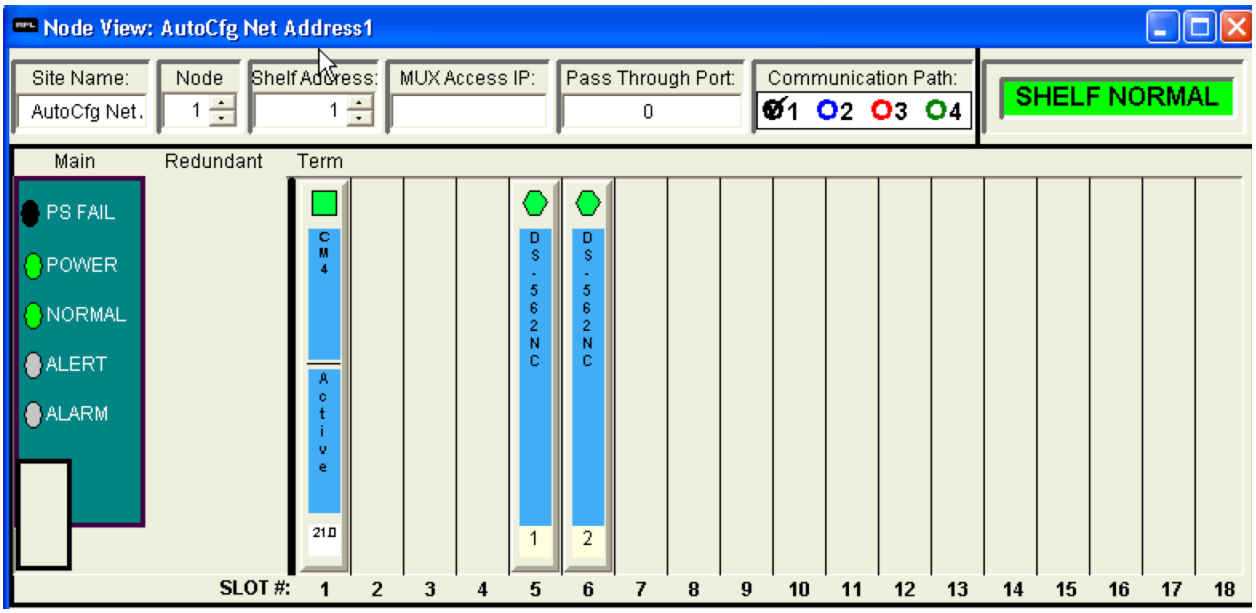
2.2.1 IMUX 2000 Overview

The IMUX has the following components:

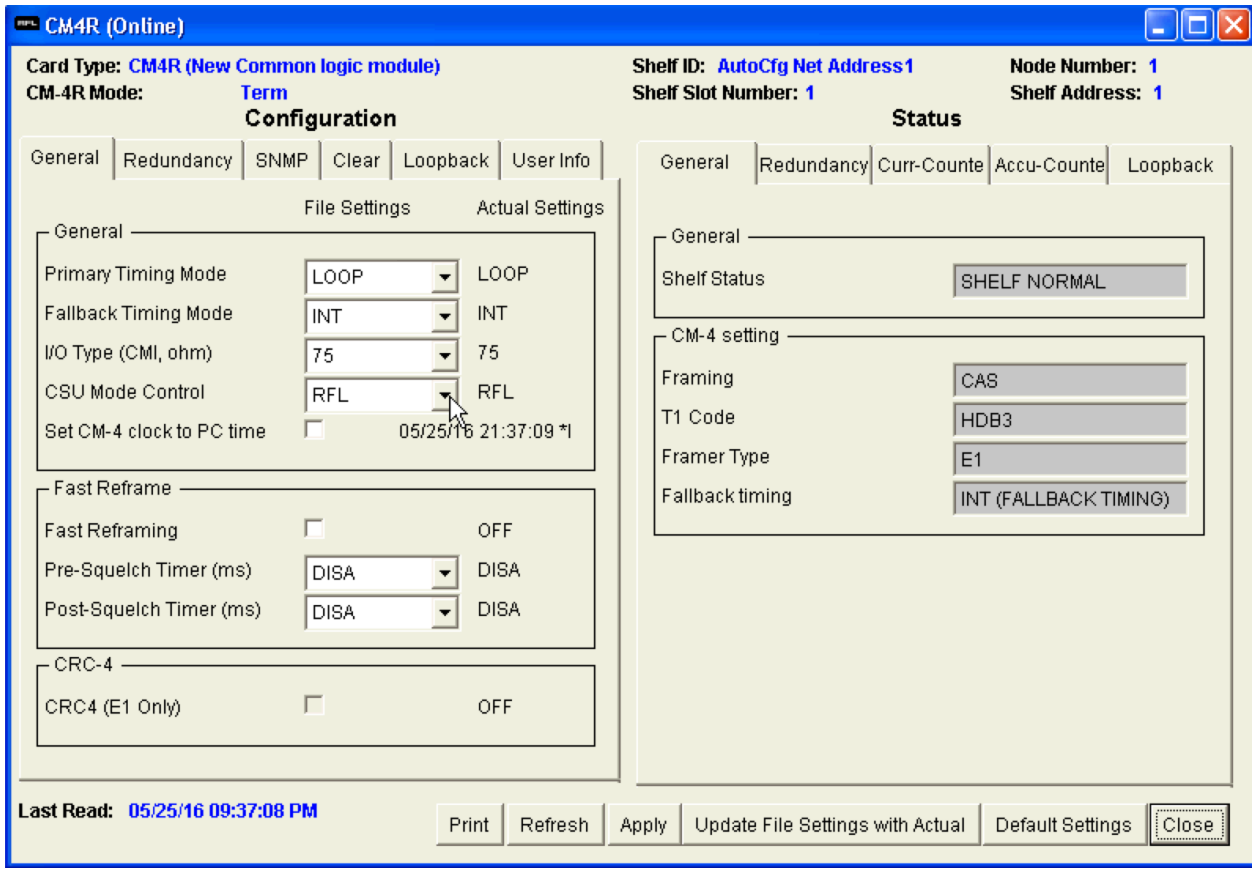
- Main Shelf: Enclosure for the IMUX 2000 multiplexer. It has plug-in slots in the front for one main power supply and one optional redundant power supply. It also provides 18 physical slots for E1 common modules and channel modules.
- E1 Common Module (CM4): It is a microprocessor-controlled module that performs all of the E1 multiplexing and de-multiplexing functions. It also provides the user interface, and may optionally provide other functions, such as an additional timing source.
- Channel Modules: All payload circuits connect to IMUX 2000 multiplexers through channel modules. RFL offers a family of channel modules that support a wide range of circuit types: voice, synchronous and asynchronous data, polling data, office-end/station end, and time slot access.

For more information, refer to http://www.rflelect.com/products/t1-e1-multiplexers/t1-multiplexer.

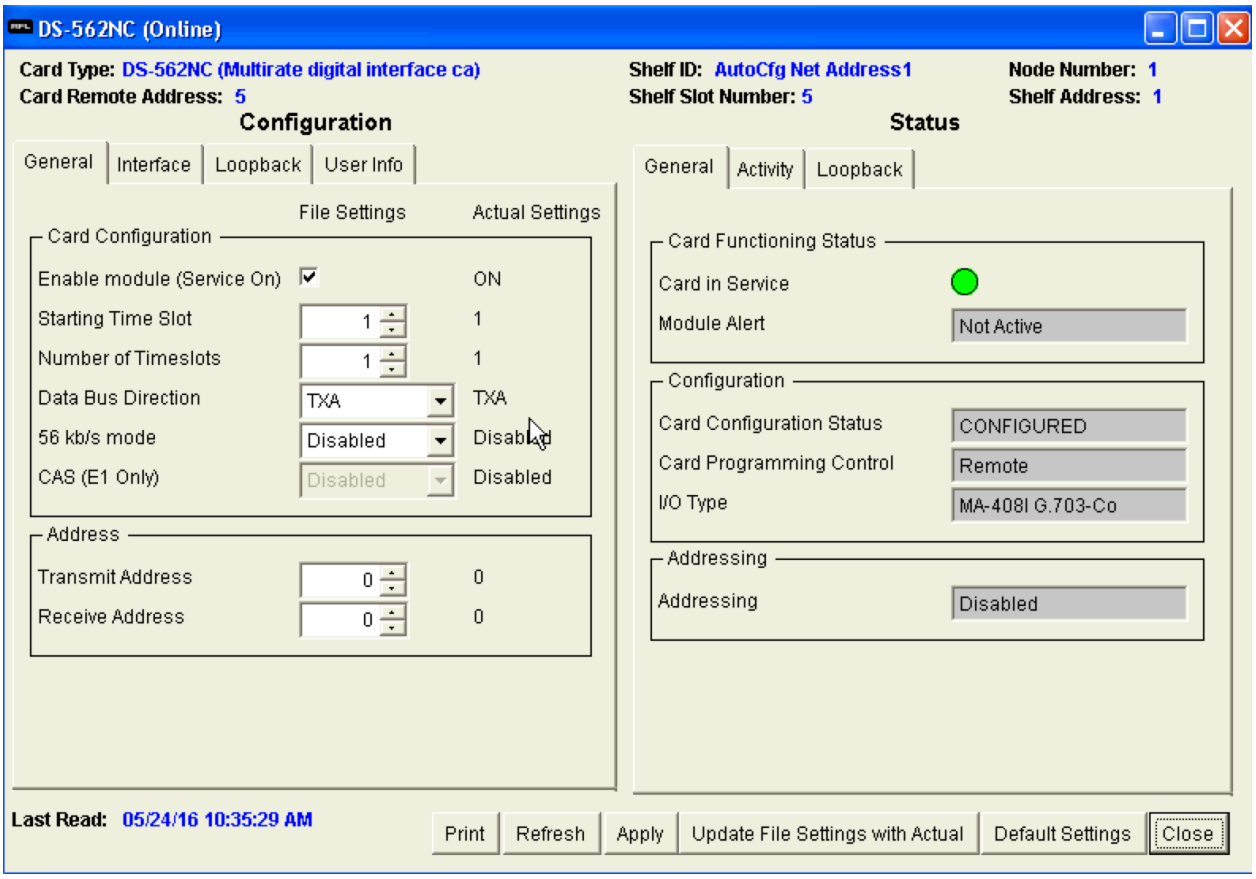
2.2.2 IMUX 2000 Main Shelf Configuration

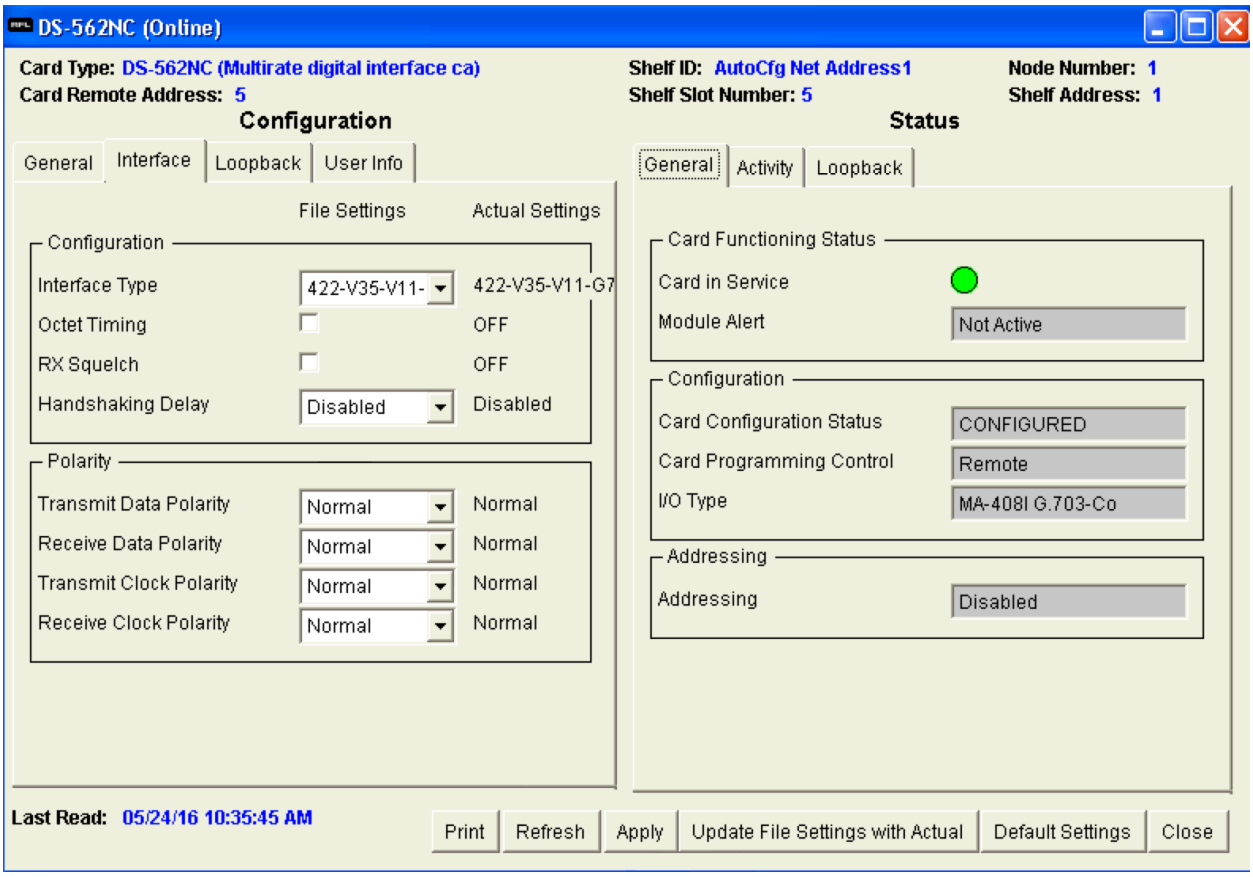


2.2.2.1 RFL CM4 Settings



2.2.2.2 Channel Module Settings


DS-562NC (Online)
Card Type: DS-562NC (Multirate digital interface ca)
Card Remote Address: 5
Shelf ID: AutoCfg Net Address1
Shelf Slot Number: 5
Node Number: 1
Shelf Address: 1
Configuration
Status
General
Interface
Loopback
User Info
File Settings
Actual Settings
Card Configuration
Enable module (Service On)
ON
Starting Time Slot
1
1
Number of Timeslots
1
1
Data Bus Direction
TXA
TXA
56 kb/s mode
Disabled
Disabled
CAS (E1 Only)
Disabled
Disabled
Address
Transmit Address
0
0
Receive Address
0
0
General
Activity
Loopback
Card Functioning Status
Card in Service
Module Alert
Not Active
Configuration
Card Configuration Status
CONFIGURED
Card Programming Control
Remote
I/O Type
MA-408I G.703-Co
Addressing
Addressing
Disabled
Last Read: 05/24/16 10:35:29 AM
Print
Refresh
Apply
Update File Settings with Actual
Default Settings
Close



2.2.3 Channel Module Configuration Considerations E1 Time Slot Usage

The specification for the E1 system calls for 32 full-duplex 64 Kbps time slots, numbered 0 to 31, providing a data rate of 2,048,000 bps, or 2.048 Mbps. Time slot 0 is reserved for system use (framing, information, CRC, and so on) and is not available to the user. This leaves a maximum aggregate payload capacity of 1.984 Mbps (31 time slots of 64 Kbps each).

Some applications require additional signaling data with the payload. In E1 systems, this signaling information is passed between nodes using Channel Associated Signaling (CAS). CAS utilizes time slot 16 to pass the signaling information for all time slots. If CAS signaling is used anywhere in a network, it should be used throughout the network, thus precluding time slot 16 for user data.

The RFL fast reframe uses time slot 30. If fast reframing is required in a network, all nodes should have fast reframing enabled, and time slot 30 will be reserved. If all nodes have fast reframe disabled, time slot 30 will be available for user payload data.

During the validation described in this document CAS and Fast Reframing were not used. Relay communication used frame 1.

2.3 CESoPSN Circuit

2.3.1 CESoPSN Circuit Overview

The following figure illustrates the CESoPSN solution implemented for the Siemens Line Differential Relay solution:

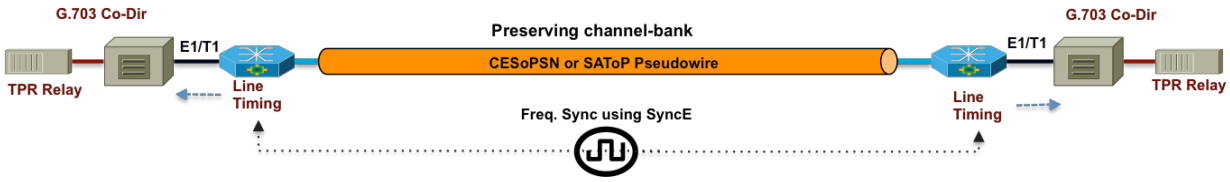


Figure CESoPSN Circuit Overview

2.3.2 Network Latency

The primary MPLS label switched path traverses a direct link between the two ASR900s. The backup MPLS label switched path traverses qty-5 ASR900 routers.

Latency delta between 1-hop and 5-hops is only 57usec due to ASR900 centralized architecture and Cisco low-latency ASIC.

Note: Latency numbers reflected here do not account for distances between substations. Add 1msec propagation delay (speed of light through fiber optic) for every 200km (124 miles) between substations.

2.3.3 De-Jitter Buffer

The TDM circuit emulation pseudowire employs a de-jitter buffer to compensate for the network Packet Delay Variation (PDV). The multiplexor also has a jitter buffer setting, which for testing was left as default. Refer to the multiplexor instruction manual for more details.

Note: The ASR900 de-jitter buffer is configurable between 1-32 ms. There is a trade-off between de-jitter buffer and latency. A large a de-jitter buffer will impact the end-to-end latency of the protection scheme, and therefore its size must be optimally tuned to smooth out network PDV to maintain TDM line synchronization and not more.

The CESoPSN pseudowire de-jitter buffer is configured at 2msec. ASR900 substation routers are frequency synchronized for TDM circuit emulation using SyncE. The pseudowire is carried over RSVP TE tunnels using explicit routing, or over MPLS-TP tunnels to ensure symmetrical forward and return paths. MPLS TE-FRR (fast re-route) protection is used to achieve 50ms recovery against failures in the transport network.

2.3.4 Synchronization

- SyncE was used to synchronize all devices in the network. ASR903-W2501 internal clock was used as a master clock.

- Relays were not using any external clock.
- Multiplexor was configured to acquire timing from the ASR900 using the Primary Timing Mode LOOP.

2.4 Using IOS CLI for Provisioning Relay Connectivity over CESoPSN

2.4.1 MPLS-TP Tunnel Endpoints

Configure MPLS-TP Tunnel Endpoints. Sample endpoint configuration on the ASR902-W2413:

```
interface Tunnel-tp0
 no ip address
 load-interval 30
 no keepalive
 tp source 100.24.13.1 global-id 1
 tp destination 100.25.4.1 global-id 1
 bfd BFD
 working-lsp
  out-label 302 out-link 1
  in-label 133
  lsp-number 0
 protect-lsp
  out-label 105 out-link 2
  in-label 134
  lsp-number 1
end
```

Sample endpoint configuration on the ASR903-W2504:

```
interface Tunnel-tp0
 description PrimeF:JobID:190()
 no ip address
 load-interval 30
 no keepalive
 tp source 100.25.4.1 global-id 1
 tp destination 100.24.13.1 global-id 1
 bfd BFD
 working-lsp
  out-label 133 out-link 1
  in-label 302
  lsp-number 0
 protect-lsp
  out-label 108 out-link 2
  in-label 303
  lsp-number 1
end
```

2.4.2 MPLS-TP Tunnel Midpoints

Configure MPLS-TP LSP at midpoint routers. In the bottom ring in the system topology, the following three router midpoints need configuration:

ASR903-W2503

```
mpls tp lsp source 100.24.13.1 tunnel-tp 0 lsp protect destination 100.25.4.1
tunnel-tp 0
 forward-lsp
  in-label 107 out-label 303 out-link 2
 reverse-lsp
  in-label 108 out-label 108 out-link 1
```

ASR902-W2415

```
mpls tp lsp source 100.24.13.1 tunnel-tp 0 lsp protect destination 100.25.4.1
tunnel-tp 0
 forward-lsp
  in-label 105 out-label 107 out-link 2
 reverse-lsp
  in-label 106 out-label 106 out-link 1
```

ASR902-W2414

```
mpls tp lsp source 100.24.13.1 tunnel-tp 0 lsp protect destination 100.25.4.1
tunnel-tp 0
 forward-lsp
  in-label 105 out-label 105 out-link 1
 reverse-lsp
  in-label 106 out-label 134 out-link 2
```

2.4.3 Pseudowire Class

A sample pseudowire-class configuration is as follows:

```
pseudowire-class EoMPLS
  encapsulation mpls
  no control-word
  preferred-path interface Tunnel-tp0
!
```

2.4.4 CEM Class and Dejitter Buffer

A sample CEM class configuration is as follows:

```
class cem TPR-CEM-2BOX
 dejitter-buffer 2
```

2.4.5 E1 Line Card Mode

The E1 line card should be set to E1 mode as follows:

```
card type e1 0 5
```

2.4.6 E1 Controller

A sample E1 controller configuration is as follows:

```
controller E1 0/5/4
 framing no-crc4
 clock source internal
  cem-group 0 timeslots 1-31
```

2.4.7 CESoPSN E1 CEM Interface

A sample CESoPSN E1 circuit emulation (CEM) interface is as follows:

```
interface CEM0/5/4
description 2-box
no ip address
load-interval 30
cem 0
```

2.4.8 Pseudowire

A sample E1 circuit emulation (CEM) pseudowire configuration is as follows:

```
interface CEM0/5/4
 cem 0
  service-policy input PMAP-UNI-TPR-IN
 xconnect 100.24.13.1 10005 encapsulation mpls pw-class EoMPLS
 cem class TPR-CEM-2BOX
!
```

2.5 Using IOS CLI to Validate Relay Connectivity over CESoPSN

2.5.1 Validate MPLS PW Circuit Emulation

The following verifications are made when the short path (MPLS-TP working path) is ACTIVE:

```
ASR903-W2504# ASR903-W2504#sh xconnect ALL
Legend:    XC ST=Xconnect State  S1=Segment1 State  S2=Segment2 State
  UP=Up       DN=Down            AD=Admin Down      IA=Inactive
```

```
  SB=Standby  HS=Hot Standby     RV=Recovering      NH=No Hardware

XC ST  Segment 1                          S1 Segment 2                          S2
------+---------------------------------+--+---------------------------------+--
UP pri   ac CE0/5/0:3(CESoPSN Basic)     UP mpls 100.24.13.1:10004           UP
UP pri   ac CE0/5/1:0(CESoPSN Basic)     UP mpls 100.24.13.1:901901          UP
UP pri   ac CE0/5/3:0(SATOP E1)          UP mpls 100.24.13.1:10003           UP
UP pri   ac CE0/5/4:0(CESoPSN Basic)     UP mpls 100.24.13.1:10005           UP
UP pri   ac CE0/5/5:0(SATOP E1)          UP mpls 100.24.13.1:10006           UP
DN pri   ac Gi0/4/3:1(Ethernet)          DN mpls 100.24.13.1:999999          DN
UP pri   ac Gi0/4/6:11(Eth VLAN)         UP mpls 100.24.13.1:1111111         UP
UP pri   ac Gi0/4/6:12(Eth VLAN)         UP mpls 100.24.13.1:1212121         UP
UP pri   ac Gi0/4/7:50(Ethernet)         UP mpls 100.24.13.1:777777          UP

ASR903-W2504#sh mpls l2 vc 10005 det
Local interface: CE0/5/4 up, line protocol up, CESoPSN Basic 0 up
  Destination address: 100.24.13.1, VC ID: 10005, VC status: up
    Output interface: Tp0, imposed label stack {133 50}
    Preferred path: Tunnel-tp0,  active
    Default path: ready
    Next hop: point2point
  Create time: 00:04:57, last status change time: 00:04:52
    Last label FSM state change time: 00:04:52
  Signaling protocol: LDP, peer 100.24.13.1:0 up
    Targeted Hello: 100.25.4.1(LDP Id) -> 100.24.13.1, LDP is UP
    Graceful restart: configured and enabled
    Non stop routing: not configured and not enabled
    Status TLV support (local/remote)   : enabled/supported
      LDP route watch                   : enabled
      Label/status state machine        : established, LruRru
      Last local dataplane   status rcvd: No fault
      Last BFD dataplane     status rcvd: Not sent
      Last BFD peer monitor  status rcvd: No fault
      Last local AC  circuit status rcvd: No fault
      Last local AC  circuit status sent: No fault
      Last local PW i/f circ status rcvd: No fault
      Last local LDP TLV     status sent: No fault
      Last remote LDP TLV    status rcvd: No fault
      Last remote LDP ADJ    status rcvd: No fault
    MPLS VC labels: local 30, remote 50
    Group ID: local 38, remote 34
    MTU: local 0, remote 0
    Remote interface description:
  Sequencing: receive disabled, send disabled
  Control Word: On
  SSO Descriptor: 100.24.13.1/10005, local label: 30
  Dataplane:
    SSM segment/switch IDs: 12365/41034 (used), PWID: 8
  VC statistics:
    transit packet totals: receive 1199921, send 1200033
    transit byte totals:   receive 93593838, send 84002310
    transit packet drops:  receive 0, seq error 0, send 0



ASR903-W2504#ping mpls pseudowire 100.24.13.1 10005
Sending 5, 72-byte MPLS Echos to 100.24.13.1,
     timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
```

```
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 3/3/4 ms
 Total Time Elapsed 27 ms

ASR903-W2504#TRACE  mpls pseudowire 100.24.13.1 10005 SEG

Tracing MS-PW segments within range [1-1] peer address 100.24.13.1 and timeout 2
seconds


Codes: '!' - success, 'Q' - request not sent, '.' - timeout,

  'L' - labeled output interface, 'B' - unlabeled output interface,

  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,

  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,

  'P' - no rx intf label prot, 'p' - premature termination of LSP,

  'R' - transit router, 'I' - unknown upstream index,

  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,

  'X' - unknown return code, 'x' - return code 0


Type escape sequence to abort.

! 1 10.24.13.0 4 ms [Labels: 133/router-alert/50 Exp: 0/0/0]

    local 100.25.4.1 remote 100.24.13.1 vc id 10005
```

The following verifications are made when the long path (MPLS-TP protect path) is ACTIVE:

```
ASR903-W2504#sh mpls l2 vc 10005 det

Local interface: CE0/5/4 up, line protocol up, CESoPSN Basic 0 up

  Destination address: 100.24.13.1, VC ID: 10005, VC status: up

    Output interface: Tp0, imposed label stack {108 50}

    Preferred path: Tunnel-tp0,  active

    Default path: ready

    Next hop: point2point

  Create time: 00:07:36, last status change time: 00:07:30

    Last label FSM state change time: 00:07:30
```

```
  Signaling protocol: LDP, peer 100.24.13.1:0 up
    Targeted Hello: 100.25.4.1(LDP Id) -> 100.24.13.1, LDP is UP
    Graceful restart: configured and enabled
    Non stop routing: not configured and not enabled
    Status TLV support (local/remote)   : enabled/supported
      LDP route watch                   : enabled
      Label/status state machine        : established, LruRru
      Last local dataplane   status rcvd: No fault
      Last BFD dataplane     status rcvd: Not sent
      Last BFD peer monitor  status rcvd: No fault
      Last local AC  circuit status rcvd: No fault
      Last local AC  circuit status sent: No fault
      Last local PW i/f circ status rcvd: No fault
      Last local LDP TLV     status sent: No fault
      Last remote LDP TLV    status rcvd: No fault
      Last remote LDP ADJ    status rcvd: No fault
    MPLS VC labels: local 30, remote 50
    Group ID: local 38, remote 34
    MTU: local 0, remote 0
    Remote interface description:
  Sequencing: receive disabled, send disabled
  Control Word: On
  SSO Descriptor: 100.24.13.1/10005, local label: 30
  Dataplane:
    SSM segment/switch IDs: 12365/41034 (used), PWID: 8
  VC statistics:
    transit packet totals: receive 1839938, send 1840079
    transit byte totals:   receive 143515164, send 128805530
    transit packet drops:  receive 0, seq error 0, send 0


ASR903-W2504#
ASR903-W2504#ping mpls pseudowire 100.24.13.1 10005
Sending 5, 72-byte MPLS Echos to 100.24.13.1,
```

```
     timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 3/3/4 ms
 Total Time Elapsed 25 ms

ASR903-W2504#
ASR903-W2504#
ASR903-W2504#
ASR903-W2504#TRACE  mpls pseudowire 100.24.13.1 10005 segment
Tracing MS-PW segments within range [1-1] peer address 100.24.13.1 and timeout 2
seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
! 1 10.24.13.2 3 ms [Labels: 134/router-alert/50 Exp: 0/0/0]
```

```
    local 100.25.4.1 remote 100.24.13.1 vc id 10005


ASR903-W2504#TRACE  mpls ipv4  100.24.13.1 255.255.255.255
Tracing MPLS Label Switched Path to 100.24.13.1/32, timeout is 2 seconds


Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0


Type escape sequence to abort.
  0 10.25.3.1 MRU 1500 [Labels: 68 Exp: 0]
L 1 10.25.3.0 MRU 1500 [Labels: 38 Exp: 0] 25 ms
L 2 10.25.2.0 MRU 1500 [Labels: 41 Exp: 0] 25 ms
L 3 10.24.15.0 MRU 1500 [Labels: 21 Exp: 0] 21 ms
L 4 10.24.14.0 MRU 1500 [Labels: explicit-null Exp: 0] 23 ms
! 5 10.24.13.2 3 ms
ASR903-W2504#
```

2.5.2 Validate BFD

The following commands are useful for verifying BFD functionality before link failure:

```
ASR903-W2504#sh bfd neighbor

MPLS-TP Sessions
Interface      LSP type                    LD/RD         RH/RS     State
Tunnel-tp0        Working                   7/5          Up        Up
Tunnel-tp0        Protect                   5/6          Up        Up

ASR903-W2504#trace mpls tp tunnel-tp 0 lsp active
Tracing MPLS TP Label Switched Path on Tunnel-tp0, timeout is 2 seconds


Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
```

```
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
  0 10.24.13.1 MRU 1500 [Labels: 133 Exp: 0]
! 1 10.24.13.0 3 ms
ASR903-W2504#
```

The following commands are useful for verifying BFD functionality after link failure:

```
ASR903-W2504#sh bfd neighbor

MPLS-TP Sessions
Interface      LSP type                      LD/RD         RH/RS     State
Tunnel-tp0        Working                     7/0          Down      Down
Tunnel-tp0        Protect                     5/6          Up        Up
Tunnel-tp1        Working                     6/7          Up        Up
Tunnel-tp1        Protect                     8/8          Up        Up
ASR903-W2504#
ASR903-W2504#
ASR903-W2504#trace mpls tp tunnel-tp 0 lsp active
Tracing MPLS TP Label Switched Path on Tunnel-tp0, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
```

```
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
  0 10.25.3.1 MRU 1500 [Labels: 108 Exp: 0]
L 1 10.25.3.0 MRU 1500 [Labels: 108 Exp: 0] 5 ms
L 2 10.25.2.0 MRU 1500 [Labels: 106 Exp: 0] 6 ms
L 3 10.24.15.0 MRU 1500 [Labels: 106 Exp: 0] 5 ms
L 4 10.24.14.0 MRU 1500 [Labels: 134 Exp: 0] 5 ms
! 5 10.24.13.2 5 ms
ASR903-W2504#
```

3 Results

- Observed roundtrip time is 3.7 ms when de-jitter buffer of 2 ms is used. Doing a back to back connectivity test confirmed that a delay introduced by multiplexor is 0.7 ms roundtrip.
- Latency introduced by the network is 18 microseconds in 1 hop path and 75 microseconds in 5 hop path.
- Convergence time is 6.74 ms average when preferred path fails. During this time, relay reported a loss of 5 packets.
- Trip time when a failure is detected was 18.6 ms average. For details on the introduced failure, refer to the test report.
- QoS was implemented to guarantee consistent behavior even during traffic load.
- Relay was configured to report an alarm when excessive delay was introduced.
- No changes in relay communication where observed when jitter upto 2 ms was introduced.
- No impact in communication was observed when using ASR internal clock to be the master clock.

Parameter	Result
Roundtrip time	3.7 ms
One way delay	1.85 ms
Network latency 1hop/5 hop	18 µs /75 µs
Network convergence time (failure in primary path)	6.74 ms
Trip time	18.6 ms

4 Conclusions

Packet-based networks reliably (dependably and securely) support the most stringent teleprotection schemes with guaranteed SLAs well below the required latency budget.

The main factors consuming delay budget are relay protection interface types and speeds, and overlay transport if used (Packet over TDM), and not the packet network itself.

RSVP MPLS TE or MPLS-TP tunnels can ensure that LSPs are co-routed when echo-based relay synchronization is used for differential schemes.

SyncE or PTP ensures efficient synchronization distribution to MPLS PEs for circuit emulation.

MPLS TDM pseudowire de-jitter buffers compensate for network PDV when clocking data on to relay synchronous protection interfaces.

Efficient QoS mechanisms will ensure Teleprotection traffic is subject to minimum latency (for faster detection) and jitter (for accurate relay synchronization) as it traverses the packet network.

5 References

Teleprotection with E1 **Design Guide** Link

Teleprotection with E1 **Implementation Guide** EDCS-10804593

Teleprotection with 2 Box Solution G.703 Co-directional to E1 Interface **Test Report** –

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