

# IxNetwork — Multiprotocol Label Switching (MPLS) Test Solution

Validate Constantly Evolving MPLS and Advanced VPN Technologies

## Problem: MPLS and Evolving Advanced Applications Require Constant Testing

MPLS provides a scalable, fast, and protocol-independent transport technology that quickly gained popularity in replacing previous leased line technologies for providing guaranteed services. Many advanced MPLS applications, such as various virtual private network (VPN) services and traffic engineering, have provided value-added services across the Internet. With its popularity and wide deployment, MPLS technology and applications are continuously evolving to support new requirements and new use cases. This trend requires constant testing before rolling out new product releases and new services to ensure quality delivery and smooth deployment.

## Solution: A Comprehensive and Scalable Test Solution to Validate Advanced MPLS Features

Keysight's IxNetwork MPLS test solution provides simulation of various MPLS and VPN technologies that include LDP and RSVP-TE as signaling protocols, various advanced VPN technologies that include L2VPN, L3VPN, Multicast VPN, Ethernet VPN, as well as MPLS OAM and MPLS Transport Profile (MPLS-TP).

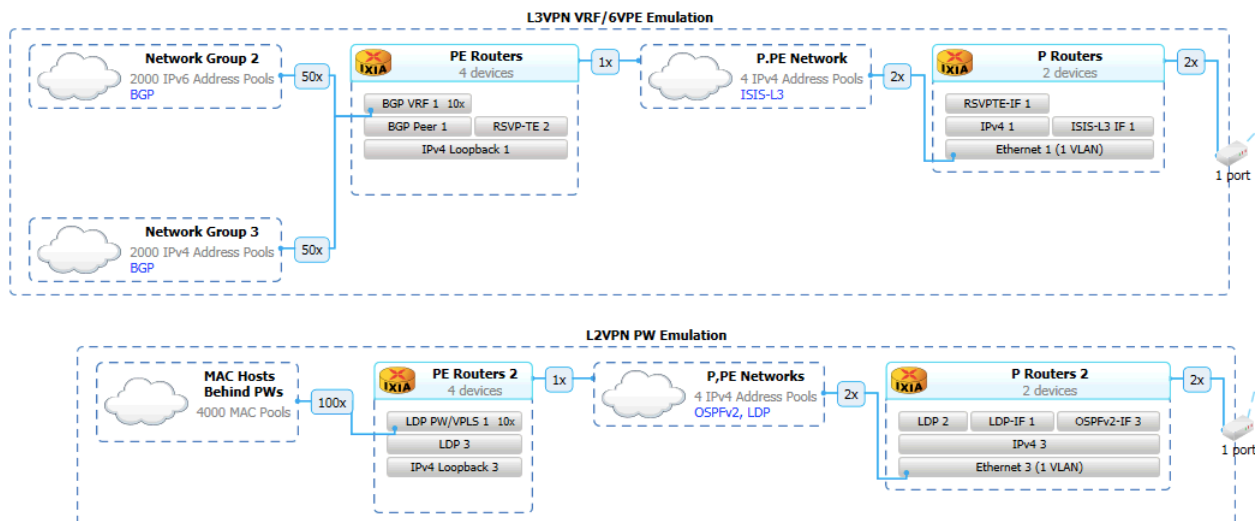
The solution emulates scaled MPLS VPN networks to stress-test provider edge and core devices under Internet scale and dynamic conditions with the flexibility and advanced operation to test every aspect of real-world user scenarios.

## Highlights

- Increase productivity and simplify management with complete test coverage using one test tool
- Ensure smooth deployment by testing with mixed VPN technologies to mimic real-world deployment in lab environment
- Deliver quality and timely products and services by stress-testing under real-world scale to ensure performance and stability
- Validate IPv6 readiness by qualifying IPv6 routes exchange and IPv6 traffic delivery in MPLS network
- Benchmark key performance metrics for failure detection and convergence with flexible action and dynamic label update

## Key features

- Emulates MPLS signaling protocols that include LDP and RSVP-TE to validate basic Label Switched Path (LSP) and Traffic Engineering tunnel setup capability, as well as fast switching based on fixed-bit MPLS labels of Ingress, Egress, and Transit Label Switched Routers (LSR)
- Extension to LDP and RSVP-TE that supports P2MP (Point to Multi-Point) LSP to qualify multicast delivery using MPLS technology
- Support different L2VPN technologies, including LDP-based pseudowire and VPLS, BGP-based VPLS, and BGP autodiscovery with FEC129
- Emulate various components of L3VPN devices including Provider (P), Provider Edge (PE), and Customer Edge (CE) routers to validate the capability to support large VPN instances without service leakage and degradation
- Support 6PE and 6VPE to qualify IPv6 capability
- Support MPLSoUDP and MPLSoGRE as additional tunnel type for L3VPN Services
- Combination of OSPF/ISIS, LDP/RSVP-TE, and BGP extensions supporting VPN services enables emulation of full VPN topology to validate PE and P router capability to support advanced VPN technologies
- Support dynamic label update to measure failure detection and convergence in MPLS network
- Support BGP Labeled Unicast to validate L3 Inter-AS VPN Options
- Support BGP RT-Constraint to validate efficient VPN route advertisement of Route-Reflector
- Rosen draft Multicast VPN and NextGen Multicast VPN emulation validates multicast delivery in VPN network using different technology flavors
- Emulates various MPLS OAM mechanism to test LSP failure detection and diagnostics capability of MPLS device and network
- Ethernet VPN emulation validates next-generation VPN technology, delivering both L2 and L3 VPN services using a unified technology with better multi-homing support and more optimized multicast delivery
- MPLS-TP emulation validates device under test (DUT) capability of supporting MPLS-TP as transport technology



IxNetwork advanced MPLS VPN topology emulation

## Specifications

LDP and MLDP	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC 5036 - LDP Specification</li> <li>• RFC 3037 - LDP Applicability</li> <li>• RFC 3215 - LDP State Machine</li> <li>• RFC 3478 - LDP Graceful Restart</li> <li>• RFC 7552 - Updates to LDP for IPv6</li> <li>• draft-pdutta-mpls-ldp-v2-00 – LDP Version 2</li> <li>• RFC 7473 - Controlling State Advertisements of Non-negotiated LDP Applications</li> <li>• RFC 6388 - Label Distribution Protocol Extensions for P2MP and MP2MP LSPs</li> <li>• RFC 6826 - mLDP based in-band signaling for P2MP and MP2MP LSPs</li> </ul>
<b>Protocol Messages</b>	<ul style="list-style-type: none"> <li>• Discovery (Basic and Extended)</li> <li>• Session Establishment (Active or Passive role)</li> <li>• Advertisements (Label Mapping and Withdraw)</li> <li>• Notifications (Fatal and Advisory)</li> </ul>
<b>LDP Configuration Options</b>	<p>Label Advertising Modes</p> <ul style="list-style-type: none"> <li>• Downstream Unsolicited</li> <li>• Downstream on Demand</li> </ul> <p>Label Retention Modes</p> <ul style="list-style-type: none"> <li>• Liberal</li> <li>• Conservative</li> </ul> <p>Authentication</p> <ul style="list-style-type: none"> <li>• NULL</li> <li>• MD5</li> </ul> <p>Session Timers</p> <ul style="list-style-type: none"> <li>• Configure Interval and Hold times for Hello and Keep Alive messages</li> </ul> <p>Labels</p> <ul style="list-style-type: none"> <li>• Create, advertise, and withdraw FEC entries. FEC information, peers and label spaces displayed for learned labels. Filters can be applied on learned labels based on FEC parameters, peers, or label spaces. Scalability can be increased by specifying only certain FECs to be stored (Explicit Include) Downstream Unsolicited</li> </ul> <p>Diagnostics</p> <ul style="list-style-type: none"> <li>• Elapsed time (millisecond) for advertising or withdrawing FEC entries, notification, and debug messages</li> </ul>

## LDP and MLDP

### LDP Statistics

- Basic Session Up
- Targeted Session Up
- Targeted Session Configured
- Established LSP Ingress
- Established LSP Egress
- Label Abort TX/RX
- Label Request TX/RX
- Label Mapping TX/RX
- Label Release TX/RX
- Label Withdraw TX/RX
- Label Notification TX/RX

### mLDP Configuration Options

- Multicast Leaf Ranges
- Root Address
  - Root Address Count
  - Root Address Step
  - LSP Count per Root
  - Label Value Start
  - Label Value Step
  - Number of Opaque Value TLVs
  - Number of Traffic Group Ranges
- Multicast Root Ranges
- Root Address
  - Root Address Count
  - Root Address Step
  - LSP Count per Root
  - Number of Opaque Value TLVs
  - Number of Traffic Source Ranges
- Multicast Leaf/Root Opaque TLVs
- Type
  - Length
  - Value
  - Increment
- Traffic Group Ranges
- IPv4 | IPv6
  - Group Address
  - Group Count
- Traffic Source Ranges
- IPv4 | IPv6
  - Source Address
  - Source Count per LSP

LDP and MLDP	
	<ul style="list-style-type: none"> <li>• Filter on Group Address</li> <li>• Learned P2P/P2MP Labels</li> <li>• Per Port</li> <li>• Per LDP Session</li> </ul>
<b>mLDP Statistics</b>	<ul style="list-style-type: none"> <li>• Established LSP Ingress</li> <li>• Established LSP Egress</li> <li>• Established P2MP LSP Ingress</li> <li>• Established P2MP LSP Egress</li> <li>• Label Abort Tx</li> <li>• Label Abort Rx</li> <li>• Label Request Tx</li> <li>• Label Request Rx</li> <li>• Label Mapping Tx</li> <li>• Label Mapping Rx</li> <li>• Label Release Tx</li> <li>• Label Release Rx</li> <li>• Label Withdraw Tx</li> <li>• Label Withdraw Rx</li> <li>• Label Notification Tx</li> <li>• Label Notification Rx</li> </ul>

RSVP-TE P2P and P2MP	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC 2205 - Resource ReSerVation Protocol (RSVP)</li> <li>• RFC 2210 – The Use of RSVP with IETF Integrated Services framework's QoS control services</li> <li>• RFC 2747 – RSVP Cryptographic Authentication</li> <li>• RSVP 2961 - RSVP Refresh Overhead Reduction Extensions</li> <li>• RFC 3097 - RSVP Cryptographic Authentication – Updated Message Type Value</li> <li>• RFC 3209 – RSVP-TE: Extensions to RSVP for LSP Tunnels</li> <li>• RFC 4090 - Fast Reroute Extensions to RSVP-TE for LSP Tunnels</li> <li>• RFC 4875 – Extension to RSVP-TE for Point-to-Multipoint TE Label Switched Paths (LSP)</li> <li>• RFC 7746 – Label Switched Path (LSP) Self-Ping</li> </ul>
<b>Configuration Options</b>	<p>Session Attributes</p> <ul style="list-style-type: none"> <li>• Session IP addresses</li> <li>• Hello Interval and Timeout Multiplier</li> <li>• Refresh Interval</li> </ul>

## RSVP-TE P2P and P2MP

- Graceful Restart Helper Mode with Hello Interval and Timeout Multiplier
- Graceful Restart Restarting Mode with Advertised Restart Time
- Actual Restart Time
- Recovery Time
- Restart Start Time and Restart Up Time
- Label Space Start and End value
- Refresh Reduction with configurable Interval
- Enable Bundle Message Sending and Threshold Timer
- Custom Hello TLVs

### Ingress Endpoints

- Local IP and Remote IP
- Tunnel ID and LSP ID
- Refresh Interval
- Timeout Multiplier

### Ingress ERO

- Enable/Disable
- Prepend DUT to ERO
- Prefix length
- Number of ERO Sub-Objects
- Type and IP
- Prefix Length
- AS
- Loose Flag

### Ingress/Head SERO (for P2MP)

- Enable/Disable
- Leaf IP Start Address and Count
- Sub Object List in IP or AS number
- Strict/Loose
- Append Leaf to SERO
- Send as ERO or SERO

### Ingress RRO

- Enable/Disable
- Number of RRO Sub-objects
- Type and IP
- Protection Available
- Protection In Use
- Label
- C-Type
- Global Label
- Bandwidth Protection

## RSVP-TE P2P and P2MP

- Node Protection
- Ingress Session Attribute
- Name field fixed or auto-generated
  - Setup and Holding priorities
  - Local Protection Desired
  - Label Recording Desired
  - SE Style Desired
  - Bandwidth Protection Desired
  - Node Protection Desired
  - Resource Affinities and flags bits
- Ingress TSpec
- Token Bucket Rate (Bps)
  - Token Bucket Size (bytes)
  - Peak Data Rate (Bps)
  - Minimum Policed Unit (bytes)
  - Maximum Packet size (bytes)
- Ingress Fast Reroute
- Enable/Disable
  - Setup and Holding priorities
  - Hop Limit
  - Bandwidth
  - Exclude Any/Include Any/Include All
  - One to One or Facility Backup
- Ingress Detour
- Enable/Disable
  - Number of Detour Sub-Objects
  - PLR ID
  - Avoid Node ID
- Ingress Path Re-Optimization
- Enable Path Re-Optimization
  - Enable Periodic Re-Evaluation Request
  - Re-Evaluation Request Interva
- Ingress Backup LSP
- Backup LSP IP
  - TSpec Same as Primary
  - TSpec parameters
  - ERO Same as Primary
  - Enable ERO
  - ERO parameters
- Egress Endpoint

## RSVP-TE P2P and P2MP

	<ul style="list-style-type: none"> <li>• Destination IP Addresses</li> <li>• Reservation Confirmation flag</li> </ul> <p>Egress Label Range</p> <ul style="list-style-type: none"> <li>• Default range: 1,000 to 100,000; Fixed label options: Explicit Null, Router Alert, IPv6 Explicit Null, and Implicit Null</li> </ul> <p>Egress RRO</p> <ul style="list-style-type: none"> <li>• Reflect/Don't Reflect</li> <li>• IP addresses or label numbers</li> </ul> <p>Egress Reservation</p> <ul style="list-style-type: none"> <li>• "FF" or "SE" supported</li> </ul> <p>Egress Custom TLVs</p> <ul style="list-style-type: none"> <li>• Resv</li> <li>• ResvTear</li> <li>• PathErr</li> </ul>
<p><b>Statistics</b></p>	<ul style="list-style-type: none"> <li>• Ingress LSPs Configured</li> <li>• Ingress LSPs Up</li> <li>• Egress LSPs Up</li> <li>• Paths TX/RX</li> <li>• Path Tears TX/RX</li> <li>• RESVs TX/RX</li> <li>• RESV-Tears TX/RX</li> <li>• Path-ERRs TX/RX</li> <li>• RESV-ERRs TX/RX</li> <li>• RESV Lifetime Expirations</li> <li>• Path Lifetime Expirations</li> <li>• RESV-CONFs TX/RX</li> <li>• Egress Out of Order Msgs RX</li> <li>• Hellos TX/RX</li> <li>• ACKs TX/RX</li> <li>• NACKs TX/RX</li> <li>• SREFRESHs TX/RX</li> <li>• Bundle Messages TX/RX</li> <li>• Paths with Recovery-Label TX/RX</li> <li>• UnRecovered RESVs Deleted</li> <li>• Own Graceful-Restarts</li> <li>• Peer Gracesful-Restarts</li> </ul> <p>P2MP specific statistics</p> <ul style="list-style-type: none"> <li>• Ingress SubLSP Configured</li> <li>• Ingress SubLSPs Up</li> </ul>



RSVP-TE P2P and P2MP	
	<ul style="list-style-type: none"> <li>• Egress SubLSP Configured</li> <li>• Egress SubLSPs Up</li> <li>• Down State Count</li> <li>• Path Send State Count</li> </ul>
<b>Learned Information</b>	<ul style="list-style-type: none"> <li>• Session Type</li> <li>• P2MP ID/Session IP</li> <li>• Tunnel ID</li> <li>• Head End IP</li> <li>• LSP ID</li> <li>• Current State</li> <li>• Last Flap Reason</li> <li>• Leaf IP</li> <li>• P2MP Sub-Group ID</li> <li>• Label Type</li> <li>• Label</li> <li>• Reservation State</li> </ul>

L2VPN LDP Based PW and VPLS	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC 4906 – Transport of Layer 2 frame over MPLS</li> <li>• draft-martini-ethernet-encap-mpls-01.txt</li> <li>• draft-martini-ppp-hdlc-encap-mpls-00.txt</li> <li>• draft-ietf-pwe3-frame-relay-02.txt</li> <li>• draft-martini-atm-encap-mpls-01.txt</li> <li>• draft-malis-sonet-ces-mpls-05.txt</li> <li>• RFC 4762 - Virtual Private LAN Service (VPLS) Using Label Distribution Protocol (LDP) Signaling</li> </ul>
<b>L2 VPN Signaling</b>	LDP Extended Martini discovery sessions
<b>Emulated VCs</b>	Frame Relay (Type 1), ATMAAL5 (Type 2), ATMXCell (Type 3), VLAN (Type 4) - default, Ethernet (Type 5), HDLC (Type 6), PPP (Type 7), Circuit Emulation Service over MPLS (CEM) - CEM (Type 8), ATMVCC (Type 9), ATMVPC (Type A), VPLS (Type B)
<b>VC FEC Parameters</b>	<p>General: Peer, VC ID, Description, Label Start, and Label Increment Mode</p> <p>Ethernet: MTU</p> <p>ATM: ATM Present, Max # of ATM Cells</p> <p>CEM: CEM Payload Enabled, CEM Payload value, CEM Option Present Enabled, and CEM Option value</p>

L2VPN LDP Based PW and VPLS	
<b>Flapping</b>	Sessions, emulated Layer 2 groups, and individual VC/FEC ranges can be flapped on demand
<b>Labels</b>	Create, advertise, and withdraw VC FEC entries. VC FEC information, peers and label spaces displayed for learned labels. VC FEC learned labels can be filtered based on Peer address, Label, Group ID, VC type, VC ID, and interface description
<b>Emulated VC Encapsulations</b>	Ethernet, VLAN, AAL5, Frame Relay
<b>Diagnostics</b>	Elapsed time (msec) for advertising or withdrawing FEC entries, notifications, and debug messages

L2VPN BGP Based VPLS/VPWS	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC4761 - Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signaling</li> <li>• RFC6624 – Layer 2 Virtual Private Networks Using BGP for Auto-Discovery and Signaling</li> </ul>

L3VPN/6VPE	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC 4364 - BGP/MPLS IP Virtual Private Networks (VPNs)</li> <li>• RFC 4360 - BGP Extended Communities Attribute</li> <li>• RFC 6286 – Autonomous-System-wide Unique BGP Identifier for BGP-4</li> <li>• RFC3107-Carrying Label Information in BGP-4</li> <li>• RFC 7510 – Encapsulating MPLS in UDP</li> <li>• RFC 4023 – Encapsulating MPLS in IP or GRE</li> </ul>
<b>Peer Types</b>	Internal BGP session with Multi-Protocol Extensions (MP-iBGP)
<b>Address Type</b>	<ul style="list-style-type: none"> <li>• VPN-IPv4 Address routes with MPLS labels</li> <li>• VPN-IPv6 Address routes with MPLS labels</li> </ul>
<b>Route Distinguisher (RD)</b>	<ul style="list-style-type: none"> <li>• Type - ASN: ASN and Assigned Number</li> <li>• Type - IP: IP Address and Assigned Number</li> <li>• The local or global part of a RD can be incremented within a VPN route range entry</li> </ul>
<b>Route Target (RT)</b>	<ul style="list-style-type: none"> <li>• Type - ASN: ASN and Assigned Number</li> <li>• Type - IP: IP Address and Assigned Number</li> </ul>

L3VPN/6VPE	
	<ul style="list-style-type: none"> <li>Multiple RTs can be assigned to an emulated site</li> </ul>
<b>Flapping</b>	VPN routes, sites, and sessions can be flapped on demand. Timed flapping (up and down time intervals) can be configured for an entire VPN route range entry or for a partial set of routes
<b>Staggered Start</b>	Multiple BGP peer sessions can be started simultaneously or staggered over a series of time intervals

NGMVPN	
<b>Standards</b>	<ul style="list-style-type: none"> <li>RFC 6514 - BGP Encodings and Procedures for Multicast in MPLS/BGP IP VPNs</li> </ul>

BGP LU (Labelled Unicast)	
<b>Standards</b>	RFC 3107 - Carrying Label Information in BGP-4 RFC 8277 – Using BGP to Bind MPLS labels to Address Prefixes RFC 8092 – BGP Large Communities Attribute
<b>Capability</b>	<ul style="list-style-type: none"> <li>Labeled Unicast IPv4</li> <li>Labeled Unicast IPv6</li> <li>Multiple Labels Capability</li> </ul>
<b>Configuration Option</b>	BGP IP Route Range <ul style="list-style-type: none"> <li>Number of Labels</li> <li>Label Start</li> <li>Label End</li> <li>Label Step</li> </ul>
<b>Learned Information</b>	<ul style="list-style-type: none"> <li>IPv4 Prefix/IPv6 Prefix</li> <li>Prefix Length</li> <li>Labels</li> <li>IPv4 Next Hop</li> <li>IPv6 Next Hop</li> </ul>

MPLS OAM	
<b>Standards</b>	<ul style="list-style-type: none"> <li>RFC 4379 – Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures</li> </ul>

MPLS OAM	
	<ul style="list-style-type: none"> <li>• RFC 5884 – Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)</li> <li>• RFC 5085 – Pseudowire Virtual Circuit Connectivity Verification (VCCV): A Control Channel for Pseudowires</li> <li>• RFC 5885 – Bidirectional Forwarding Detection (BFD) for the Pseudowire Virtual Circuit Connectivity Verification (VCCV)</li> </ul>
<b>Protocol Options</b>	<ul style="list-style-type: none"> <li>• LDP auto negotiated CC/CV type</li> <li>• MPLS Echo Reply Mode selection</li> <li>• MPLS OAM CC/CV option</li> <li>• On-demand vs. periodic LSP Ping option</li> <li>• BFD Interval option</li> <li>• LSP Ping Request, LSP Ping Reply, LSP BFD can be individually enabled</li> <li>• VCCV Ping and VCCV BFD can work separately or simultaneously</li> <li>• Open options for LSP Ping and Traceroute message</li> </ul>
<b>Statistics</b>	<ul style="list-style-type: none"> <li>• BFD Session Count</li> <li>• BFD Up-Sessions</li> <li>• BFD Sessions Flap Count</li> <li>• BFD PDU Tx</li> <li>• BFD PDU Rx</li> <li>• LSP Ping Request Tx</li> <li>• LSP Ping Request Rx</li> <li>• LSP Ping Reply Tx</li> <li>• LSP Ping Reply Rx</li> </ul>

EVPN/PBB-EVPN	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC 7432 – EVPN</li> <li>• RFC 7623 – PBB-EVPN</li> <li>• draft-ietf-bess-evpn-overlay-01</li> <li>• draft-ietf-bess-evpn-inter-subnet-forwarding-01</li> <li>• RFC5512</li> <li>• draft-ietf-bess-evpn-vpws-07</li> <li>• draft-sajassi-bess-evpn-vpws-fxc-01</li> </ul>
<b>Capability</b>	<ul style="list-style-type: none"> <li>• AFI = 25 (L2VPN)</li> <li>• SAFI 70 (EVPN)</li> </ul>
<b>Route Type</b>	<ul style="list-style-type: none"> <li>• Type 1 – Ethernet Auto-Discovery (A-D) Route</li> </ul>

EVPN/PBB-EVPN	
	<ul style="list-style-type: none"> <li>• Type 2 – MAC/IP Advertisement Route</li> <li>• Type 3 – Inclusive Multicast Ethernet Tag Route</li> <li>• Type 4 – Ethernet Segment Route</li> <li>• Type 5 – IP Prefix Route Function</li> </ul>
<b>Extended Community</b>	<ul style="list-style-type: none"> <li>• ESI Label Extended Community</li> <li>• ES Import Route Target</li> <li>• MAC Mobility Extended Community</li> <li>• Default Gateway Extended Community</li> <li>• BGP encapsulation Extended Community</li> <li>• Router MAC Extended Community</li> <li>• Layer 2 attributes Extended Community</li> </ul>
<b>Multi-Homing Functions</b>	<ul style="list-style-type: none"> <li>• All-Active Ethernet Segment</li> <li>• Single-Active Ethernet Segment</li> <li>• Fast Convergence</li> <li>• Split Horizon</li> <li>• Aliasing and Back-Up Path</li> <li>• Designated Forwarder Election</li> </ul>
<b>BUM Traffic Forwarding</b>	<ul style="list-style-type: none"> <li>• Ingress Replication</li> <li>• RSVP-TE P2MP (MPLS data plane only)</li> <li>• mLDP P2MP (MPLS data plane only)</li> </ul>

MPLS-TP	
<b>Standards</b>	<ul style="list-style-type: none"> <li>• RFC 5654 - Requirements of an MPLS Transport Profile</li> <li>• RFC 5860 - Requirements for Operations, Administration, and Maintenance (OAM) in MPLS Transport Networks</li> <li>• RFC 5921 - A Framework for MPLS in Transport Networks</li> <li>• RFC 6435 - Operations, Administration and Maintenance Framework for MPLS-based Transport Networks</li> <li>• RFC 5586 - MPLS Generic Associated Channel</li> <li>• draft-bhh-mpls-tp-oam-y1731-06 - MPLS-TP OAM based on Y.1731</li> <li>• RFC 6428 - Proactive Connectivity Verification, Continuity Check and Remote Defect indication for MPLS Transport Profile</li> <li>• RFC 6426 - MPLS On-demand Connectivity Verification and Route Tracing</li> <li>• RFC 6427 - MPLS Fault Management OAM</li> <li>• RFC 6378 - MPLS-TP Linear Protection</li> </ul>

MPLS-TP	
	<ul style="list-style-type: none"> <li>• RFC 6375- Packet Loss and Delay Measurement for the MPLS Transport Profile</li> </ul>
<b>Protocol Options</b>	<ul style="list-style-type: none"> <li>• DUT role selection (Ingress, Egress, or Transit)</li> <li>• Y.1731 or BFD extensions to support MPLS-TP over G-ACh/GAL encapsulation</li> <li>• Uni- or Bi-directional 1:1 or 1+1 APS</li> <li>• APS manual switching commands</li> <li>• PSC state machine</li> <li>• OAM CC at all intervals including 3.33ms</li> <li>• LSP or PW for working and protect path</li> <li>• ICC or IP based MEP/MEG ID</li> <li>• Traffic Wizard to generate traffic from Traffic Source or LSP/PW for both IP / L2 Ethernet types</li> <li>• APS control over traffic; supports revertive operation</li> <li>• Automation API</li> </ul>
<b>Statistics</b>	<ul style="list-style-type: none"> <li>• CC-Up</li> <li>• CC-Dn</li> <li>• CV-Up</li> <li>• CV-Down</li> <li>• CC-BFD Rx</li> <li>• CC-BFD Tx</li> <li>• CC-CV-BFD Rx</li> <li>• CC-CV-BFD Tx</li> <li>• RDI-BFD-Rx</li> <li>• RDI-BFD-Tx</li> <li>• CV-LspPing-Rx</li> <li>• CV-LspPing-Tx</li> <li>• Successful Protection Switches</li> <li>• Failed Protection Switches</li> <li>• Reverts</li> <li>• DM-MPLS-TP-Delay Tx</li> <li>• DM-MPLS-TP-Delay Rx</li> <li>• LM-MPLS-TP-Loss Tx</li> <li>• LM-MPLS-TP-Loss Rx</li> <li>• CC-CV-CCM Rx</li> <li>• CC-CV-CCM Tx</li> <li>• CV-LBM-Rx</li> <li>• CV-LBM-Tx</li> <li>• RDI-CCM-Rx</li> <li>• RDI-CCM-Tx</li> </ul>

MPLS-TP	
	<ul style="list-style-type: none"> <li>• AIS-Y1731-Rx</li> <li>• AIS-Y1731-TP-Tx</li> <li>• LCK-Y1731-Rx</li> <li>• LCK-Y1731-Tx</li> <li>• DM-Y1731-1DM Tx</li> <li>• DM-Y1731-1DM Rx</li> <li>• DM-Y1731-DMM Tx</li> <li>• DM-Y1731-DMM Rx</li> <li>• DM-Y1731-DMR Tx</li> <li>• DM-Y1731-DMR Rx</li> <li>• LM-Y1731-LMM Tx</li> <li>• LM-Y1731-LMM Rx</li> <li>• LM-Y1731-LMR Tx</li> <li>• LM-Y1731-LMR Rx</li> </ul>

## Platform Options

Visit <a href="http://www.keysight.com">www.keysight.com</a> for More Information on IxNetwork Platform Options	
<b>Virtual Platform</b>	<ul style="list-style-type: none"> <li>• IxNetwork Virtual Edition (VE)</li> </ul>
<b>Chassis</b>	<ul style="list-style-type: none"> <li>• XGS12-HSL/SDL/SD Chassis</li> <li>• XGS2-HSL/SDL/SD Chassis</li> </ul>
<b>Fixed Chassis</b>	<ul style="list-style-type: none"> <li>• AresONE-400G QSFP-DD 400/200/100/50GE</li> <li>• AresONE-400G OSFP 400/200/100/50GE</li> <li>• AresONE-400G High Performance QSFP-DD 400/200/100/50GE</li> <li>• NOVUS ONE PLUS 10GE/5GE/2.5GE/1GE/100M</li> </ul>
<b>Appliances</b>	<ul style="list-style-type: none"> <li>• NOVUS ONE 10GE/1GE/100M</li> </ul>
<b>Load Modules</b>	<ul style="list-style-type: none"> <li>• K400 QSFP-DD 400/200/100/50GE</li> <li>• K400 CFP8 400GE</li> <li>• NOVUS High Density QSFP28 100/50/25GE</li> <li>• NOVUS 10GE/1GE/100M</li> <li>• NOVUS 10GE/5GE/2.5GE/1GE/100M</li> <li>• Xcellon-Multis QSFP28 100/50/25GE</li> <li>• Xcellon-Multis CFP4 100GE</li> <li>• Xcellon-Multis CXP 100/40/10GE</li> <li>• Xcellon-Multis QSFP 40/10GE</li> <li>• Xcellon-Lava CFP 100/40GE</li> </ul>

Visit [www.keysight.com](http://www.keysight.com) for More Information on IxNetwork Platform Options

- Xcellon-Flex QSFP/SFP+ 40/10GE
- NGY SFP+/BASE-T 10GE
- XMVDC Dual PHY 1GE

**Note 1:** MPLS-TP is not supported on following load modules:

- IxNetwork Virtual Edition (VE)
- Xcellon-Multis 10GE Reduced
- Xcellon-Multis 4x10GE/8x10GE
- Xcellon-FlexFE40QP

## IxNetwork Technology Solutions

Visit [www.keysight.com](http://www.keysight.com) for More Information on IxNetwork Technology Solutions

- IxNetwork Overview—L2/3 Network Infrastructure Performance Testing
- IxNetwork Software Defined Networking (SDN) Test Solution
- IxNetwork Routing and Switching Test Solution
- IxNetwork MPLS Test Solution
- IxNetwork Industrial Ethernet Test Solution
- IxNetwork Broadband and Authentication Test Solution
- IxNetwork Data Center Ethernet Test Solution

## Ordering Information

### LDP and mLDP Emulation

#### 930-2015

IxNetwork, Optional Software, MPLS LDP Emulation includes Layer 2 MPLS VPN and VPLS support; **REQUIRES** pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

#### 930-2052

IxNetwork, Optional Software, LDP extension to support FEC 129; **REQUIRES** pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076), 930-2005 BGP Emulation, 930-2006 BGP ext to support MPLS L3VPN/L2VPN/VPLS, 930-2015 LDP Emulation

#### 930-2080

IxNetwork, Optional Software, MPLS mLDP Emulation **REQUIRES** pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076), 930-2015 MPLS LDP Emulation



### **930-2115**

IxNetwork, MPLS LDPv6 Emulation, includes Layer 2 MPLS VPN and VPLS support; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### **RSVP-TE P2P and P2MP Emulation**

### **930-2014**

IxNetwork, Optional Software, MPLS RSVP-TE Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### **930-2036**

IxNetwork, Optional Software, MPLS P2MP RSVP-TE Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076) and 930-2014 MPLS RSVP-TE Emulation

### **L2/L3 VPN Emulation**

### **930-2006**

IxNetwork, Optional Software, BGP4 Emulation with additional Layer 3 MPLS/VPN, VPLS & Multicast VPN Support; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076) and 930-2005 BGP4 Emulation

### **930-2015**

IxNetwork, Optional Software, MPLS LDP Emulation, includes Layer 2 MPLS VPN and VPLS support; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### **Multicast VPN Emulation**

### **930-2004**

IxNetwork, Optional Software, Multicast Emulation, includes IGMPv1/v2/v3, MLDv1/v2, PIM-SM/SSMv4/v6, and Multicast VPN support; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### **930-2053**

IxNetwork, Optional Software, BGP Extension for NG mVPN with RSVP-TE P2MP; REQUIRES 930-2005 BGP Emulation, 930-2006 BGP ext to support MPLS L3VPN/VPLS, 930-2014 RSVP-TE Emulation, 930-2036 RSVP-TE P2MP Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### **930-2081**

IxNetwork, Optional Software, BGP Extensions for NG mVPN with mLDP REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076), 930-2004 Multicast Emulation 930-2015 MPLS LDP Emulation 930-2080 MPLS mLDP Emulation 930-2005 BGP Emulation 930-2006 BGP extensions to support MPLS L3VPN/VPLS

### **MPLS-TP Emulation**

#### **930-2061**

IxNetwork, Optional Software, MPLS-TP emulation; REQUIRES either 930-2032 Y.1731 protocol emulation or 930-2023 BFD protocol emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

#### **930-2062**

IxNetwork, Optional Software, MPLS-TP APS Protocol State Coordination emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076) and 930-2061 MPLS-TP emulation

### **EVPN Emulation**

#### **930-2102**

IxNetwork, Optional Software, BGP Extension to support EVPN and PBB-EVPN Emulation; REQUIRES 930-2005 BGP Emulation AND 930-2006 BGP Extension to support MPLS L3VPN/L2VPN/VPLS; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

### **MPLS-OAM Emulation**

#### **930-2094**

IxNetwork, Optional Software, MPLS OAM Ping and Traceroute; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076), and 930-2015 MPLS LDP Emulation or 930-2014 MPLS RSVP-TE Emulation

#### **930-2095**

IxNetwork, Optional Software, BFD over MPLS LSP; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076), and 930-2020 BFD Emulation, and 930-2015 MPLS LDP Emulation or 930-2014 MPLS RSVP-TE Emulation

### 930-2096

IxNetwork, Optional Software, VCCV Ping and BFD VCCV; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076), and 930-2020 BFD Emulation, and 930-2015 MPLS LDP Emulation or 930-2014 MPLS RSVP-TE Emulation, and 930-2006 BGP Extension to support BGP VPLS or 930-2052 LDP extension to support FEC 129

### Bundles

#### 930-2003

IxNetwork, Optional Software Bundle, MPLS VPN; includes 930-2006 Layer 3 MPLS/VPLS Support, 930-2014 RSVP-TE Emulation, 930-2015 LDP Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076) and 930-2001 Optional Software Bundle, IPv4 Routing Protocols; includes Media Kit

#### 930-2057

IxNetwork, Optional Software Bundle, Basic MPLS Bundle (L2 VPN/VPLS, L3 VPN, Multicast VPN (draft-rosen)); INCLUDES; 930-2001 IPv4 Routing Bundle 930-2002 IPv6 Routing Bundle 930-2003 MPLS VPN Bundle 930-2004 Multicast Bundle; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

#### 930-2064

IxNetwork, Optional Software Bundle, MPLS-TP Bundle; INCLUDES: 930-2023 BFD emulation 930-2032 ITU-T Y.1731 emulation 930-2061 MPLS-TP emulation 930-2062 MPLS-TP APS emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

#### 930-2512

IxNetwork Software Bundle MPLS-OAM, BFD-LSP and VCCV. Includes: MPLS OAM Ping&TR, BFD over MPLS LSP, and VCCV Ping and BFD VCCV Emulation; REQUIRES pre-existing 930-1999 IxNetwork Base license OR new purchase of either IxNetwork Base PLUS (930-2056) or IxNetwork Base PREMIUM (930-2076)

Learn more at: [www.keysight.com](http://www.keysight.com)

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: [www.keysight.com/find/contactus](http://www.keysight.com/find/contactus)

